Watershed

February 2026

Draft Duluth Urban Area Watershed Chloride Total Maximum Daily Load Report 2026

Restoring and Protecting Five Streams in the Duluth Urban Area.

MINNESOTA POLLUTION CONTROL AGENCY

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- City of Hermantown
- City of Proctor
- City of Rice Lake
- Lake Superior College
- Minnesota Department of Natural Resources
- Minnesota Department of Transportation
- Minnesota State College and University System
- South St. Louis Soil and Water Conservation District
- St. Louis County
- University of Minnesota Duluth and the Natural Resources Research Institute
- Western Lake Superior Sanitary District

Editing

Jinny Fricke (MPCA_Public Notice 2.5.26)

Cover photo: Aerial lift bridge from the Lakewalk, Duluth, MN (Tom Estabrooks, MPCA)

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Abbreviations

1W1P	One Watershed, One Plan
BMP	best management practice
BWSR	Board of Water and Soil Resources
C-CAP	Coastal Change Analysis Program
CWMP	Comprehensive Watershed Management Plan
DIA	Duluth International Airport
DNR	Minnesota Department of Natural Resources
DUA	Duluth Urban Area
DUAW	Duluth Urban Areas Watershed
E. coli	*Escherichia coli*
EPA	U.S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
HSPF	Hydrologic Simulation Program–Fortran
HUC	hydrologic unit code
LA	load allocation
lbs	pounds
mg/L	milligrams per liter
MOS	margin of safety
MPCA	Minnesota Pollution Control Agency
MS4	municipal separate storm sewer system
NLCD	National Land Cover Database
NPDES	National Pollutant Discharge Elimination System
NRRI	Natural Resources Research Institute (University of Minnesota)
RSPT	Regional Stormwater Protection Team
SDS	State Disposal System
SLRW	St. Louis River Watershed
SSTS	subsurface sewage treatment systems
SWCD	soil and water conservation district
SWPPP	Stormwater Pollution Prevention Plan

TCMA	Twin Cities Metropolitan Area
TMDL	total maximum daily load
TSS	total suspended solids
WBIF	watershed-based implementation funding
WCL	Wisconsin Central Limited
WID	water unit identification
WLA	wasteload allocation
WLSSD	Western Lake Superior Sanitary District
WRAPS	Watershed Restoration and Protection Strategy
WWTP	wastewater treatment plant

Executive summary

The Federal Clean Water Act (CWA), Section 303(d) requires total maximum daily loads (TMDLs) to be produced for surface waters that do not meet applicable water quality standards necessary to support their designated uses (i.e., an impaired water). A TMDL determines the maximum amount of a pollutant a receiving waterbody can assimilate while still achieving water quality standards and allocates allowable pollutant loads to various sources needed to meet water quality standards. This TMDL study addresses the chloride impairments in the 141-square mile Duluth Urban Area Watershed (DUAW) in northeast Minnesota, within the Lake Superior Basin. Five chloride TMDLs were developed to address five streams in the DUAW impaired for their aquatic life use by high levels of chloride.

Figure 1. Lakewalk in Duluth, MN.

Source: Tom Estabrooks (MPCA)

The DUAW is predominantly developed land along the St. Louis River Estuary and the north shore of Lake Superior, while the headwaters areas of many of the tributaries to the St. Louis River and Lake Superior are forested, with undeveloped tracts of land. The major sources of chloride causing impairment to Kingsbury, Keene, Miller, Chester, and Tischer creeks are (1) winter road maintenance (i.e., deicing or anti-icing agents [e.g., road salt, brine] applied to roads, parking lots, sidewalks, and driveways during the winter before and during snow events) and (2) dust suppressants applied to unpaved roads or parking lots during dry periods of the summer. Chloride from deicing, anti-icing, and dust suppressant activities is transported to streams through runoff or stormwater from precipitation events. Very minor sources of impairment include (1) water softeners applied to hard water in areas not served by centralized wastewater (i.e., homes and businesses that use subsurface sewage treatment systems [SSTS]), (2) sanitary waste (i.e., human excreta) treated by SSTS, and (3) natural background (e.g., wildlife excreta, atmospheric deposition).

Chloride loads generated from key sources in the DUAW were estimated using the Smart Salting Tool. This web-based tool can be used by private or public winter maintenance organizations to identify opportunities to reduce salt use and track progress. The Smart Salting Tool can be run with either default data (to generally represent anywhere in Minnesota) or user-input local data for a specific area of interest (e.g., county, city, subwatershed). Such data include lane-miles of roads, salt-based anti-icing/deicing application rates, lane-miles of gravel roads, and chloride-based dust suppressant application rates. Using the tool's defaults, the estimated major source is winter maintenance activities (91% to 94%). Using input provided by several road authorities in the DUAW for winter maintenance yields larger chloride loads estimates, which indicates that the tool defaults may not be representative of winter maintenance in the DUAW. Dust suppressant and water-softening are likely the next largest sources of chloride, but limited local data are available to estimate their loads. As much of the impaired subwatersheds (46% to 92% by area) are served by sanitary sewers in the Western Lake Superior Sanitary District (WLSSD) and most septage is disposed of at WLSSD, much of the chloride load generated from water softening is not delivered to the impaired streams.

Chloride TMDLs are developed using a simple, zero-dimensional, steady-state modeling approach that the Minnesota Pollution Control Agency (MPCA) previously used to develop chloride TMDLs in the Twin Cities Metropolitan Area (TCMA). In this approach, the loading capacity is based on Minnesota's chronic chloride standard (230 milligrams per liter) and the average amount of winter season (November through March) runoff. Long-term, winter season precipitation data (Duluth International Airport [DIA]) and a runoff coefficient are used to determine the amount of average winter season runoff.

Necessary reductions are calculated using Minnesota's chronic chloride standard and the maximum observed chloride concentration in each impaired stream. Reductions needed for the five impaired streams ranged from 17% to 80%.

The TMDL implementation strategy relies on the *Minnesota Statewide Chloride Management Plan* and Statewide chloride resources (including reports, guidance, and educational materials) provided by MPCA. Since stormwater is an important pathway for transporting chloride, best management practices (BMPs) will need to be implemented by permitted point sources to address stormwater from municipal separate storm sewer systems (MS4) and industrial facilities.

Public participation included meetings and information communication with watershed stakeholders at various points during the project. A Core Team composed of representatives from communities, universities, and local and state agencies provided important data and information and worked with MPCA to develop the TMDLs and implementation strategy.

Figure 2. Ice breakup on Lake Superior in Canal Park, Duluth, MN.

Source: Tom Estabrooks (MPCA)

1. Project overview

1.1 Introduction

Section 303(d) of the federal CWA requires that TMDLs be developed for waters that do not support their designated uses. These waters are referred to as “impaired” and are included in Minnesota’s list of impaired waterbodies. The term “TMDL” refers to the maximum amount of a given pollutant a waterbody can receive on a daily basis and still achieve water quality standards. A TMDL study determines what is needed to attain and maintain water quality standards in waters that are not currently meeting those standards. A TMDL study identifies pollutant sources and allocates pollutant loads among those sources. The total of all allocations, including wasteload allocations (WLAs) for permitted sources, load allocations (LAs) for nonpermitted sources (including natural background), and the margin of safety (MOS), which is implicitly or explicitly defined, cannot exceed the maximum allowable pollutant load.

This TMDL study addresses streams impaired for their aquatic life use by chloride in the Duluth Urban Area (DUA) in northeast Minnesota (Figure 3). The DUAW is composed of the developed area in the city of Duluth and the surrounding communities. This “administrative watershed” is composed of portions of two of Minnesota’s major watersheds: the St. Louis River Watershed (SLRW; hydrologic unit code [HUC] 04010201) and Lake Superior South Watershed (HUC 04010102). The project area is composed of the subwatersheds draining to five streams impaired by chloride (Figure 4). The project area is approximately 39 square miles.

Figure 3. Northeastern Minnesota.

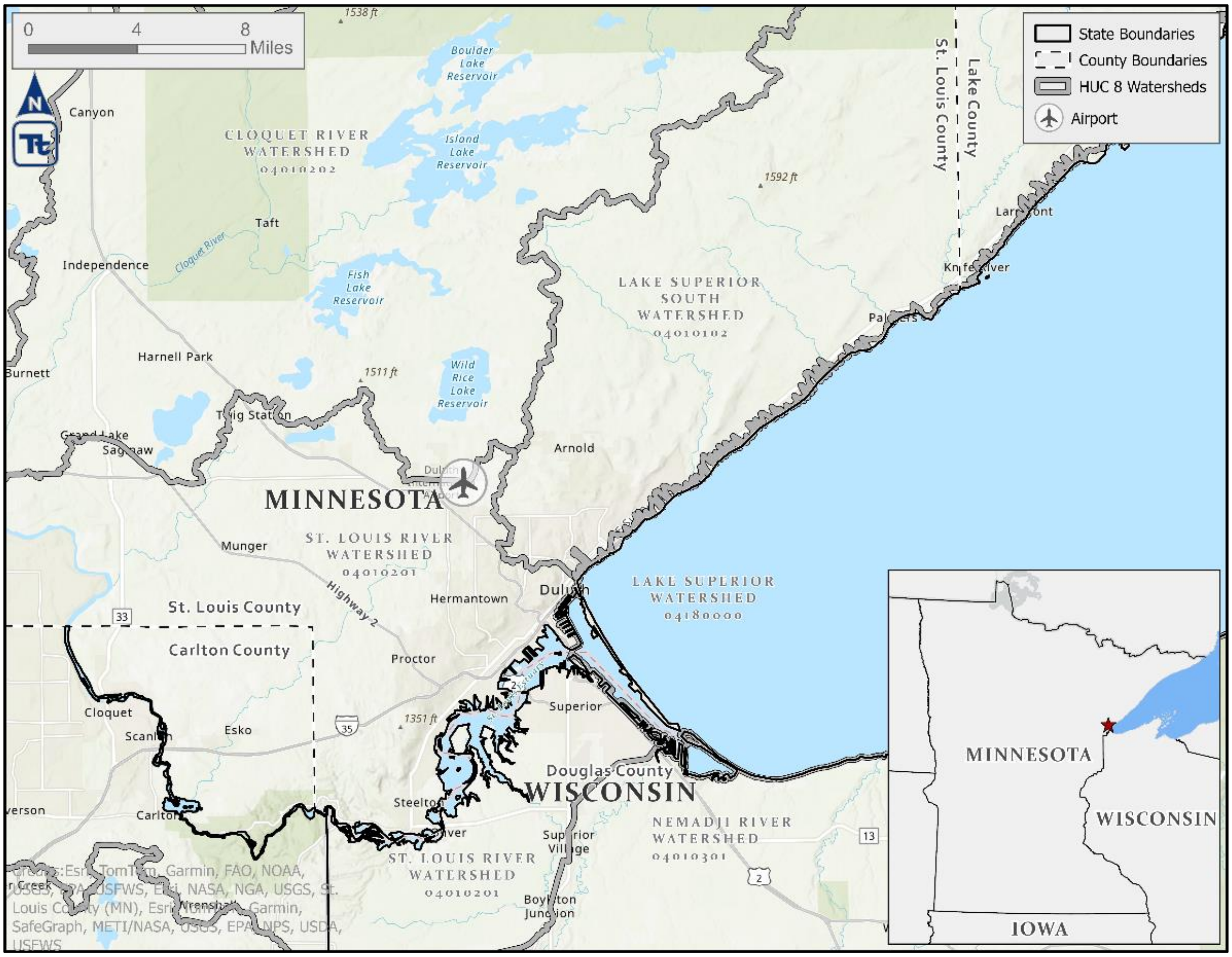
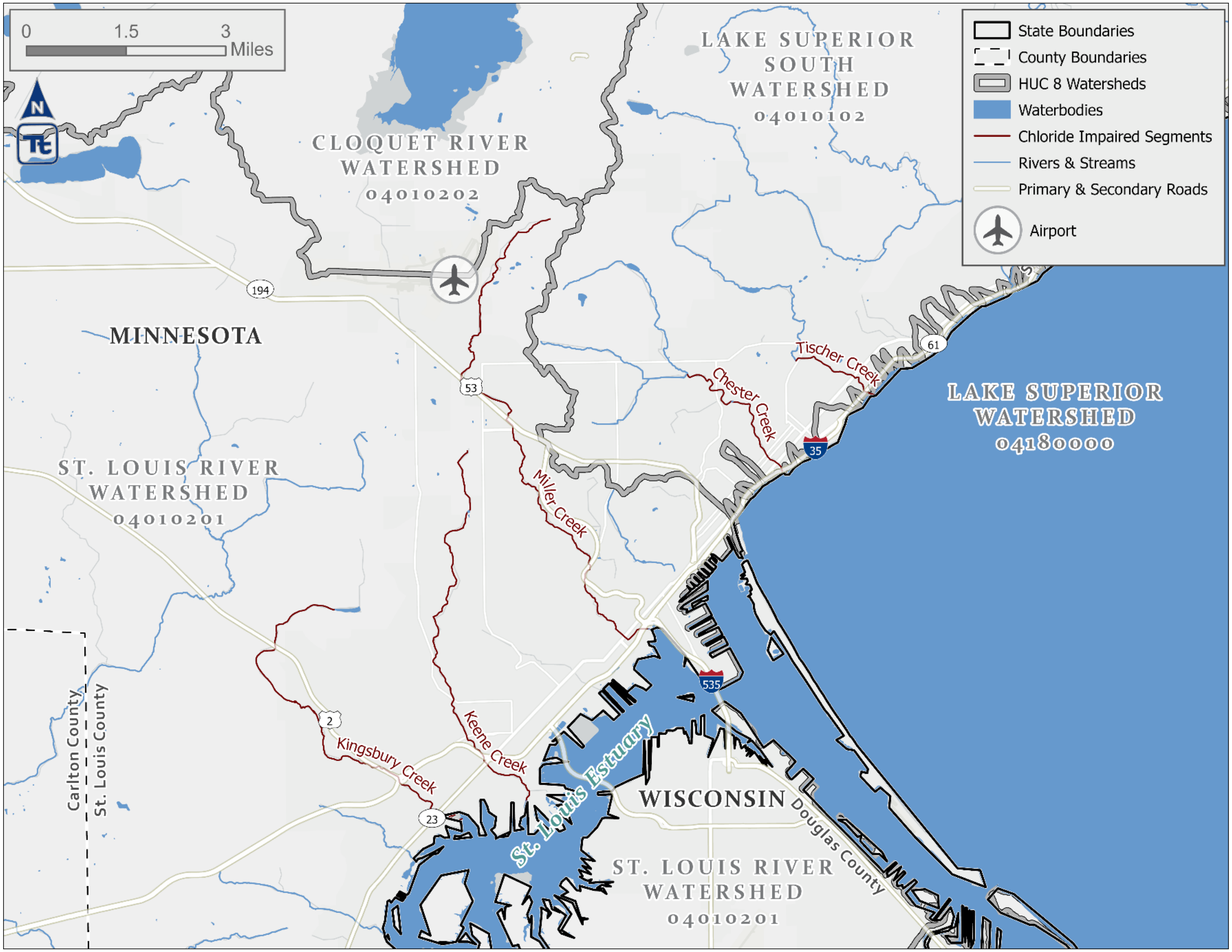


Figure 4. Streams impaired by chloride in the DUAW.



While this TMDL study is the first to develop TMDLs to address chloride impairments in the DUAW, three previous studies evaluated chloride in several of the chloride-impaired waters in the area:

- **Duluth Metropolitan Area Streams Snowmelt Runoff Study (Anderson et al. 2000)**: The MPCA collected water quality data in 1999 and evaluated chloride levels in Amity, Keene, Kingsbury, and Miller creeks in the DUA. No samples exceeded the chloride chronic standard. The MPCA opined that no samples exceeded standards because chloride levels were diluted by higher flows during snowmelt and no chloride-based deicer or anti-icer was applied during the summer. This study also cited data collected by the South St. Louis Soil and Water Conservation District (SWCD) as part of the Miller Creek Clean Water Partnership; the SWCD's data indicated that the chronic standard was exceeded during first flush events prior to ice-out. Thus, MPCA concluded that "chloride does not appear to be a problem at the streams studied *during snowmelt after ice-out*" (Anderson et al. 2000, Page 20).

  The 1999 chloride data were further evaluated for this TMDL study. Chloride concentrations were always largest on the rise of the snowmelt hydrograph and always decreased from the rise to the peak flow and from the peak flow to the fall of the snowmelt hydrograph. No trends were apparent spatially, between the headwaters, middle, and mouth samples; this may indicate the predominance of localized sources within each subwatershed. Baseflow concentrations were almost always larger than peak flow concentrations, which may indicate (1) summertime sources of chloride are present in these watersheds, (2) that groundwater contributes residual chloride to area streams during summer low-flows when groundwater contributes a larger portion of overall streamflow, (3) residual chloride from surface runoff remains sequestered in the streams themselves (rather than all being flushed downstream, or (4) some combination of these three scenarios.

- ***Final Duluth Urban Area Watershed Restoration and Protection Study* (WRAPS; MPCA 2020b)**: At the time of the WRAPS report, only Miller Creek was listed as impaired for its aquatic life use due to chloride (along with other stressors), and chloride was identified as a potential stressor for Kingsbury Creek. The Hydrologic Simulation Program – FORTRAN (HSPF) model for the DUAW, which was developed at a finer scale than most of MPCA's HSPF models, was used to spatially evaluate chloride yields. High yields (500 to 768-lbs/acre/year) were identified in several model subwatersheds, including model subwatersheds draining to Chester, Keene, Kingsbury, Miller, and Tischer creeks.

  The WRAPS report recommended further investigating sources of chloride in the DUAW, developing regional chloride monitoring and planning, and potentially developing chloride TMDLs.

- **Chloride Contamination Assessment in the Lake Superior South Watershed (Chun et al. 2021)**: The Natural Resources Research Institute (NRRI) at the University of Minnesota Duluth (UMD) collected water quality data in 2020 and 2021 and evaluated chloride levels in Amity, Kingsbury, and Tischer creeks in the DUA and Skunk Creek in Two Harbors. NRRI predicted continuous chloride concentrations using continuous conductivity monitoring data and a regression between chloride concentration and conductivity. NRRI found that chloride, likely from anthropogenic sources, was the dominant anion in conductivity (or salinity). "Most streams show higher levels of correlation between chloride in months more impacted by snow and rain with Kingsbury showing consistently high correlations year-round" (Chun et al. 2021, Page 6). Finally, NRRI found that "chloride concentration and loads into the streams appear to be site-specific in relation to the degree of urbanization, buffer zone and stream size" (Chun et al. 2021, Page 8).

This TMDL study addresses aquatic life uses in five streams that are impaired by chloride. Multiple designated uses are impaired by multiple pollutants in the DUAW. Several additional impairments in the DUAW are addressed by TMDLs that MPCA previously developed:

- *Miller Creek Water Temperature Total Maximum Daily Load Report* (MPCA 2018)
- *Duluth Urban Area Streams Watershed Total Maximum Daily Load* (MPCA 2020a)
- *Duluth Area Beaches Total Maximum Daily Load Report* (MPCA 2022a)

Similar to previous TMDL and WRAPS efforts, this TMDL study was conducted with the assistance of many organizations and individuals. The following organizations participated in coordination meetings and provided key input for TMDL development as part of a Core Team:

- Minnesota Department of Natural Resources (DNR)
- Minnesota Department of Transportation (MnDOT)
- Minnesota State College and University System
- WLSSD
- UMD and NRRI
- Lake Superior College
- St. Louis County
- Regional Stormwater Protection Team (RSPT)
- City of Duluth
- City of Hermantown
- City of Proctor
- City of Rice Lake
- South St. Louis SWCD

1.2 Identification of waterbodies

Table 1 below and Table 37 in Appendix A (which includes all impairments in this watershed) summarize DUAW impairments and those addressed by chloride TMDLs in this document. Refer to Figure 4, in Section 1.1, for a map of the chloride-impaired streams addressed by this TMDL study.

The TMDLs in this report do not replace nor revise previously approved TMDLs.

Figure 5. Chester Creek at Chester Park in Duluth, MN.
Source: Tom Estabrooks (MPCA)

Table 1. Impaired waterbodies and impairments in the DUAW addressed in this TMDL report

WID	Waterbody name	Waterbody description	Use class [a]	Listing year	Target commitment group	Affected designated use	Listing Parameter	TMDL Pollutant	Category in next impaired waters list [b]
04010102-544	Tischer Creek	Unnamed cr to Lake Superior	1B, 2AG	2026	--	AQL	Chloride	Chloride	4A
04010102-545	Chester Creek	E Br Chester Cr to Lk Superior	1B, 2AG	2024	2	AQL	Chloride	Chloride	4A
04010201-512	Miller Creek	Headwaters to St Louis R	1B, 2AG	2010	2	AQL	Chloride	Chloride	4A
04010201-626	Kingsbury Creek	Mogie Lk to St Louis R	1B, 2AG	2022	2	AQL	Chloride	Chloride	4A
04010201-627	Keene Creek	Headwaters to St Louis R	1B, 2AG	2022	2	AQL	Chloride	Chloride	4A

AQL: aquatic life; TMDL = total maximum daily load; WID = water unit identification.

Waterbodies are sorted numerically by WID.

a. Class 1 waters are protected for domestic consumption, and Class 2 waters are protected for aquatic life and human aquatic recreation (Minn. R. ch. 7050.0140).

b. Impairment will be categorized as 4A (impaired and a TMDL study has been approved by the U.S. Environmental Protection Agency) upon approval of this TMDL and will appear as 4A in the next impaired waters list.

1.3 Tribal lands

The DUAW is located on the traditional homelands of the Anishinaabe. However, no part of the DUAW is located within the boundary of federally recognized tribal land, and the TMDL does not allocate pollutant load to any federally recognized Tribal Nation in this watershed.

1.4 Priority ranking

The MPCA's TMDL commitments, as indicated on Minnesota's Section 303(d) impaired waters list, reflect Minnesota's priority ranking of the impairments addressed in this report. To meet the needs of EPA's *2022–2032 Vision for the Clean Water Act Section 303(d) Program* (U.S. Environmental Protection Agency [EPA] 2022), the MPCA aligned TMDL commitments with the watershed approach and other statewide strategies and initiatives in *Minnesota's Total Maximum Daily Load Studies Prioritization Framework* (MPCA 2024a). As part of these efforts, the MPCA identified water quality impaired segments to be addressed by TMDLs through the watershed approach and other statewide strategies and initiatives (MPCA 2024b).

Figure 6. Sunrise at Leif Erikson Park in Duluth, MN.

Source: Tom Estabrooks (MPCA)

2. Applicable water quality standards and numeric water quality targets

The federal CWA requires states to designate beneficial uses for all waters and develop water quality standards to protect each use. Water quality standards consist of several parts:

- Beneficial uses—Identify how people, aquatic communities, and wildlife use our waters
- Numeric standards—Amounts of specific pollutants allowed in a body of water that still protect it for the beneficial uses (note that EPA uses the phrase “numeric criteria” whereas Minnesota uses the phrase “numeric standards")
- Narrative standards—Statements of unacceptable conditions in and on the water (note that EPA uses the phrase “narrative criteria” whereas Minnesota uses the phrase “narrative standards")
- Antidegradation protections—Extra protection for high-quality or unique waters and existing uses

Together, the beneficial uses, numeric and narrative standards, and antidegradation protections provide the framework for achieving CWA goals. Minnesota’s water quality standards are in Minn. R. chs. 7050 and 7052.

2.1 Beneficial uses

The beneficial uses for waters in Minnesota are grouped into one or more classes as defined in Minn. R. 7050.0140. The classes and associated beneficial uses are:

- Class 1 – domestic consumption
- Class 2 – aquatic life and recreation
- Class 3 – industrial consumption
- Class 4 – agriculture and wildlife
- Class 5 – aesthetic enjoyment and navigation
- Class 6 – other uses and protection of border waters
- Class 7 – limited resource value waters

The Class 2 aquatic life beneficial use includes a tiered aquatic life uses framework for rivers and streams. The framework contains three tiers—exceptional, general, and modified uses.

All surface waters are protected for multiple beneficial uses, and numeric and narrative water quality standards are adopted into rule to protect each beneficial use. TMDLs are developed to protect the most sensitive use of a waterbody.

2.2 Narrative and numeric standards

Narrative and numeric water quality standards for all uses are listed for four common categories of surface waters in Minn. R. 7050.0220. The four categories are:

- Cold water aquatic life and habitat, drinking water, and associated use classes: Classes 1B; 2A, 2Ae, or 2Ag; 3; 4A and 4B; and 5
- Cool and warm water aquatic life and habitat, drinking water, and associated use classes: Classes 1B or 1C; 2Bd, 2Bde, 2Bdg, or 2Bdm; 3; 4A and 4B; and 5
- Cool and warm water aquatic life and habitat and associated use classes: Classes 2B, 2Be, 2Bg, 2Bm, or 2D; 3; 4A and 4B; and 5
- Limited resource value waters: Classes 3; 4A and 4B; 5; and 7

The narrative and numeric water quality standards for the individual use classes are listed in Minn. R. 7050.0221 through 7050.0227. The procedures for evaluating the narrative standards are presented in Minn. R. 7050.0150.

The MPCA assesses surface waters for the following beneficial uses:

- Class 1: Drinking water and aquatic consumption (human health-based standards)
- Class 2: Aquatic life (toxicity-based standards, conventional pollutants, biological indicators)
- Class 2: Aquatic recreation (*E. coli* bacteria, eutrophication)
- Class 2: Aquatic consumption (fish tissue and wildlife-based standards)
- Class 4A: Waters used for production of wild rice
- Class 7: Limited value resource waters (toxicity-based standards, *E. coli* bacteria, conventional pollutants)

Class 2 waters are further broken down into Class 2A and 2B waters. Class 2A waters are protected for the propagation and maintenance of a healthy community of cold water aquatic life and their habitats. Class 2B waters are protected for the propagation and maintenance of a healthy community of cool or warm water aquatic life and their habitats. Both Class 2A and 2B waters are also protected for aquatic recreation activities including bathing and swimming, and for human consumption of fish and other aquatic organisms.

2.3 Antidegradation policies and procedures

The purpose of the antidegradation provisions in Minn. R. ch. 7050.0250 through 7050.0335, is to achieve and maintain the highest possible quality in surface waters of the state. To accomplish this purpose:

- Existing uses and the level of water quality necessary to protect existing uses are maintained and protected.

- Degradation of high water quality is minimized and allowed only to the extent necessary to accommodate important economic or social development.
- Water quality necessary to preserve the exceptional characteristics of outstanding resource value waters is maintained and protected.
- Proposed activities with the potential for water quality impairments associated with thermal discharges are consistent with section 316 of the Clean Water Act, United States Code, title 33, section 1326.

2.4 DUAW water quality standards

Chester, Keene, Kingsbury, Miller, and Tischer creeks are designated class 2Ag for general coldwater aquatic life and habitat. Each of the five stream supports coldwater species. Minnesota adopted numeric criteria for class 2A waters in Minn. R. 7050.0222b, subp. 2.

The chronic standard for chloride to protect for class 2A use is 230 mg/L. The chronic standard is defined in Minn. R. 7050.0218, subp. 3.Q., as “the highest water concentration or fish tissue concentration of a toxicant or effluent to which aquatic life, humans, or wildlife can be exposed indefinitely without causing chronic toxicity.” The 230 mg/L value is based on a 4-day exposure of aquatic organisms to chloride. The *maximum standard* for chloride to protect for class 2B uses is 860 mg/L. The maximum standard is defined in Minn. R. 7050.0218, subp. 3.JJ., as “the highest concentration of a toxicant in water to which organisms can be exposed for a brief time with zero to slight mortality.” The 860 mg/L value is based on a 24-hour exposure of aquatic organisms to chloride. The final acute value for chloride to protect for class 2A uses is 1,720 mg/L. The final acute value is defined in Minn. R. 7050.0218, subp. 3.Y as “an estimate of the concentration of a pollutant corresponding to the cumulative probability of 0.05 in the distribution of all the acute toxicity values for the genera or species from the acceptable acute toxicity tests conducted on a pollutant.” These numeric standards are adopted from the EPA's recommended water quality criteria for chloride.

Table 2. Water quality standards for chloride in rivers and streams.

Parameter	Waterbody type	Water quality standard	Numeric standard
Chloride	Class 2A streams	Chronic standard: 230 mg/L Maximum standard: 860 mg/L Final acute value: 1,720 mg/L	230 mg/L

mg/L = milligram per liter.

3. Watershed and waterbody characterization

The DUAW is dominated by natural land covers with low slopes in the headwaters and by developed land along the St. Louis River Estuary and Lake Superior, with steep slopes separating the two areas. Streams in the DUAW typically have high gradients. The combination of high gradient, thin soils, and surficial bedrock geology limits the potential for infiltration (Anderson et al. 2000). Infiltration is also limited by the high levels of imperviousness. The connected impervious cover and storm sewers have altered the natural hydrology of the area.

Figure 7. Portland Malt Shoppe in Duluth, MN.
Source: Tom Estabrooks (MPCA)

In-depth watershed characterization is presented in the monitoring and assessment reports for the SLRW (HUC 04010201; MPCA 2013) and Lake Superior South Watershed (HUC 04010102; MPCA 2014). Additional watershed characterization is provided in the *St. Louis River Watershed Comprehensive Watershed Management Plan (CWMP) 2023-2032* (Bomier et al. 2022).

3.1 Climate trends

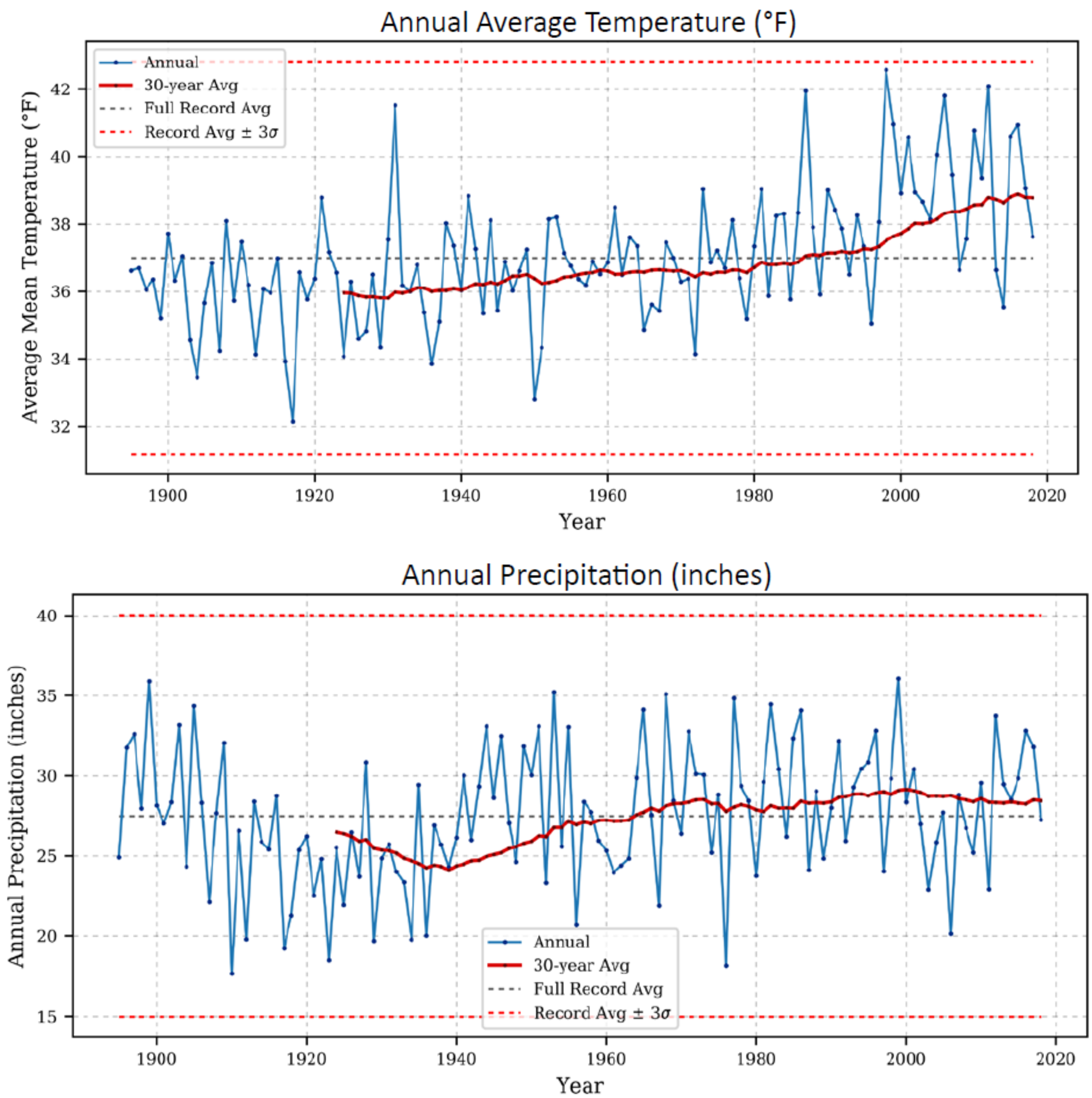
Temperatures in northeast Minnesota have been rising and are expected to continue to do so (Coffman et al. 2024). The rolling, 30-year annual average temperature for the SLRW has generally, steadily increased since 1924 (Figure 8, top chart). From 1989-2018 in the SLRW, the winter (December through February) temperature departure from long-term average was an increase of 3°F.

Trends with the rolling, 30-year annual average precipitation have varied: precipitation has slightly decreased from 2000 to 2020, after having slowly increased from 1955 to 2000 (Figure 8, bottom chart). More precipitation occurs in the summer months (June through August) of the SLRW than in the other seasons (Figure 9). From 1989 through 2018 in the SLRW, the summer average precipitation was 11.8 inches (DNR 2019), which is 42% of the annual precipitation. In more recent decades, more precipitation has occurred in September through December than historically (Figure 9). From 1989 through 2018 in the SLRW, the fall (September through November) departure was an increase of 0.5 inch (DNR 2019).

In northeast Minnesota, average annual temperature is projected to increase by 3.7° to 4.4°F and average annual precipitation is projected to increase by up to 1.3” by mid-century (2040-2059) (Coffman et al. 2024). The timing and intensity of precipitation is also expected to shift, with wetter springs, drier summers, shorter snow seasons, heavier rain events (Coffman et al. 2024).

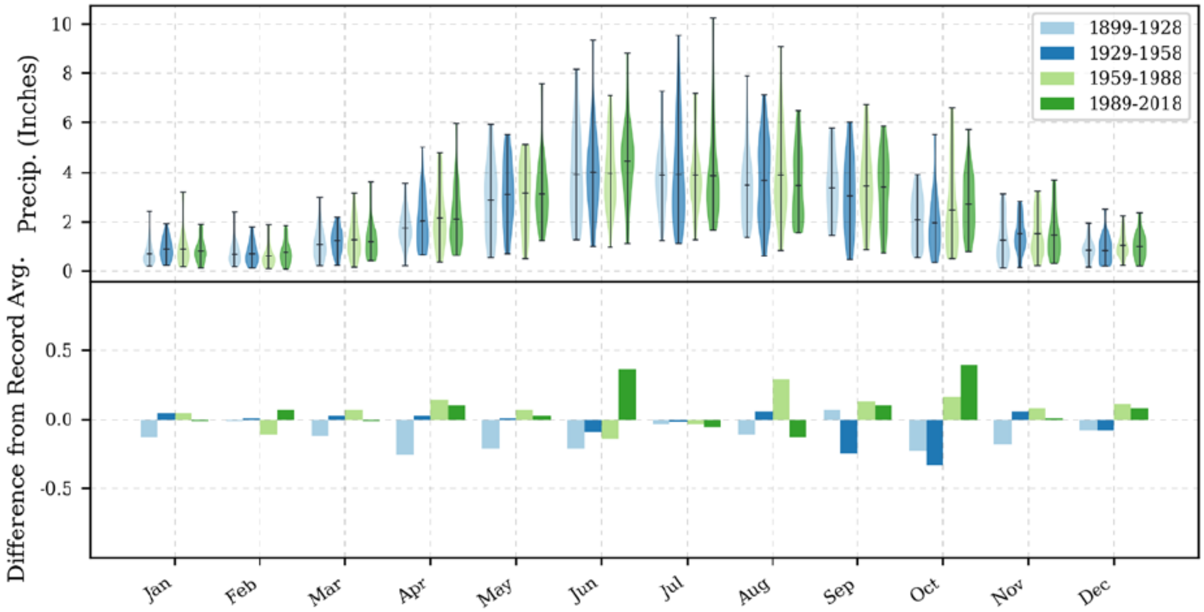
This TMDL study addresses five streams in the DUAW that are impaired for their aquatic life use due to high levels of chloride. As much of the chloride is from winter road maintenance activities, changes in snow and ice patterns will impact winter road maintenance and the timing and volume of chloride applications. Rising temperatures throughout the year can cause a reduction in snowpack and ice-melt and increases in precipitation volume and intensity, all of which will impact winter road maintenance and may require more application of anti-icing and de-icing agents. Additionally, these climate trends could detrimentally impact already stressed transportation and stormwater conveyance infrastructure that may have been designed for different climatological and hydrological conditions.

Figure 8. SLRW annual average air temperature (top) and precipitation (bottom) trends from 1900 - 2020.



Source: DNR 2019, Page 9 and Page 11

Figure 9. SLRW monthly precipitation distribution and departure from record mean (inches).



Source: DNR 2019, Page 10

3.2 Streams and subwatersheds

Subwatersheds for the five chloride-impaired streams in the DUAW are presented in Table 3 and Figure 10. The subwatersheds for Chester, Kingsbury, Miller, and Tischer creeks are Level 08 catchments from the DNR *Watershed Suite* (DNR 2023).

The Keene Creek Subwatershed is within (i.e., a portion of) a Level 08 catchment. The Keene Creek impairment subwatershed was delineated by starting with the Level 08 catchment 0318900 and using the Level 09 auto-catchments and a topographic map to manually cut the polygon following the borders and vertices of the Level 09 auto-catchments. The most downstream portion at the St. Louis River Estuary was manually delineated using best professional judgement and visual analysis of a topographic map.

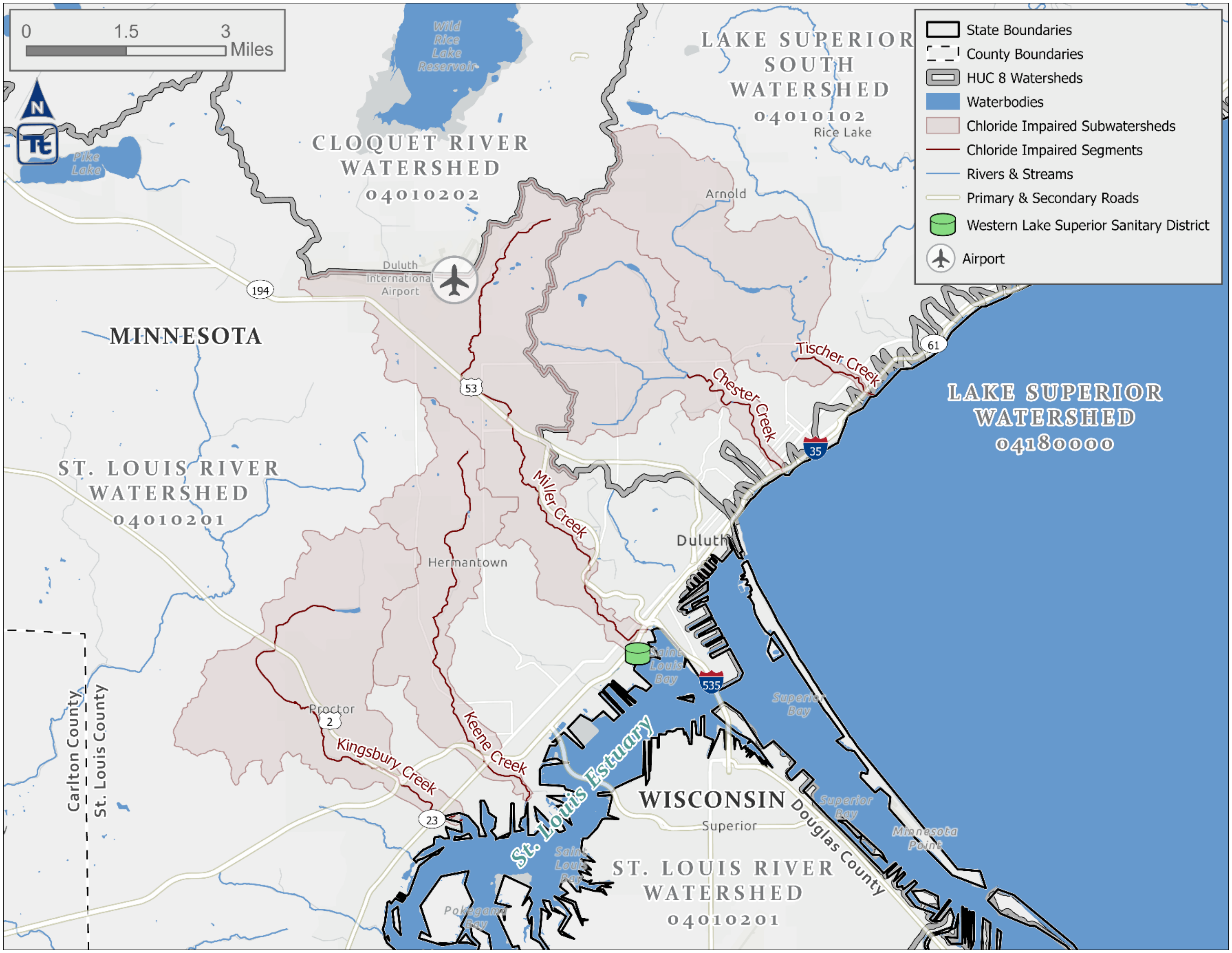
Table 3. Summary of subwatersheds for impaired streams receiving chloride TMDLs.

Major watershed	Impaired stream	WID	Subwatershed area (Acres) [a]	DNR (2023) Level 08 Catchment
Lake Superior South	Tischer Creek	04010102-544	4,658	0203900
	Chester Creek	04010102-545	4,309	0204000
St. Louis River	Keene Creek	04010201-627	3,712	0318900 [b]
	Kingsbury Creek	04010201-626	5,652	0318600
	Miller Creek	04010201-512	6,387	0300100

a. Area calculated by Tetra Tech (North American Datum 1983, state plane, Minnesota North).

b. Keene Creek is a small portion (about 14%) of DNR Level 08 catchment 03189000.

Figure 10. Impaired stream subwatersheds.



3.3 Land use and land cover

Land use and land cover for each impairment subwatershed are evaluated using the National Oceanic and Atmospheric Administration (NOAA) 2021 Coastal Change Analysis Program (C-CAP) Regional Land Cover. No single land use or land cover comprises a majority of any of the impairment subwatersheds. The largest individual land covers are deciduous forest (21% to 40%), low intensity developed (10% to 14%), and open developed (6% to 14%). The largest groupings are forest[1] (24% to 46%) and developed[2] (15% to 33%).

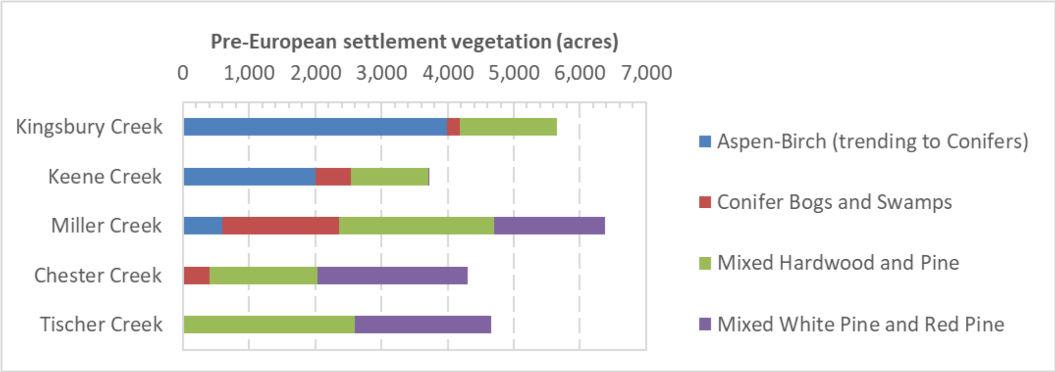
Land use and land cover from the 2016 National Land Cover Database (NLCD) are presented in Appendix B. The 2016 data may be more representative of the land use and land cover at the time when in-stream monitoring occurred (2016-2018).

The Multi-Resolution Land Characteristics Consortium now estimates impervious area annually. The 2023 *Fractional Impervious Surface* (USGS 2024) was plotted with the five impairment subwatersheds (Figure 13 on Page 18) and used to calculate the percentage of each subwatershed that is impervious:

- Kingsbury Creek: 12%
- Keene Creek: 11%
- Miller Creek: 26%
- Chester Creek: 14%
- Tischer Creek: 13%

In the SLRW, "prior to European settlement, much of the upland forest was aspen-birch and some old growth red and white pine" (Bomier et al. 2022, Page 18). The Kingsbury and Keene creeks subwatersheds to the west were dominated by aspen-birch (trending to conifers), while the Chester and Tischer creeks subwatersheds to the east were co-dominated by mixed hardwood and pine (maple, white pine, basswood, etc.) and mixed white pine and red pine. The Miller Creek Subwatershed, in the middle, was split across all four pre-European settlement vegetation types (Figure 11). Pre-European settlement vegetation is plotted in Figure 59 on Page 113 in Appendix B.

Figure 11. Pre-European settlement vegetation area summary by impairment subwatershed



Source: *Native Vegetation at the Time of the Public Land Survey 1847*-1907 (DNR 2022)

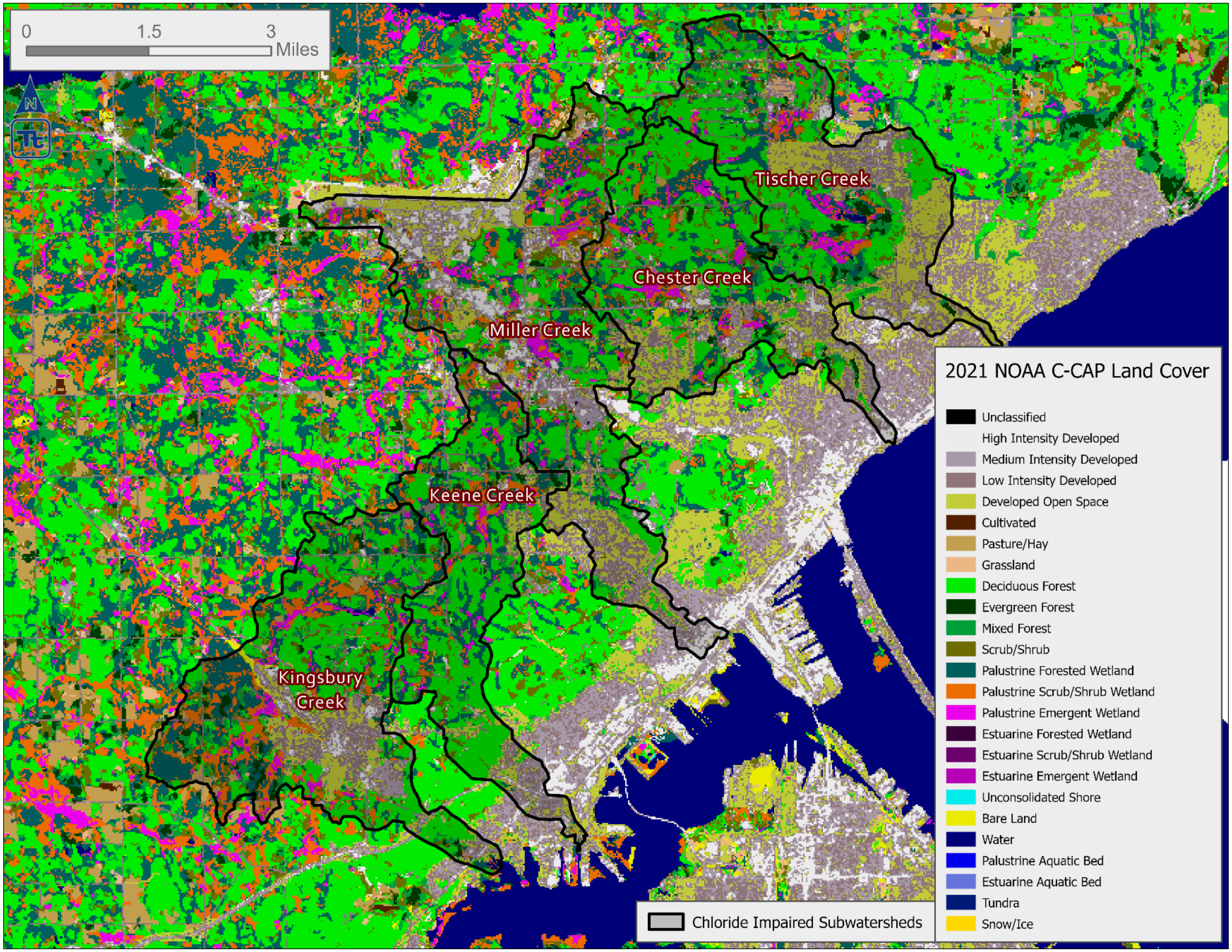
[1] The forest group is composed of deciduous forest, evergreen forest, and mixed forest.
[2] The developed group is composed of low-intensity, medium-intensity, and high-intensity developed.

Table 4. Land cover and land use by impairment subwatershed

Land cover	Kingsbury Creek		Keene Creek		Miller Creek		Chester Creek		Tischer Creek	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Water	19	<1%	3	<1%	9	<1%	3	<1%	17	<1%
Developed, open space	391	7%	214	6%	869	14%	468	11%	789	12%
Developed, low-intensity	585	10%	359	10%	890	14%	499	12%	731	11%
Developed, medium-intensity	266	5%	167	5%	757	12%	269	6%	224	4%
Developed, high-intensity	86	2%	46	1%	459	7%	87	2%	71	1%
Barren	27	<1%	8	<1%	23	<1%	26	1%	2	<1%
Deciduous forest	1,657	29%	1,501	40%	1,349	21%	1,474	34%	1,436	22%
Evergreen forest	147	3%	48	1%	46	1%	75	2%	112	2%
Mixed forest	221	4%	157	4%	157	2%	177	4%	325	5%
Shrub/scrub	326	6%	198	5%	418	7%	286	7%	234	4%
Grassland	16	<1%	19	1%	79	1%	32	1%	41	1%
Pasture/hay	109	2%	11	<1%	13	<1%	14	<1%	--	--
Palustrine Emergent Wetland	183	3%	120	3%	247	4%	152	4%	150	2%
Palustrine Forested Wetland	965	17%	605	16%	645	10%	508	12%	363	6%
Palustrine Scrub/Shrub Wetland	647	11%	253	7%	419	7%	236	5%	159	2%

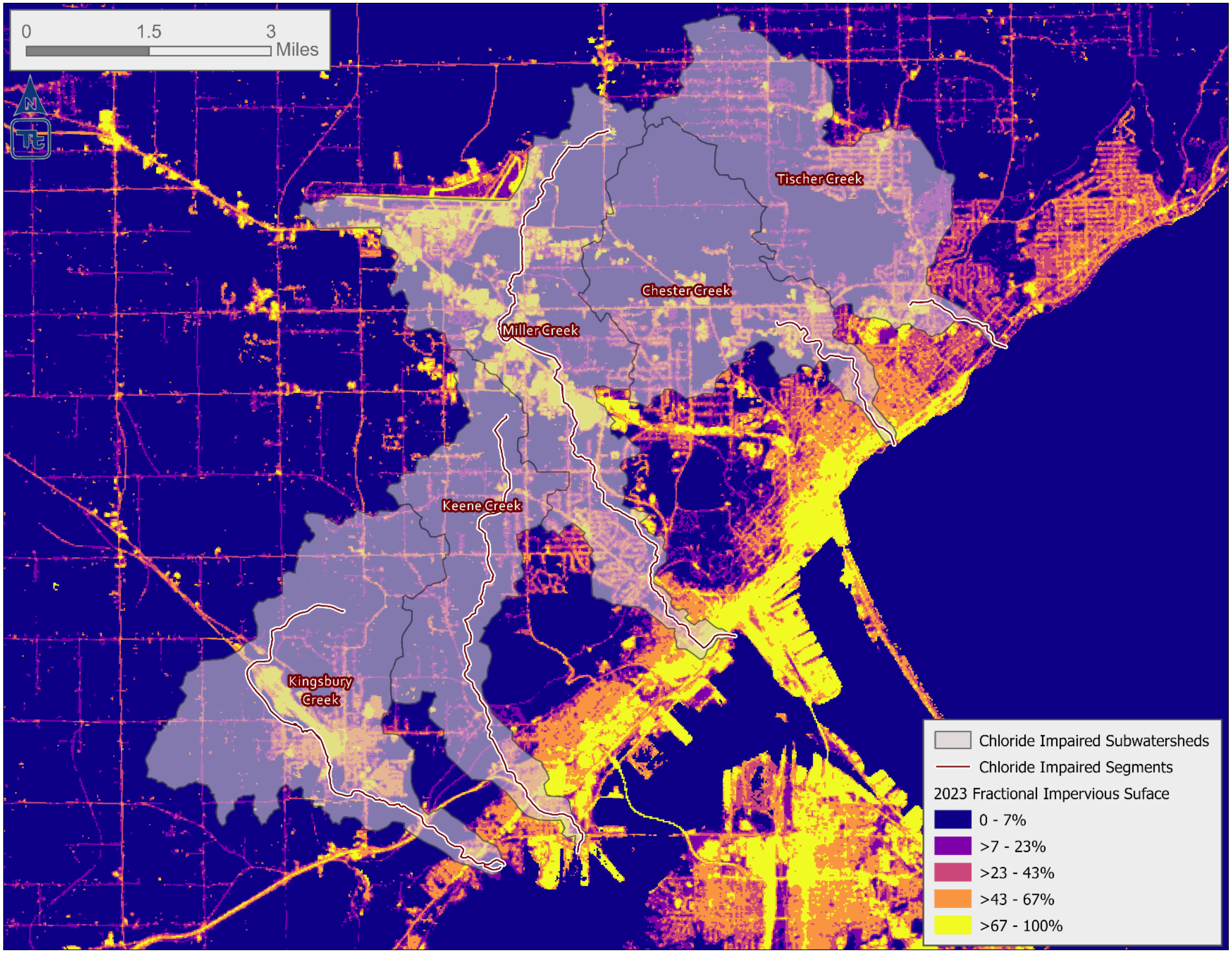
Source: C-CAP Regional Land Cover (NOAA 2021)
Note: Areas are rounded to the nearest acre and nearest percentage point.

Figure 12. Land cover and land use



Source: 2021 C-CAP Regional Land Cover (NOAA 2021)

Figure 13. Impervious cover and impairment subwatersheds



Source: 2023 Fractional Impervious Surface (USGS 2024)

3.4 Water quality

Water quality is often a function of stream flow, and water quality duration analyses are used to evaluate the relationships between hydrology and water quality. The water quality duration approach provides a visual display of the relationship between stream flow and water quality. Water quality duration curves were derived as follows.

Develop flow duration curves: Flow duration curves relate mean daily flow to the percent of time those values have been met or exceeded. For example, an average daily flow at the 50% exceedance value is the midpoint or median flow value; average daily flow in the reach equals the 50% exceedance value 50% of the time. The curve is divided into flow zones, including very high flows (0% to 10%), high flows (10% to 40%), mid-range flows (40% to 60%), low flows (60% to 90%), and very low flows (90% to 100%). These flow zones are shown on the water quality duration figures in sections 3.4.1 to 3.4.5 and the load duration curves figures in Section 4.8.

Flow duration curves were developed using daily average flow (1995 through 2021) from MPCA's HSPF modeling for the DUAW. Flows across the entire year were used because chloride samples were collected throughout the entire year. The simulated flows were calibrated with long-term data from three flow gaging stations and validated with short-term data from six flow gaging stations. Simulated flows are available at the downstream end of each model reach (Table 5). The model report (Tetra Tech 2022 and references within) describes the framework and the data that were used to develop the model and includes information on the calibration

Table 5. Model reaches used to simulate stream flow in impaired reaches

Reach name	AUID	Model Reach ID
Kingsbury Creek	04010201-626	272
Keene Creek	04010201-627	302
Miller Creek	04010201-512	330
Chester Creek	04010102-545	385
Tischer Creek	04010102-544	406

The table is sorted from top to bottom as west to east. Model reach IDs are from the DUAW HSPF model (Tetra Tech 2022).

Develop water quality duration figures: Water quality monitoring data and water quality standards are plotted on charts. The water quality monitoring data are plotted as the observed concentration and the flow exceedance on the day that the sample was taken.

Flow and water quality data are presented to evaluate the impairments and trends in water quality. Data from the last 10 years (2014 through 2023) were used in the water quality summary tables. Water quality data from the Environmental Quality Information System (EQuIS) database were used for the analysis.

3.4.1 Kingsbury Creek (WID 04010201-626)

Site S009-100 was sampled most frequently in 2014 through 2023 (n=30). Results from five samples were greater than the numeric value (230 mg/L) of the chronic chloride standard (Table 6); the five samples were collected in January and March (Table 7) and occurred during higher flow conditions (Figure 14).

Samples were also collected farther upstream at site S007-104 in 2017 and 2018 (n=28). Results from four samples were greater than the numeric value of the chronic standard in 2018 (n=15; June through December). Paired samples were collected at sites S007-104 and S009-100 in 2017 (n=12) and 2018 (n=14; Figure 15). In 2017, chloride concentrations at the downstream site S009-100 were always larger than concentrations at the upstream site S007-104 by an average of 12 mg/L (range: 8 to 21mg/L). No trend is visually apparent in January through March 2018 (Figure 15). From April through July 2018, concentrations were greater at downstream site S009-100 (average: 19 mg/L; range: 6 to 34mg/L).

Table 6. Annual summary of chloride data at Kingsbury Creek (WID 04010201-626, S009-100)

Year	Sample count	Minimum (mg/L)	Maximum (mg/L)	No. exceed chronic std	Percent exceed chronic std	No. exceed acute std	Percent exceed acute std
2017	14	43	89	0	0%	0	0%
2018	16	28	559	5	31%	0	0%

Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.

Concentrations are rounded to the nearest integer, and percentages are rounded to the nearest percentage point.

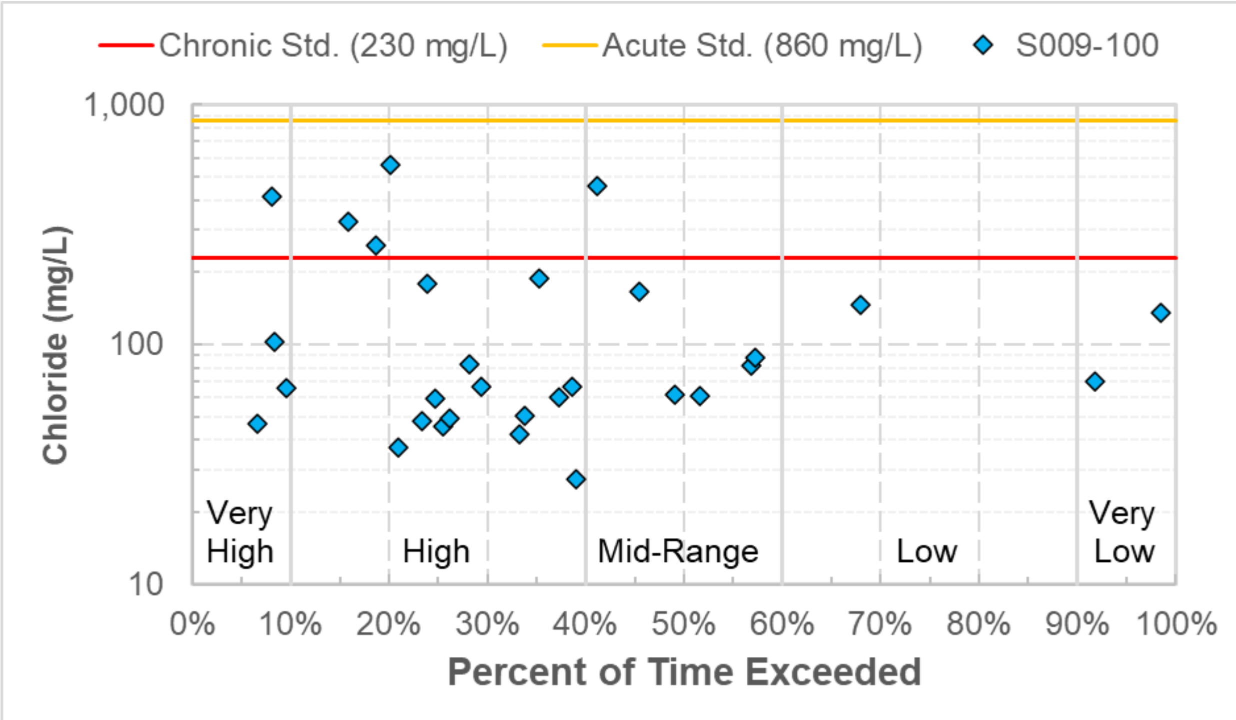
Table 7. Monthly summary of chloride data at Kingsbury Creek (WID 04010201-626, S009-100, 2017-2018)

Month	Sample count	Minimum (mg/L)	Maximum (mg/L)	No. exceed chronic std	Percent exceed chronic std	No. exceed acute std	Percent exceed acute std
January	3	146	460	2	67%	0	0%
February	0	--	--	--	--	--	--
March	4	180	559	3	75%	0	0%
April	5	28	188	0	0%	0	0%
May	2	59	70	0	0%	0	0%
June	2	37	66	0	0%	0	0%
July	3	51	136	0	0%	0	0%
August	1	83	83	0	0%	0	0%
September	1	48	48	0	0%	0	0%
October	2	43	47	0	0%	0	0%
November	4	46	67	0	0%	0	0%
December	3	67	89	0	0%	0	0%

Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.

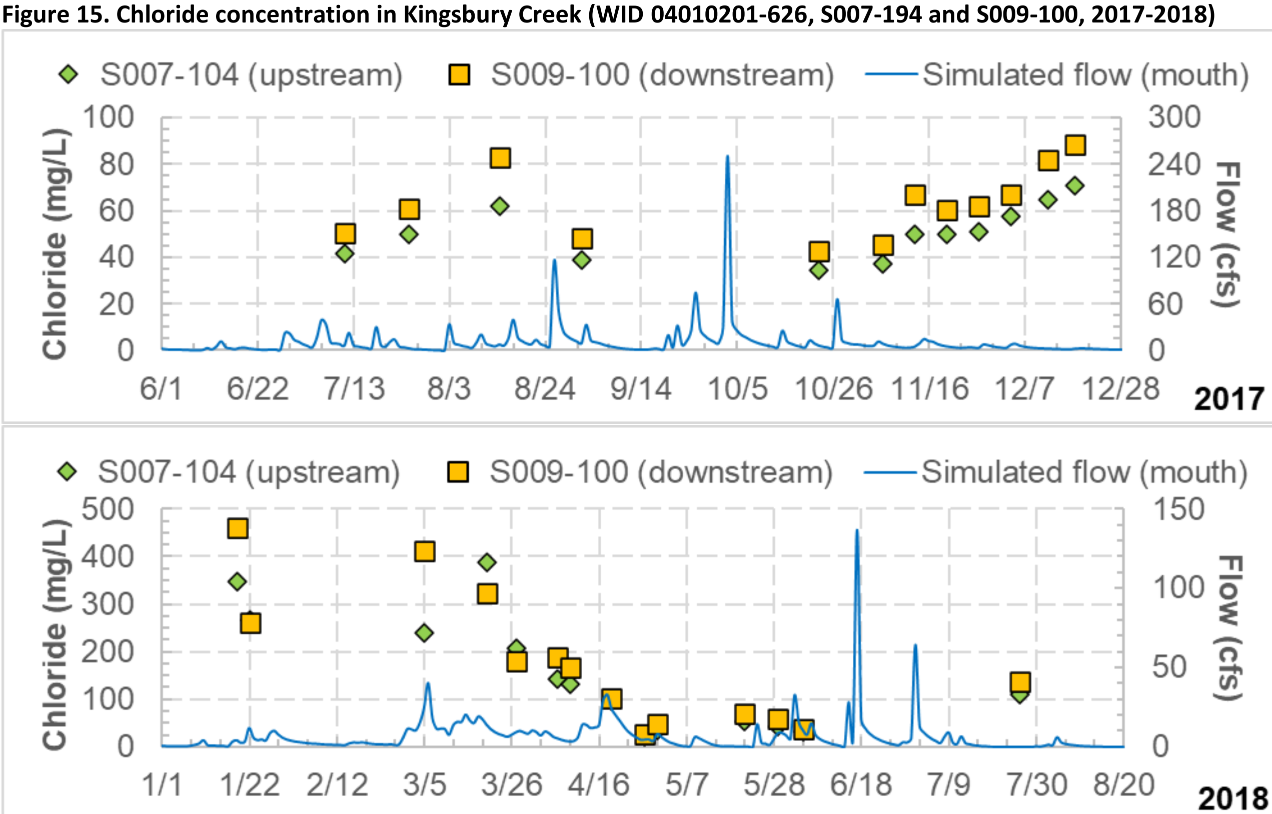
Concentrations are rounded to the nearest integer, and percentages are rounded to the nearest percentage point.

Figure 14. Chloride concentration by flow in Kingsbury Creek (WID 04010201-626, S009-100, 2017-2018)



The loads and percentage of time exceeded are calculated using HSPF-simulated daily flow from 1994-2021. Percent of time exceed is calculated using flows from January through December. Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.

Figure 15. Chloride concentration in Kingsbury Creek (WID 04010201-626, S007-194 and S009-100, 2017-2018)



3.4.2 Keene Creek (WID 04010201-627)

Only site S008-482 was sampled in 2014 through 2023 (n=87). Results from six samples were greater than 230 mg/L and the result from one sample was also greater than 860 mg/L (Table 8). These seven samples were collected in January and March (Table 9). Most concentrations in May through October ranged from 30 to 100 mg/L (Table 9 and Figure 16) and larger concentrations occurred during higher flow conditions (Figure 17). During baseflow and drier flow conditions (i.e., the low flow and very low flow zones in Figure 17), chloride concentrations ranged from 71 to 131 mg/L.

Table 8. Annual summary of chloride data at Keene Creek (WID 04010201-627, S008-482)

Year	Sample count	Minimum (mg/L)	Maximum (mg/L)	No. exceed chronic std	Percent exceed chronic std	No. exceed acute std	Percent exceed acute std
2016	38	23	215	0	0%	0	0%
2017	32	32	303	1	3%	0	0%
2018	17	35	874	5	29%	1	6%

Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.

Concentrations are rounded to the nearest integer, and percentages are rounded to the nearest percentage point.

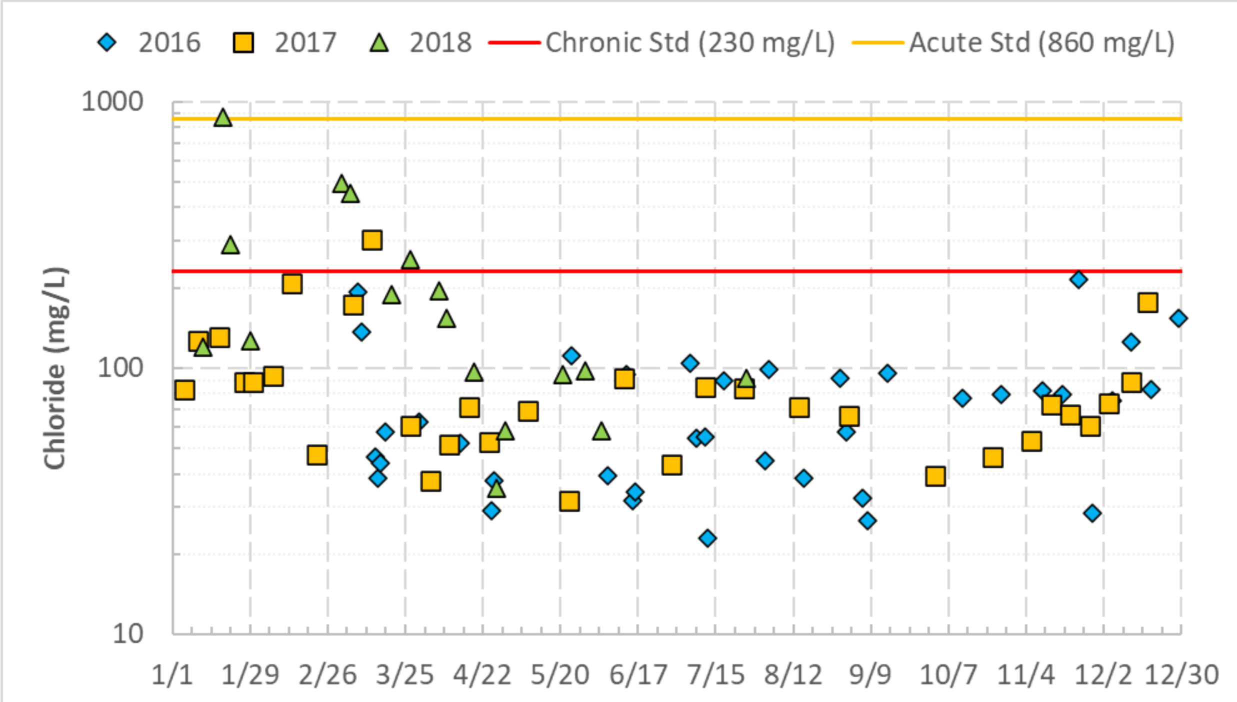
Table 9. Monthly summary of chloride data at Keene Creek (WID 04010201-627, S008-482, 2016-2018)

Month	Sample count	Minimum (mg/L)	Maximum (mg/L)	No. exceed chronic std	Percent exceed chronic std	No. exceed acute std	Percent exceed acute std
January	9	83	874	2	22%	1	11%
February	3	47	207	0	0%	0	0%
March	14	39	492	4	29%	0	0%
April	12	29	195	0	0%	0	0%
May	5	32	111	0	0%	0	0%
June	7	32	95	0	0%	0	0%
July	8	23	104	0	0%	0	0%
August	6	38	98	0	0%	0	0%
September	4	27	96	0	0%	0	0%
October	4	40	79	0	0%	0	0%
November	8	29	215	0	0%	0	0%
December	7	73	176	0	0%	0	0%

Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.

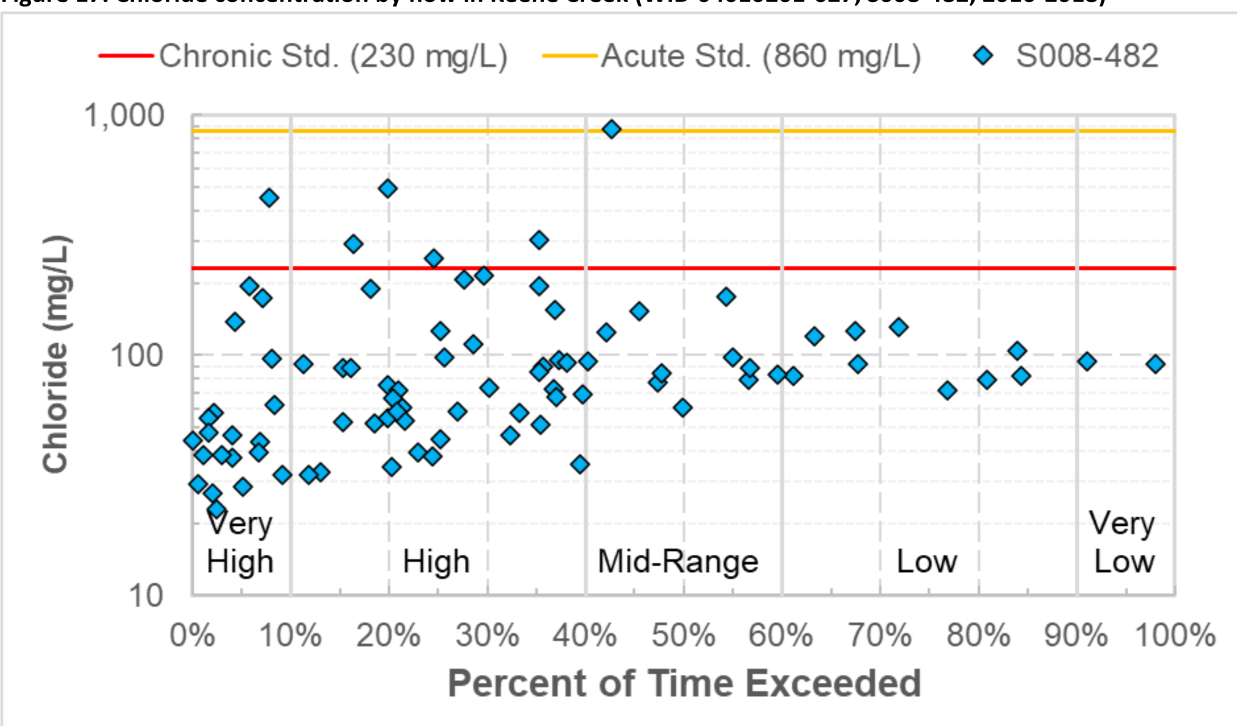
Concentrations are rounded to the nearest integer, and percentages are rounded to the nearest percentage point.

Figure 16. Chloride concentration by date in Keene Creek (WID 04010201-627, S008-482, 2016-2018)



Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.

Figure 17. Chloride concentration by flow in Keene Creek (WID 04010201-627, S008-482, 2016-2018)



The loads and percentage of time exceeded are calculated using HSPF-simulated daily flow from 1994-2021. Percent of time exceed is calculated using flows from January through December. Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.

3.4.3 Miller Creek (WID 04010201-512)

Site S008-484 was sampled most frequently in 2014-2023 (n=86). Results from 26 samples were greater than 230 mg/L and results from two samples were greater than 860 mg/L (Table 10). These samples were collected in November through April and July (Table 11), and these samples were collected during all flow conditions (Figure 18). Visual analysis of chloride concentrations in the lower and very low flow zones of Figure 18 indicates that chloride concentrations during baseflow are just above or 230 mg/L. A similar analysis for the other four impaired streams (Figure 14, Figure 17, Figure 21, and Figure 23) indicates that baseflow chloride concentrations are less than 170 mg/L.

Data collected in the past decade (2014 through 2023) are consistent with earlier data. In 1998 to 2010, sample results were frequently greater than 230 mg/L (MPCA 2016a). The *St. Louis River Watershed Stressor ID Report* (MPCA 2016a, Page 139) concluded that:

Monitoring results indicate that chloride concentrations in Miller Creek peak during the late winter months and increase again during the late summer and early fall. High streamflow during the spring snowmelt periods of March and April dilute chloride concentrations. Samples were also collected farther upstream at site S007-978 in 2017 and 2018 (n=31). Results from 11 samples (January through April) were greater than 230 mg/L in 2018 (n=17; January through June). Paired samples were collected at sites S008-484 and S007-978 in 2017 (n=14) and 2018 (n=13; Figure 19). In 2017, chloride concentrations at the downstream site S008-484 were always larger than concentrations at the upstream site S007-978 by an average of 42 mg/L (range: 6 to 101mg/L). In 2018, the general temporal trend is decreasing concentrations from January to June (Figure 19). Downstream concentrations at site S008-484 were often (but not always) larger than upstream concentrations, especially in January.

Table 10. Annual summary of chloride data at Miller Creek (WID 04010201-512, S008-484)

Year	Sample count	Minimum (mg/L)	Maximum (mg/L)	No. exceed chronic std	Percent exceed chronic std	No. exceed acute std	Percent exceed acute std
2016	38	44	440	6	16%	0	0%
2017	32	46	469	11	34%	0	0%
2018	14	78	1,170	9	64%	2	14%

Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.

Concentrations are rounded to the nearest integer, and percentages are rounded to the nearest percentage point.

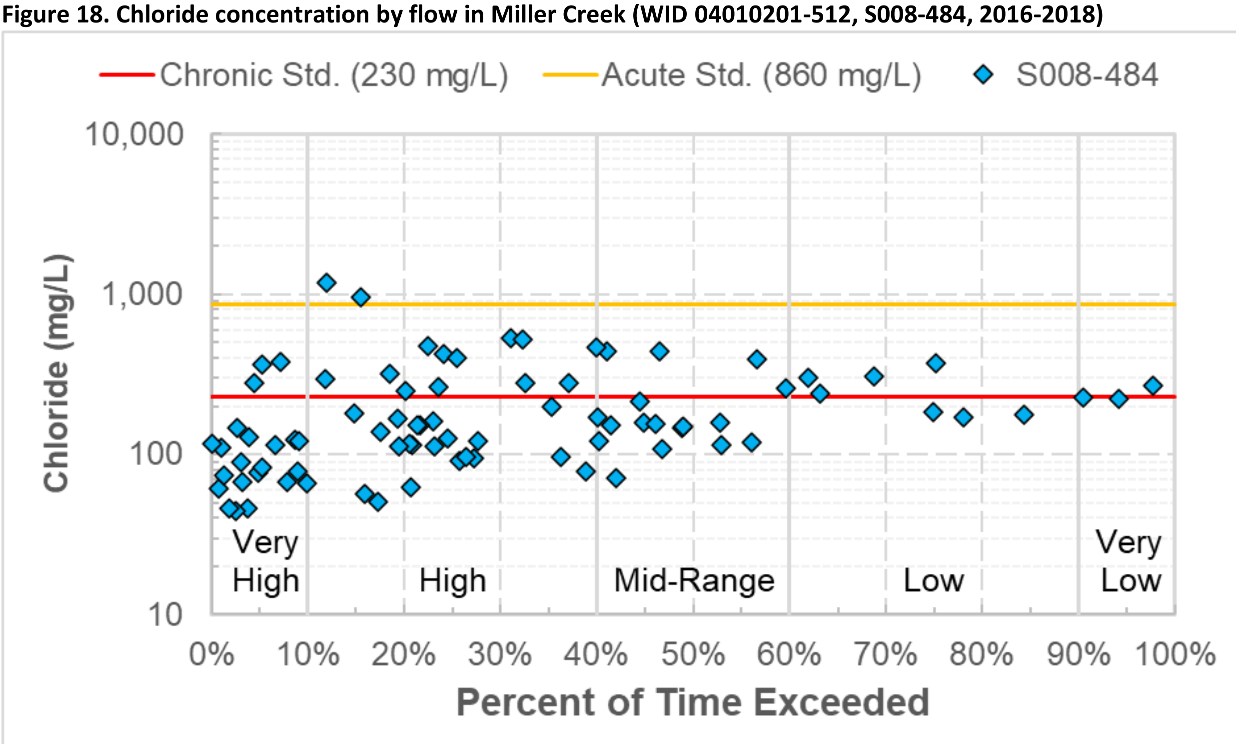
Table 11. Monthly summary of chloride data at Miller Creek (WID 04010201-512, S008-484, 2016-2018)

Month	Sample count	Minimum (mg/L)	Maximum (mg/L)	No. exceed chronic std	Percent exceed chronic std	No. exceed acute std	Percent exceed acute std
January	7	247	1,170	7	100%	1	14%
February	3	147	420	2	67%	0	0%
March	13	111	952	7	54%	1	8%
April	12	62	517	3	25%	0	0%
May	5	56	224	0	0%	0	0%
June	7	46	138	0	0%	0	0%
July	8	46	268	1	13%	0	0%
August	6	67	121	0	0%	0	0%
September	4	44	157	0	0%	0	0%
October	4	79	157	0	0%	0	0%
November	8	89	279	1	13%	0	0%
December	7	153	440	5	71%	0	0%

Minnesota’s chronic chloride standard is 230 mg/L and Minnesota’s acute chloride standard is 860 mg/L.

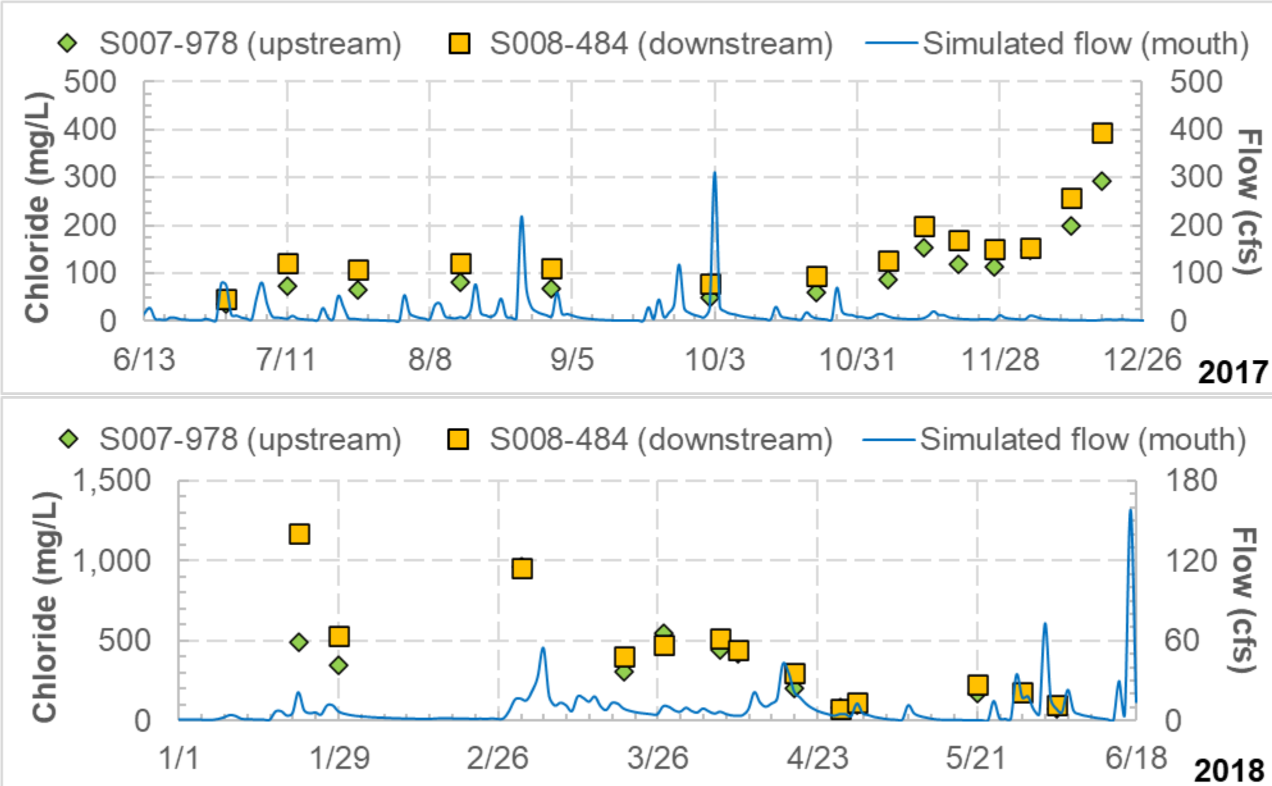
Concentrations are rounded to the nearest integer, and percentages are rounded to the nearest percentage point.

Figure 18. Chloride concentration by flow in Miller Creek (WID 04010201-512, S008-484, 2016-2018)



The loads and percentage of time exceeded are calculated using HSPF-simulated daily flow from 1994-2021. Percent of time exceed is calculated using flows from January through December. Minnesota’s chronic chloride standard is 230 mg/L and Minnesota’s acute chloride standard is 860 mg/L.

Figure 19. Chloride concentration in Miller Creek (WID 04010201-626, S007-978 and S009-100, 2017-2018)



3.4.4 Chester Creek (WID 04010102-545)

Site S008-481 was sampled most frequently in 2014-2023 (n=107). Results from only four samples were greater than 230 mg/L (Table 12); these samples were collected in January and March (Table 13) and occurred during higher flow conditions (Figure 21). During baseflow and drier flow conditions (i.e., the right-side of Figure 21), chloride concentrations ranged from 57 to 170 mg/L.

Samples were also collected farther downstream at site S014-891 in 2017 and 2018. No samples results were greater than 230 mg/L in 2017 (n=14; June through December), while eight sample results were greater than 230 mg/L in 2018 (n=19; January through July).

Table 12. Annual summary of chloride data at Chester Creek (WID 04010102-545, S008-481)

Year	Sample count	Minimum (mg/L)	Maximum (mg/L)	No. exceed chronic std	Percent exceed chronic std	No. exceed acute std	Percent exceed acute std
2014	0	--	--	--	--	--	--
2015	0	--	--	--	--	--	--
2016	38	39	206	0	0%	0	0%
2017	32	37	207	0	0%	0	0%
2018	18	41	277	4	10%	0	0%
2019	0	--	--	--	--	--	--
2020	1	27	27	0	0%	0	0%
2021	0	--	--	--	--	--	--
2022	18	41	166	0	0%	0	0%
2023	0	--	--	--	--	--	--

Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.
Concentrations are rounded to the nearest integer, and percentages are rounded to the nearest percentage point.

Table 13. Monthly summary of chloride data at Chester Creek (WID 04010102-545, S008-481, 2015-2022)

Month	Sample count	Minimum (mg/L)	Maximum (mg/L)	No. exceed chronic std	Percent exceed chronic std	No. exceed acute std	Percent exceed acute std
January	9	78	273	2	22%	0	0%
February	5	84	127	0	0%	0	0%
March	14	54	277	2	14%	0	0%
April	12	27	161	0	0%	0	0%
May	8	37	103	0	0%	0	0%
June	9	41	66	0	0%	0	0%
July	11	39	170	0	0%	0	0%
August	11	63	166	0	0%	0	0%
September	7	42	153	0	0%	0	0%
October	6	44	132	0	0%	0	0%
November	8	50	81	0	0%	0	0%
December	7	62	134	0	0%	0	0%

Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.

Concentrations are rounded to the nearest integer, and percentages are rounded to the nearest percentage point.

Figure 20. Chloride concentration by date in Chester Creek (WID 04010102-545, S008-481, 2016-2018)
Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.

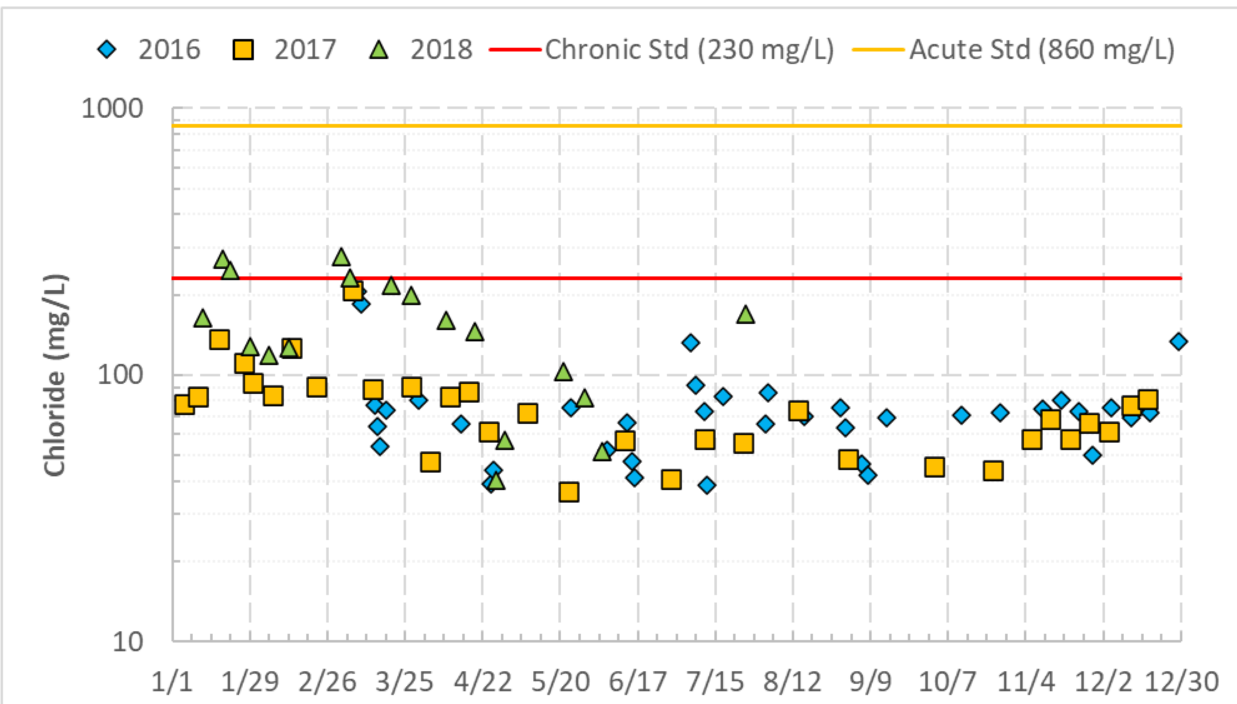
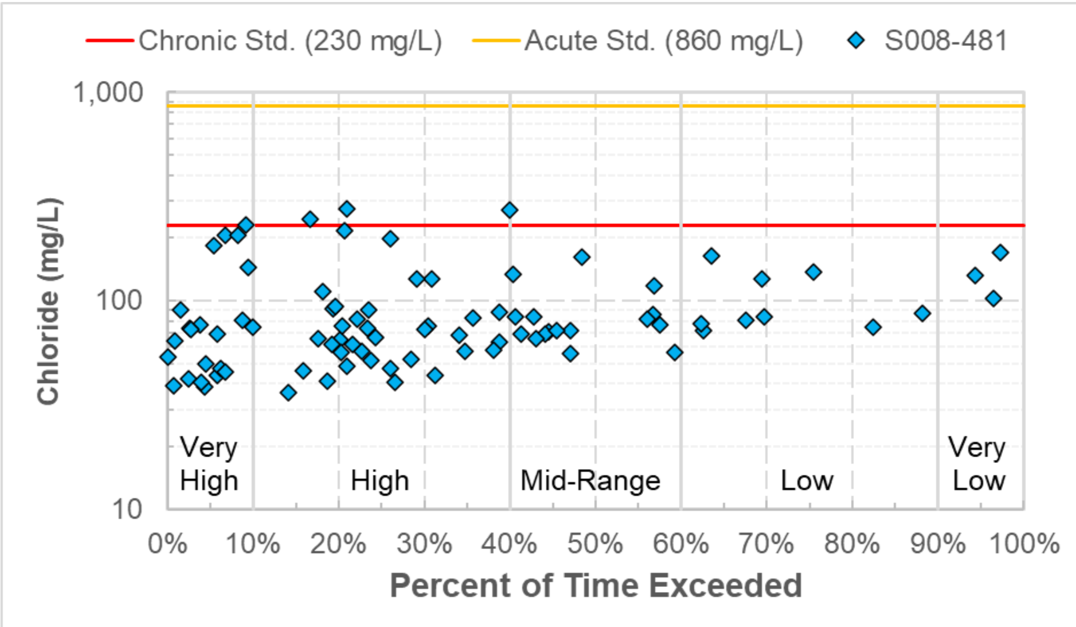


Figure 21. Chloride concentration by flow in Chester Creek (WID 0410102-545, S008-481, 2016-2018)



The loads and percentage of time exceeded are calculated using HSPF-simulated daily flow from 1994-2021. Percent of time exceed is calculated using flows from January-December. Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.

3.4.5 Tischer Creek (WID 04010102-544)

Only site S004-364 was sampled in 2014-2023 (n=111). Results from 10 samples were greater than 230 mg/L but no sample result was greater than 860 mg/L (Table 14). The larger concentrations occurred in the January, March, and November (Table 15) and occurred during higher flow conditions (Figure 17). Concentrations in May through October ranged from 16 to 99 mg/L (Table 15 and Figure 22).

Chloride concentrations collected at site S004-364 in 2008-2020 (n=136) were evaluated with hourly, simulated flow from the HSPF model. Samples were collected on the rising (n=15; 11%) and falling (n=61; 45%) limbs of the hydrograph and during stable flow conditions (n=60; 44%). No trends between concentration and location on the hydrograph was visually apparent (Figure 24).

Table 14. Annual summary of chloride data at Tischer Creek (WID 04010102-544, S004-364)

Year	Sample count	Minimum (mg/L)	Maximum (mg/L)	No. exceed chronic std	Percent exceed chronic std	No. exceed acute std	Percent exceed acute std
2014	0	--	--	--	--	--	--
2015	1	261	261	1	100%	0	0%
2016	37	26	436	1	3%	0	0%
2017	32	34	287	2	6%	0	0%
2018	18	50	453	4	22%	0	0%
2019	4	37	401	2	50%	0	0%
2020	1	42	42	0	0%	0	0%
2021	0	--	--	--	--	--	--
2022	18	39	99	0	0%	0	0%
2023	0	--	--	--	--	--	--

Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.
Concentrations are rounded to the nearest integer, and percentages are rounded to the nearest percentage point.

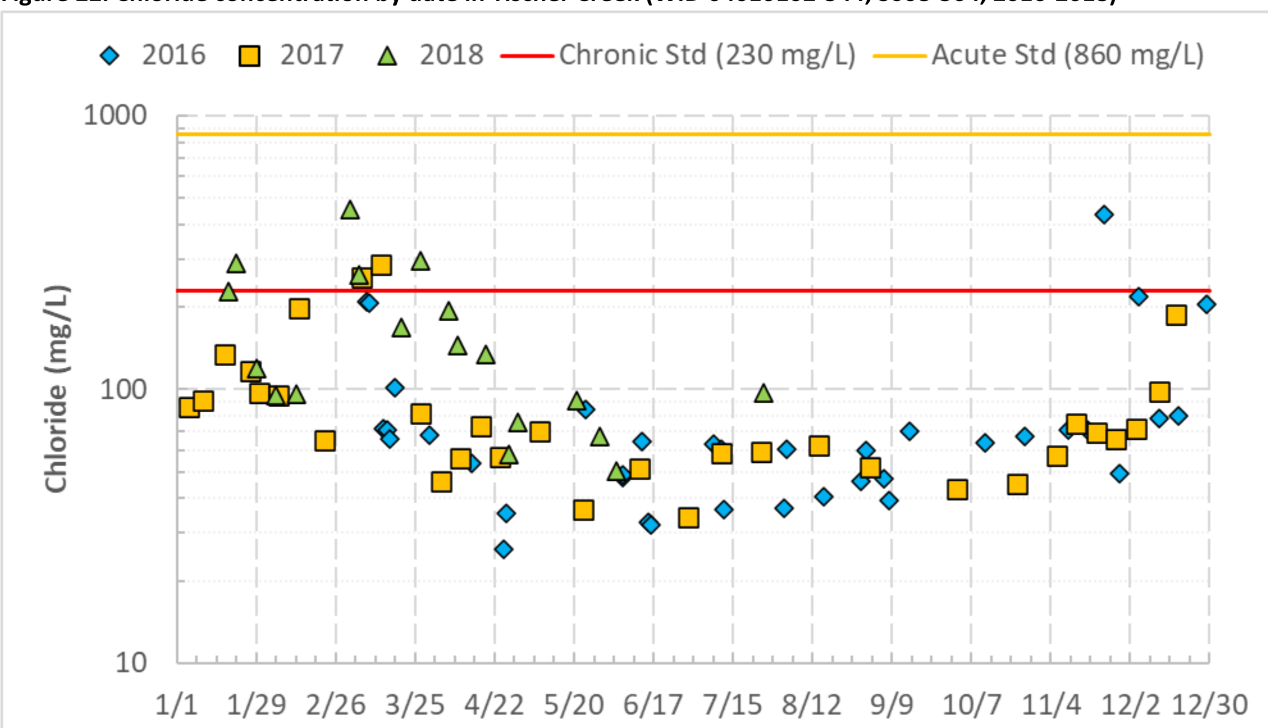
Table 15. Monthly summary of chloride data at Tischer Creek (WID 04010102-544, S004-364, 2015-2022)

Month	Sample count	Minimum (mg/L)	Maximum (mg/L)	No. exceed chronic std	Percent exceed chronic std	No. exceed acute std	Percent exceed acute std
January	8	86	288	1	13%	0	0%
February	5	65	199	0	0%	0	0%
March	22	32	453	7	32%	0	0%
April	22	26	194	0	0%	0	0%
May	11	37	91	0	0%	0	0%
June	17	16	88	0	0%	0	0%
July	16	16	99	0	0%	0	0%
August	17	37	99	0	0%	0	0%
September	13	39	95	0	0%	0	0%
October	7	25	97	0	0%	0	0%
November	9	49	436	2	22%	0	0%
December	7	72	219	0	0%	0	0%

Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.

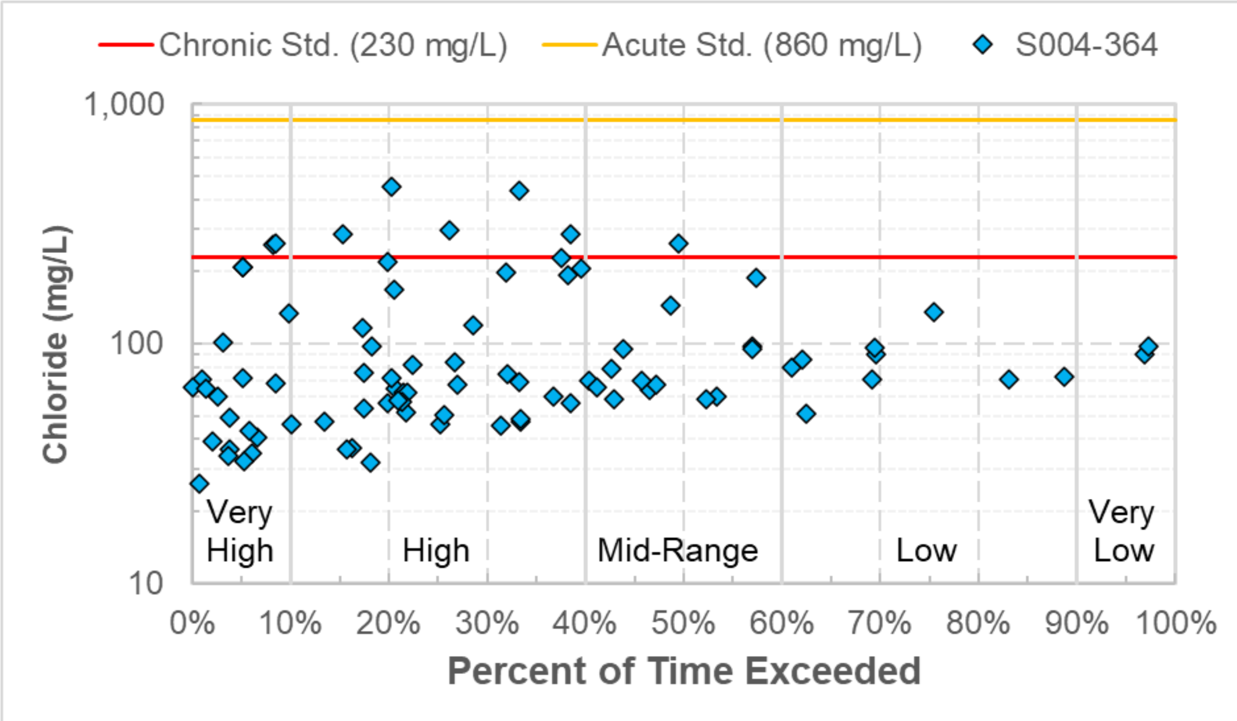
Concentrations are rounded to the nearest integer, and percentages are rounded to the nearest percentage point.

Figure 22. Chloride concentration by date in Tischer Creek (WID 04010102-544, S008-364, 2016-2018)



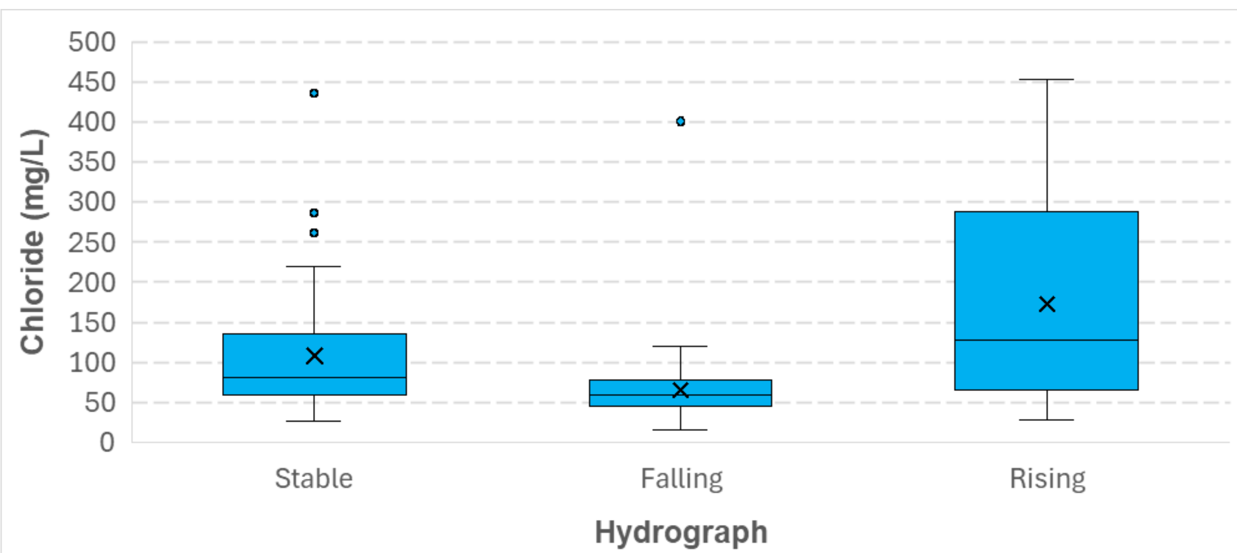
Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.

Figure 23. Chloride concentration by flow in Tischer Creek (WID 04010102-544, S004-364, 2016-2018)



The loads and percentage of time exceeded are calculated using HSPF-simulated daily flow from 1994-2021. Percent of time exceed is calculated using flows from January through December. Minnesota's chronic chloride standard is 230 mg/L and Minnesota's acute chloride standard is 860 mg/L.

Figure 24. Chloride concentration by hydrograph condition in Tischer Creek (WID 04010102-544, S004-364, 2008-2020)



Hydrograph condition was determined using HSPF-simulated daily flow from 1994-2021. The "rising" limb of a hydrograph represents increasing flow during and following precipitation, while the "falling" limb represents decreasing flow after precipitation. The "stable" condition is the period between precipitation when flow does not vary considerably.

3.4.6 Summary

The MPCA evaluated chloride in water quality samples most frequently during the period of 2016 through 2018 (Figure 25). Chloride concentrations from individual samples were greater than the value (230 mg/L) of Minnesota's chronic chloride standard each year in this period but were most frequently greater than 230 mg/L in 2018. The higher frequency in 2018 may be a reflection of varying amounts of sampling each year, with more winter samples collected in 2018. All but one result greater than 230 mg/L (July) occurred during November through April, with the most results greater than 230 mg/L occurring in March (44% of exceedances).

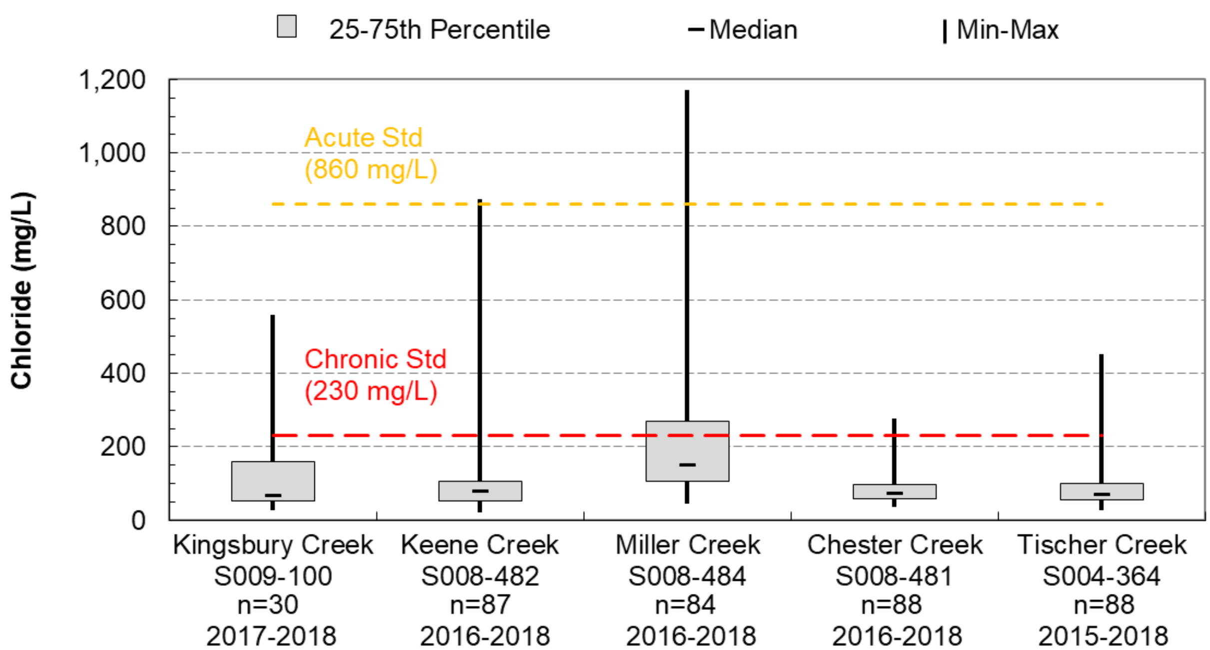
While results greater than 230 mg/L occurred across all flow zones (Table 16), such results most frequently occurred during high flow conditions (17%). Since larger concentrations occurred across all flow zones, multiple sources of chloride are likely. Sources during higher flow conditions are likely due to precipitation and runoff.

Table 16. Number of individual samples greater than 230 mg/L by flow zone (2016–2018)

Flow zone	Number of samples greater than 230 mg/L	Sample count	Percent of samples greater than 230 mg/L
Very high	8	89	9%
High	29	175	17%
Mid-range	7	66	11%
Low	4	35	11%
Very low	1	12	8%
Total	*49*	*377*	*13%*

Data from five assessment units were compiled.

Figure 25. Summary of chloride concentrations at key sites on impaired streams (2016-2018).



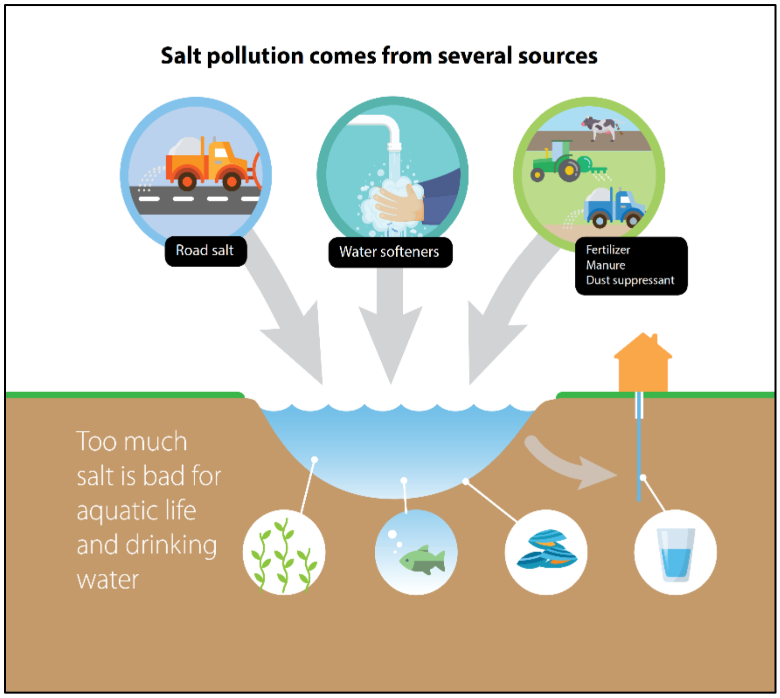
3.5 Pollutant source summary

Sources of chloride in the DUAW include permitted and nonpermitted sources. The permitted sources discussed here are pollutant sources that require a National Pollutant Discharge Elimination System (NPDES) permit. Nonpermitted sources are pollutant sources that do not require an NPDES permit. Most Minnesota NPDES permits are also State Disposal System (SDS) permits; however, some pollutant sources require SDS permit coverage alone without NPDES permit coverage (e.g., spray irrigation, large septic systems, land application of biosolids, and some feedlots).

The phrase "nonpermitted" does not indicate that the pollutants are illegal, but rather that they do not require an NPDES permit. Some nonpermitted sources are unregulated, and some nonpermitted sources are regulated through non-NPDES programs and permits such as state and local regulations.

A simple summary of chloride (i.e., salt) pollution sources that MPCA uses for public engagement is presented in Figure 26.

Figure 26. Sources of salt pollution
Source: MPCA

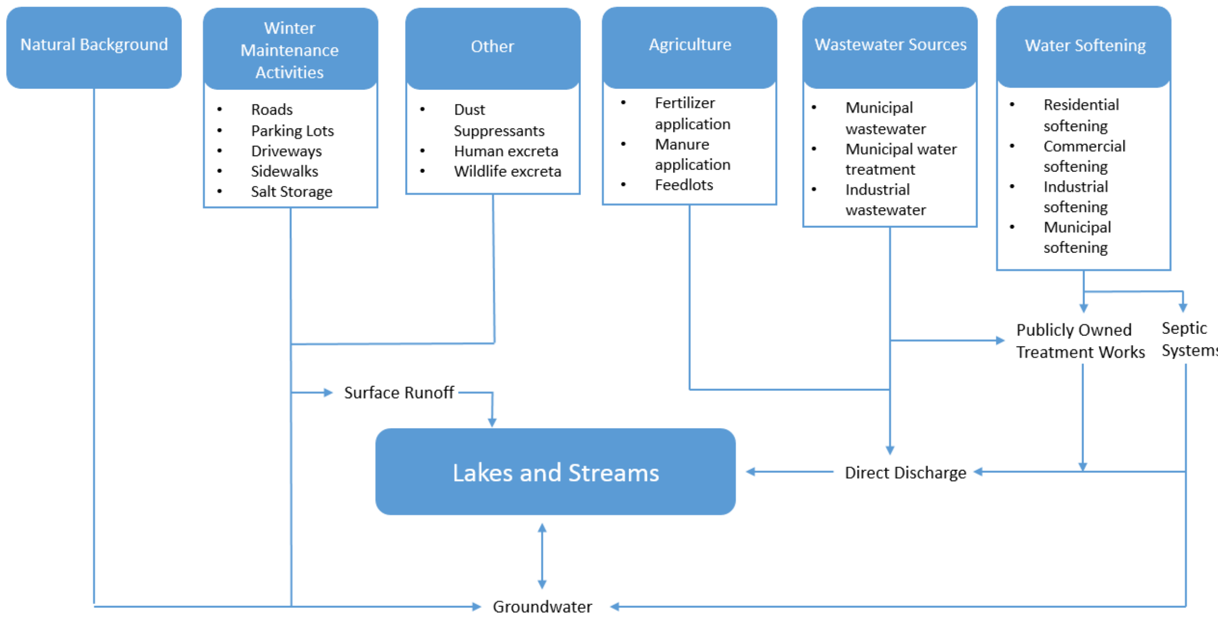


3.5.1 Typical sources of chloride in Minnesota

In Minnesota, "winter maintenance activities are typically the primary source of chloride to local water resources" in urbanized areas, while "fertilizer, water softening systems, dust suppressants, and animal manure" can be more important sources in rural and agricultural areas (MPCA 2020c, Page 14). These and other sources (including natural background sources) are summarized in Figure 27.

Refer to the *Minnesota Statewide Chloride Management Plan* (MPCA 2020c) for in-depth discussion of each source.

Figure 27. Conceptual model of anthropogenic sources of chloride and pathways



Source: MPCA 2020c.

The MPCA and the University of Minnesota (Overbo et al. 2019) quantified these sources and developed two chloride mass balances: (1) statewide sources and (2) wastewater treatment plant (WWTP) sources for those WWTPs with chloride data. The MPCA (2020c) incorporated these mass balances into the *Minnesota Statewide Chloride Management Plan.*

In the statewide chloride mass balance, Overbo et al. (2019) found that following distribution of sources of chloride (in rank order):

1. Road salt (42%)
2. Fertilizer (23%)
3. WWTPs (22%)
4. Livestock waste (6%)
5. Residential septic systems (3%)
6. Atmospheric deposition (1%)
7. Permitted industries (1%)
8. Dust suppressant (1%)

At the statewide scale, road salt, fertilizers, and WWTPs are the three largest sources of chloride load that contribute a combined 87% of the statewide chloride load. However, as is discussed in Section 3.5.2, no agricultural operations are in the five impaired subwatersheds and wastewater generated in the five impaired subwatersheds is transported outside of the subwatersheds (i.e., fertilizer and WWTPs are not sources of delivered chlorides to the impaired streams, nor are the typically smaller sources of livestock waste or permitted industries).

In the WWTP chloride mass balance, Overbo et al. (2019) found the following distribution of chloride sources contributing to WWTPs loads (in rank order):

1. Household water softening (49%)
2. Industry (22%)
3. Commercial water softening (16%)
4. Human excreta (4%)
5. Drinking water source (4%)
6. Commercial products (2%)
7. Drinking water chlorination (1%)
8. Household products (1%)
9. Wastewater chlorination (1%)

No WWTPs discharge in the five chloride impairment subwatersheds in the DUAW. However, household water softening, human excreta, drinking water, and household products are also sources for wastewater treated by SSTS. Considerable areas in the DUAW are served by SSTS. The results from Overbo et al. (2019) can provide insight to chloride in wastewater that is treated by SSTS.

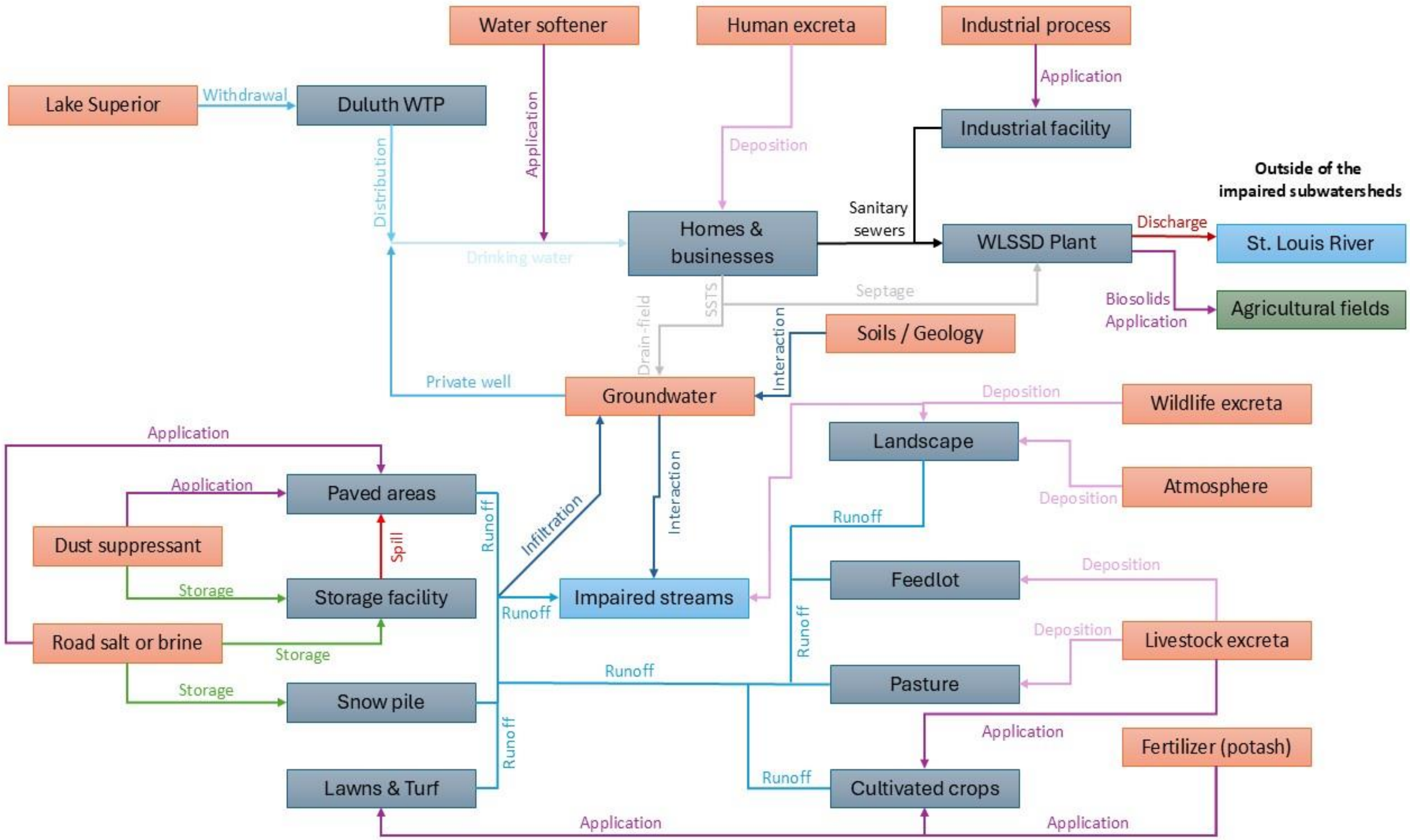
3.5.2 Sources of chloride in the impairment subwatersheds

The sources of chloride in the five impairment subwatersheds are the atmosphere, dust suppressants, excreta (from humans and wildlife), fertilizer, groundwater, industrial operations, public drinking water (from Lake Superior), water softeners, and winter road maintenance (Figure 28 on page 35). However, not all sources of chloride generated in the impairment subwatersheds are delivered to all five impaired streams.

Construction stormwater and nonmetallic mining wastewater covered by general NPDES permits are present in the chloride impairment subwatersheds but are not considered to be significant sources of chloride.

The following subsections discuss each source.

Figure 28. Chloride sources and pathways in the DUAW.



3.5.2.1 Atmosphere

Chloride in the atmosphere can be deposited anywhere via wet deposition (chloride ions in precipitation) or dry deposition (wind-blown, chloride-bearing particles). "Statewide, Minnesota monthly average precipitation chloride concentrations range from 0.006 to 3.2 mg/L" (Minnesota Groundwater Association [MGA] 2020, Page 10; citing the National Atmospheric Deposition Program). The MGA (2020) concludes that atmospheric deposition of chloride in Minnesota is minimal relative to other sources. In the statewide, annual chloride mass balance, atmospheric deposition of chloride was estimated to be 1.5% of the total of all generated source loads (Overbo et al. 2019).

Atmospheric deposition of chloride in the five impairment subwatersheds is assumed to be low (relative to winter road maintenance and summer dust suppression). Additionally, atmospheric deposition is assumed to be accounted for in the natural background load.

3.5.2.2 Dust Suppressants

Dust suppressants, often composed of chloride solutions, are applied to unpaved roads (e.g., gravel roads, dirt roads) during the warmer, windier time periods to prevent clouds of dust from forming along the roadways. After application, chemical dust suppressants can be transported to nearby streams via overland flow during and following precipitation events. Typical chemical dust suppressants include calcium chloride and magnesium chloride. While dust suppressant application rates are high relative to road salt and fertilizer application rates (on a chloride-basis), dust suppressant loads are only 1.0% of the statewide mass balance of all generated chloride load (Overbo et al. 2019).

Dust suppressant application on gravel roads owned by permitted MS4s in regulated areas is considered to be a point source, while dust suppressant application on gravel roads in unregulated areas of an MS4 or on most private land is considered to be a nonpoint (or nonpermitted) source of chloride. However, dust suppressant applications on private land at facilities regulated by stormwater NPDES permits are regulated as point sources. One such facility with dust suppressant application on private land is within the Kingsbury Creek impairment subwatershed.

Annual dust suppression along gravel roads in regulated MS4 areas occurs in the cities of Hermantown[3], Proctor[4], and Rice Lake[5]. Most of the gravel roads in Midway Township[6] are in unregulated MS4 areas. No dust suppression occurs in the city of Duluth[7]. MnDOT[8] and UMD[9] do not own any gravel roads in the project area and do not use dust suppressants; UMD owns gravel parking lots but does not use dust suppressants. Refer to Appendix C for additional information about dust suppression at regulated MS4s.

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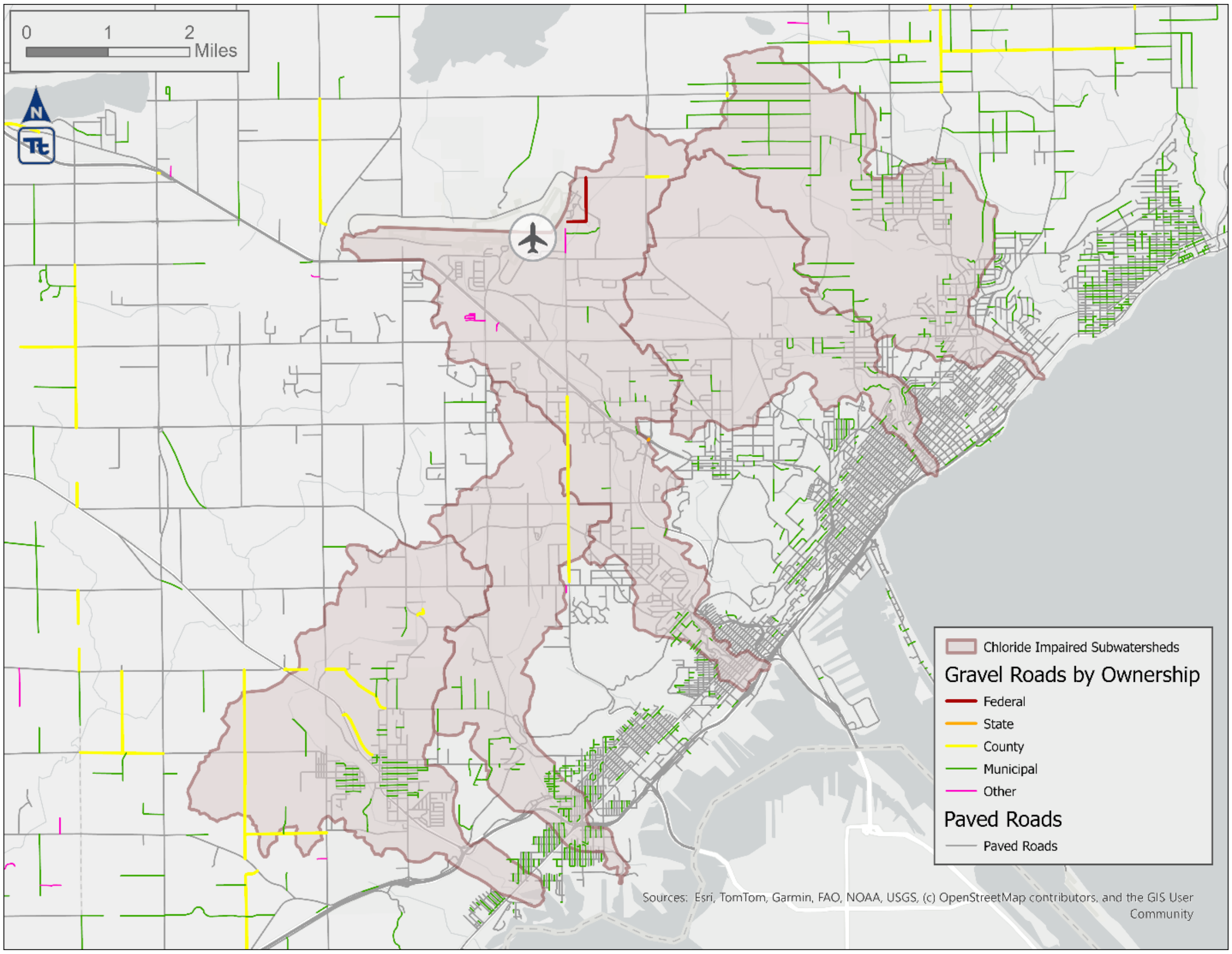
[3] Trish Crego, Utility and Infrastructure Director, City of Hermantown, electronic questionnaire, February 14, 2025.
[4] Jess Rich, City Administrator, City of Proctor, electronic questionnaire, March 3, 2025.
[5] Shayne Downey, Public Works Supervisor, City of Rice Lake, electronic questionnaire, February 26, 2025.
[6] James E. Aird, Town Board Chair, Midway Township, electronic questionnaire, March 4, 2025.
[7] Geoff Vukelich, Streets Maintenance Operations Coordinator, City of Duluth, electronic questionnaire, February 4, 2025.
[8] Matthew Meyer, Environmental Coordinator, MnDOT, electronic communication, February 27, 2025.
[9] Issac Kasper, Grounds and Fleet Manager, UMD, electronic questionnaire, January 31, 2025.

Figure 29 presents gravel roads in and around the DUAW. This map uses *Road Surface Material in Minnesota* data from the *Roadway Details in Minnesota* file geodatabase (MnDOT 2025c). In this map, gravel roads represent roads MnDOT identified as “Aggregate/Gravel”. However, several roads identified as “Aggregate/Gravel” are actually paved. Additional roads maps are in Appendix B.

Figure 29. Gravel roads in the DUAW and chloride impairment subwatersheds.



Source: MnDOT 2025a,b

Note: Several roads shown in this map as gravel are actually paved roads.

Watershed runoff

Precipitation that falls in a watershed drains across the land surface, and a portion of it eventually reaches lakes and streams. Pollutants such as chloride are carried with the runoff water and delivered to surface waterbodies.

Chloride loads derived from dust suppressant application were estimated for each impairment watershed using the Smart Salting Tool (Table 17). This tool estimates chloride load generated during upland application of dust suppressants; the tool does not consider delivery to surface waters. The tool was run with default data and assumptions[10]. The Smart Salting Tool estimated that dust suppressant application was a relatively small source of chloride load generated in the five impairment subwatersheds (about 1% of the total chloride load generated).

Table 17. Estimated chloride loads from dust suppressant application (Smart Salting Tool)

Subwatershed	Lane miles	Chloride load (tons/year)
Chester Creek	9.2	1.1
Keene Creek	7.4 [a]	0.9 [a]
Kingsbury Creek	27.1	3.1
Miller Creek	12.6	1.4
Tischer Creek	32.1	3.7

Subwatersheds are sorted alphabetically from top to bottom.
Estimated chloride loads using default data and assumptions to run the Smart Salting Tool.

a. The Keene Creek Subwatershed is approximately 14% of the Level 08 catchment 03189000. As such, the lane miles and chloride load for Keene Creek are estimated by calculating 14% of the lane miles (53.093) and chloride load (6.096) for catchment 0318900.

Industrial stormwater

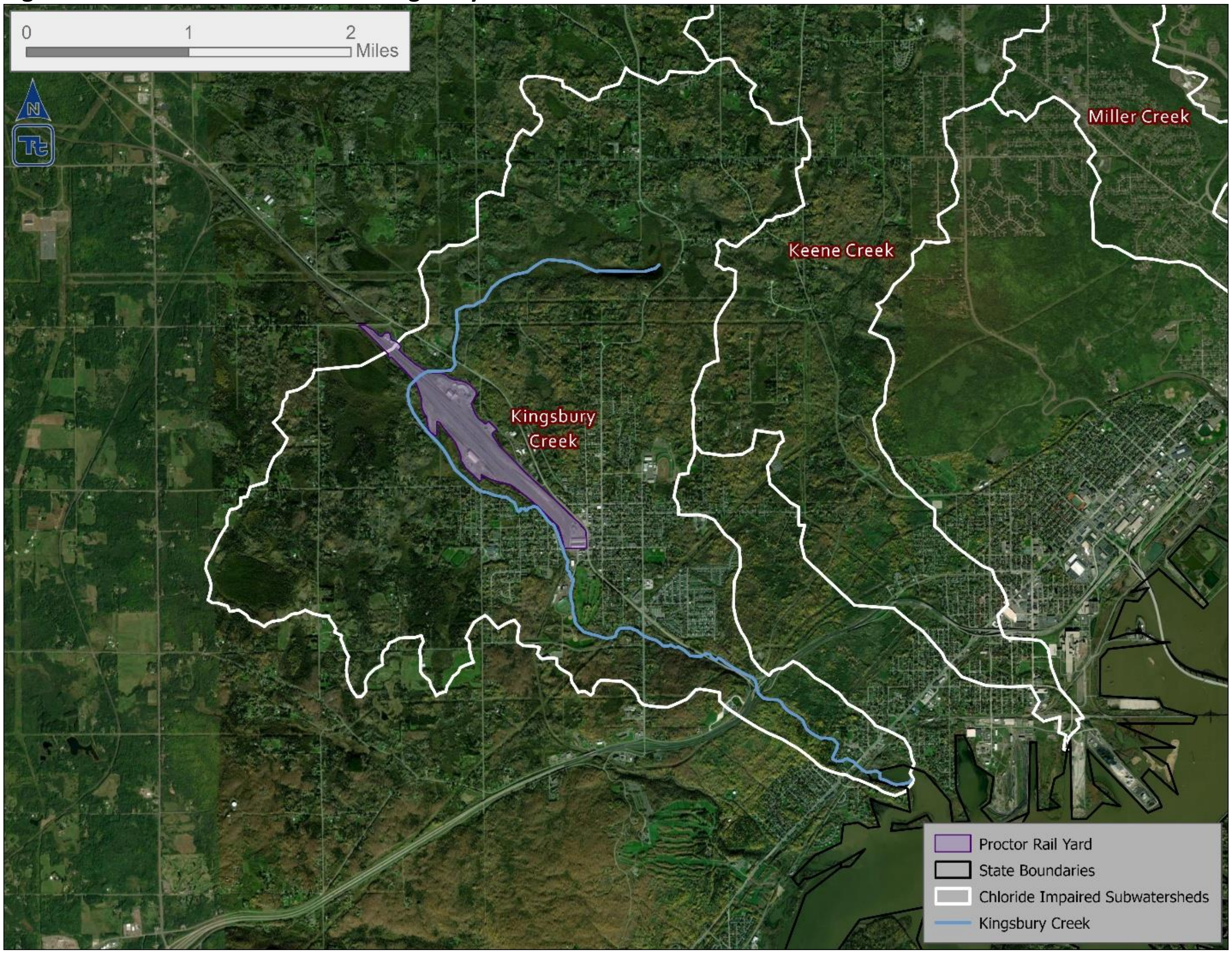
Industrial stormwater is regulated through an NPDES/SDS permit when stormwater discharges have the potential to come into contact with materials and activities associated with industrial activity.

Several industrial facilities authorized to discharge industrial stormwater through general NPDES permits are in the headwaters of the Miller Creek Subwatershed.

The Wisconsin Central Limited (WCL) Proctor Rail Yard (MN0000361) is an industrial facility that is authorized to discharge industrial stormwater through an individual NPDES permit. The permittee's contractors applied a chloride-based dust suppressant on unpaved roads during dry periods of the year in 2022, 2023, and 2024. The rail yard is within the city of Proctor and Midway Township. Kingsbury Creek flows west through the northern portion of the rail yard and then flows southeast along the western edge of the rail yard (Figure 30). Unpaved roads are located throughout the rail yard.

[10] The default dust suppressant application rate is 0.910 tons of salt per lane mile per year. The default percent of gravel roads that dust suppressant is applied to annually is 12.61% of lane miles.

Figure 30. Proctor Rail Yard in the Kingsbury Creek Subwatershed.



The permit requires annual dust suppressant application reporting but does not include stormwater effluent chloride monitoring requirements or limits. WCL monitors its property for dust during daylight hours and subcontracts with other firms to spray the dust suppressant using drip bars mounted on the rear end of tanker trucks (WCL 2024). The subcontractors avoids spraying the dust suppressant within 100-feet of Kingsbury Creek.

The dust suppressant is *EnviroTech® Services, Inc. Calcium Chloride Solution* that is 60% to 75% water and 25% to 40% calcium chloride (WCL 2024). The subcontractor dilutes this solution using a 65:35 ratio (water:solution). WCL did not report dust suppressant application rates. The WCL contractor applied 15,923 gallons (gal.) in 2022[11] and 3,501 gal. in 2023[12] (WCL 2022, 2023).

In 2024, WCL (2025) reports that all but one dust suppression application was with only water; a single dust suppression application on May 16, 2024 (4,901 gallons) was with a magnesium chloride solution. WCL (2025) intends “to use water only for dust control activities at the Proctor Rail Yard in the future”.

[11] In 2022, the following volumes were applied: 3,000 gal. on May 20th, 2,000 gal. on Jun. 12th, 3,923 gal. on Aug. 3rd, 3,000 gal. on Aug. 11th, 3,000 gal. on Aug. 12th, and 1,000 gal. on Sep. 7th.
[12] In 2023, the following volumes were applied: 1,250 gal. on Jun. 2nd, 1,251 gal. on Jun. 5th, and 1,000 gallons on Jun. 6th.

3.5.2.3 Excreta

"Salt is a natural mineral that is required for biotic processes" in humans, livestock, and wildlife (MPCA 2020c, Page 27). Generation and delivery of chloride from excreta vary by lifeform.

Human excreta

In an analysis of chloride loading to WWTPs, Overbo et al. (2019) estimated that chloride load generated from human excreta was about 4% of the generated chloride load transported to WWTPs.

No permitted municipal or industrial wastewater treatment facilities are within the five impairment subwatersheds in the DUAW. Municipal and industrial wastewater[13] generated within the five impairment watersheds is transported to the WLSSD wastewater treatment facility that discharges to the St. Louis River Estuary. Chloride loads from human excreta at homes and businesses that use SSTSs may be delivered to impaired streams. The WLSSD sanitary sewer service system and wastewater treatment facility are discussed in more detail in Section 3.5.2.11 and SSTS are discussed in more detail in Section 3.5.2.12.

Livestock excreta

In the statewide, annual chloride mass balance, chloride generated from livestock was estimated to be 6% of the total of all generated source loads (Overbo et al. 2019).

No NPDES/SDS permitted or nonpermitted feedlots are in the DUAW or within the five impairment subwatersheds. Thus, no chloride loads are generated from livestock excreta at feedlots.

Land cover and land use data (Section 3.3, Appendix B) and aerial imagery were evaluated to identify pasture and small, unregulated livestock operations. The analysis indicates that the tiny amounts of pasture/hay in the 2016 NLCD (Homer et al. 2020) and 2021 C-CAP Regional Land Cover (NOAA 2021) are in the headwaters of the impairment subwatersheds, far from the impaired streams. Additionally, much of the pasture/hay in the Kingsbury Creek Subwatershed and most of the pasture/hay in the Keene Creek Subwatershed is mowed grass around rural structures (i.e., more likely lawns than pasture/hay). As such, livestock excreta deposited on pastures in the five impairment subwatersheds is assumed to be negligible.

Evaluation of the 2021 C-CAP Regional Land Cover (NOAA 2021) indicates that no cultivated cropland is within the five impairment subwatersheds. As such, no chloride load is generated from livestock excreta as manure application to cropland.

Wildlife excreta

Chloride in wildlife excreta can be deposited anywhere in the five impairment subwatersheds. Four potential pathways are relevant: (1) deposition directly in surface waterways, (2) deposition in riparian areas (transported to surface waterways by runoff), (3) deposition on upland areas served by storm sewers (transported to surface waterways by stormwater runoff), and (4) deposition on upland areas

[13] Three significant industrial users in the impairment subwatersheds do have WLSSD pretreatment requirements and standards.

not served by storm sewers (transported to surface waters by runoff). The statewide, annual chloride mass balance did not identify wildlife excreta as a source.

Chloride from wildlife excreta in the five impairment subwatersheds is assumed to be extremely low (relative to winter road maintenance and summer dust suppression). Additionally, wildlife excreta is assumed to be accounted for in the natural background load.

3.5.2.4 Fertilizer

Commercial fertilizer (e.g., potash), manure (i.e., livestock excreta), and biosolids (i.e., human excreta) application to cultivated crops and commercial fertilizer application to lawns or turf grass are sources of chloride in the state of Minnesota. Chloride from fertilizer application on cultivated crops in the five impairment subwatersheds is assumed to be negligible, while application on lawns and turf grass is assumed to be low (relative to winter road maintenance and summer dust suppression).

Cultivated crops

In the statewide, annual chloride mass balance, chloride from fertilizer (potash) application was estimated to be 23% of the total of all generated source loads (Overbo et al. 2019). This study further estimated that 2% of chloride loads to WWTPs were land-applied. This study did not quantify chloride load from land-application of manure or septage.

Evaluation of the 2021 C-CAP Regional Land Cover (NOAA 2021) indicates that no cultivated cropland is within the five impairment subwatersheds in the DUAW. However, according to the 2016 NLCD (Homer et al. 2020), one to two acres of cultivated cropland are in the Kingsbury and Keene Creeks Subwatersheds. As such, fertilizer application to crops may previously have been a source of chloride but is not likely a source today. The cultivated cropland identified in the 2016 NLCD was not near the impaired stream segments.

Chloride loads derived from potash application to cultivated crops were estimated for each impairment watershed using the Smart Salting Tool. This tool uses older land use and land cover data. The chloride loads estimated from potash use in the Kingsbury Creek (0.01 ton) and Keene Creek (0.05 tons)[14] subwatersheds were less than 0.1% of the total load in each subwatershed.

Land-application of biosolids, manure, and septage are not sources of chloride in the five impairment subwatersheds in the DUAW. Biosolids from WLSSD are not land-applied in the five impairment subwatersheds[15]. No manure or septage application is known to occur in the impairment subwatersheds.

[14] The Keene Creek Subwatershed is approximately 14% of the Level 08 catchment 03189000. The chloride load for the Keene Creek Subwatershed is calculated as 14% of the load to the Level 08 catchment.
[15] Peter Douglas, Planner, WLSSD, electronic communication, January 28, 2025.

Lawns and turf grass

The five impairment subwatersheds are between 28% and 47% developed land, according to the 2021 C-CAP Regional Land Cover (NOAA 2021) and lawns or turf grass are included within these developed areas.

UMD applies potash to turf grass at its campus; depending on the needs of a specific area of grass, potash can be applied from none to three times per year at a rate of 0.3 pound per thousand square feet[16]. The city of Proctor applies potash to its turf grass in the summer[17]. The cities of Hermantown and Rice Lake and Midway Township do not apply potash to municipal or township turf grass fields.

Fertilizer application (notably potash) to lawns and turf grass at residential, commercial, and institutional properties in the DUAW is a data gap. Based on input from the Core Team, MPCA assumes fertilizer application to lawns and turf grass is a minor source compared to winter maintenance and dust suppression on unpaved roads.

3.5.2.5 Groundwater

Shallow groundwater is generally a pathway for chloride migration because chloride is water soluble. Chloride in shallow groundwater can migrate downward to deep aquifers that are often used for private drinking water or could migrate to surface waters as baseflow (MGA 2020; MPCA 2019). Migration to deep aquifers and to surface waters are both pertinent to the DUAW because private wells provide drinking water outside of the Duluth public water service area and baseflow contributes to summer low-flows in the five chloride-impaired streams.

Natural Sources

Both shallow and deep groundwater can contain chloride from natural or anthropogenic sources. “Many minerals comprising sand and gravel aquifers and bedrock contain chloride, and weathering can release some or all of it to groundwater” (MGA 2020, Page 18). However, “no bedded evaporite deposits, including halite, have been mapped in Minnesota” (MGA 2020, Page 11). For the DUAW, chloride levels in both shallow and deep groundwater derived from natural sources are assumed to be very low relative to anthropogenic chloride levels.

Anthropogenic Sources in Shallow Groundwater

In shallow groundwater, elevated chloride levels are often due to anthropogenic activities and anthropogenic chloride is “gradually accumulating and increasing in concentration in groundwater in northern climates” (MGA 2020c, Page 17). Typical pathways for anthropogenic chloride to migrate to shallow groundwater are (1) infiltration from pervious surfaces, (2) discharge of wastewater from SSTS drain-fields, (3) inflow and infiltration from buried sanitary or storm sewer lines, and (4) leakage from buried water supply lines.

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[16] Issac Kasper, Grounds and Fleet Manager, UMD, electronic questionnaire, January 31, 2025. Erik Larson, Stormwater Coordinator, UMD, electronic communications, September 9, 2025.
[17] Jess Rich, City Administrator, City of Proctor, electronic questionnaire, March 3, 2025.

- *Infiltration from pervious surfaces*: MGA (2020) assumed a chloride concentration of 50 mg/L, after reviewing several studies and estimating a chloride concentration range of 35 to 105 mg/L for areas where deicing occurs.
- *Discharge of wastewater from SSTS drain-fields*: In Baxter, Minnesota (in the Upper Mississippi River Basin), the maximum chloride concentration observed in septic plumes in groundwater was 107 mg/L, which was considerably higher than the observed background groundwater concentration of 20 mg/L (MPCA 1999)
- *Inflow and infiltration from buried sanitary or storm sewer lines:* MGA (2020) assumed a sanitary wastewater concentration of 280 mg/L, which was the median from a review of three studies (range: 113 to 700 mg/L).
- *Leakage from buried water supply lines:* Duluth treated water typically has a chloride concentration of approximately 3.4 mg/L; refer to Section 3.5.2.7 for additional discussion of Duluth public water.

In 2013 through 2017, chloride levels in shallow groundwater underlying residential areas served by SSTSs ranged from <5 to 429 mg/L, while chloride levels in shallow groundwater underlying sewered residential areas ranged from <4 to 463 mg/L (MPCA 2019).

Private Drinking Water

The statewide chloride mass balance found that 99% of drinking water wells had chloride concentrations less than 250 mg/L and that 95% of cities using groundwater for public drinking water had chloride concentrations less than 20 mg/L (Overbo et al. 2019).

The cities of Duluth, Hermantown, Proctor, and Rice Lake use Duluth public water; refer to Section 3.5.2.7 for additional discussion of Duluth public water. Elsewhere in the DUAW, drinking water is obtained from groundwater wells.

3.5.2.6 Industrial Operations

Effluent from industrial operations can also include chloride. Typical industries with higher chloride effluent loads are breweries, drink bottlers, ethanol or biofuel facilities, food processing facilities, metal finishing or metal painting facilities, rendering plants, and drinking water treatment facilities (MPCA 2020c). In the statewide, annual chloride mass balance, chloride from permitted industries was estimated to be 1.5% of the total of all generated source loads (Overbo et al. 2019).

No industrial operations are covered by individual NPDES permits (i.e., all industrial operations wastewater in the DUAW is transported to the WLSSD wastewater treatment facility). Breweries, metal finishing or metal painting facilities, and drinking water treatment facilities are within WLSSD and WLSSD accepts dairy brine/whey[18] (which has high chloride content). The WLSSD wastewater treatment facility is discussed in more detail in Section 3.5.2.9.

[18] Peter Douglas, Planner, WLSSD, electronic communication, January 15, 2025.

3.5.2.7 Drinking Water (Lake Superior)

Public drinking water can be a source of chloride that eventually contributes to municipal or industrial wastewater. In the DUAW, public drinking water is derived from Lake Superior. Chloride from public drinking water that becomes wastewater is either transported to the WLSSD wastewater treatment facility (i.e., not delivered to the five impaired streams) or discharged through the drain-field from SSTSs (i.e., potentially delivered to the five impaired streams via groundwater).

The City of Duluth owns and operates a public drinking water supply. The city withdraws water from Lake Superior, treats the raw water at the Lakewood drinking water treatment plant, and distributes the finished water to the city of Duluth and the neighboring cities of Hermantown, Proctor, and Rice Lake. The Lakewood drinking water treatment plant does not use water-softening[19]. The typical concentration of chlorides in finished drinking water is 3.4 mg/L (Duluth *no date*), which is almost equal to the natural background concentration estimated for this study using a reference stream approach (Section 3.5.2.10).

3.5.2.8 Water softeners[20]

Figure 31. Water softener salt.
Source: MPCA

Water softeners are used in areas with hard water to remove minerals that can build-up in pipes or appliances. Various types of water softeners can be used to remove the calcium or magnesium of the hard water (e.g., distillation, reverse osmosis, electromagnetism, ion exchange). Ion exchange water softeners use a salt (e.g., potassium chloride, sodium chloride; Figure 31). After water softening, the chloride residue is a waste product (MPCA 2020c).

In Minnesota, groundwater is generally hard (MGA 2020). In southeast St. Louis County, domestic supply well water ranges from soft to very hard (MPCA 2020c). Public water supplies in Minnesota do not often soften their hard water and individual homes and businesses must install water softeners (MPCA 2020c). Overbo et al. (2019) estimated that 52% of households use water softeners in northeast Minnesota, which includes areas in the DUAW not served by Duluth public drinking water.

[19] The City of Duluth uses monochloramine to disinfect public drinking water. Chloramine is more stable than free chlorine in potable water supplies and reduces the formation of other decontamination by-products. Chloramine slowly decomposes into nitrogen gas and ammonium and chloride ions.

[20] The Smart Salting Tool estimates chloride loads generated from water-softening. Results from the tool are not presented herein because MPCA is in the process of upgrading the water-softening component in 2025, while this TMDL report was developed.

Residual chloride from water softening becomes part of the municipal or industrial wastewater generated in homes and businesses. In the DUAW, municipal or industrial wastewater in the WLSSD sanitary sewer service area is transported to the WLSSD WWTP and discharged in treated effluent to the St. Louis River Estuary. Such water softener-derived chloride load is generated in the five impairment subwatersheds but is not delivered to the impaired streams.

Outside the WLSSD sanitary sewer service area, wastewater is treated by SSTS. Chloride load from homes and businesses served by SSTSs may pass through the septic tank and leach-field, then potentially enter shallow groundwater, and migrate to surface waterways, including impaired streams. SSTS chloride load may also remain in the septic tank or leach-field and be pumped out by septage or leachate haulers. Refer to Section 3.5.2.12 for additional discussion of SSTSs, septage, and leachate. Thus, while water softener derived chloride load is generated in the five impairment subwatersheds, a portion of the load can be delivered to impaired streams, while another portion is not delivered to the impaired streams.

3.5.2.9 Winter Maintenance

The application of de-icing and anti-icing agents to paved surfaces during winter road maintenance is 42% of the chloride load generated in the state (Overbo et al. 2019), which is the single largest source. De-icing and anti-icing agents are often applied to roadways using plow trucks (Figure 33). Stormwater from these paved surfaces is transported to area streams, including chloride-impaired streams, via storm sewers. With a few exceptions, most of the storm sewers within the impairment subwatersheds are regulated as point sources because they are owned by permitted MS4 entities.

Figure 32. Snow on the elevated Lakewalk in Duluth, MN.
Source: Tom Estabrooks (MPCA)

In addition to the application of de-icing/ant-icing agents on impervious surfaces, de-icing/anti-icing agents can be a source of chloride delivered to impaired streams (via runoff over pavement and then storm sewers) from spills at winter maintenance facilities and from melt water at snow pile locations. Winter maintenance facilities include deicer/anti-icer storage facilities and facilities for maintaining and cleaning winter maintenance equipment (e.g., plow trucks). Such facilities often have spill prevention, containment, and mitigation plans and are not a significant source of chlorides. Snow pile locations are places where excess snow is temporarily stored because insufficient space is available at the location where the snow was plowed from.

Based on available data and input from the Core Team, winter maintenance is assumed to be the largest source of chloride load delivered to the five impaired streams in the DUAW. The five impairment subwatersheds are entirely covered by regulated MS4s and impervious cover ranges from 11% to 26%. Paved roads in the DUAW and chloride impairment subwatersheds are presented in Figure 34; additional roads maps are in Appendix B.

Winter maintenance activities in the DUAW are summarized in Appendix C. Typical activities are summarized in the list below:

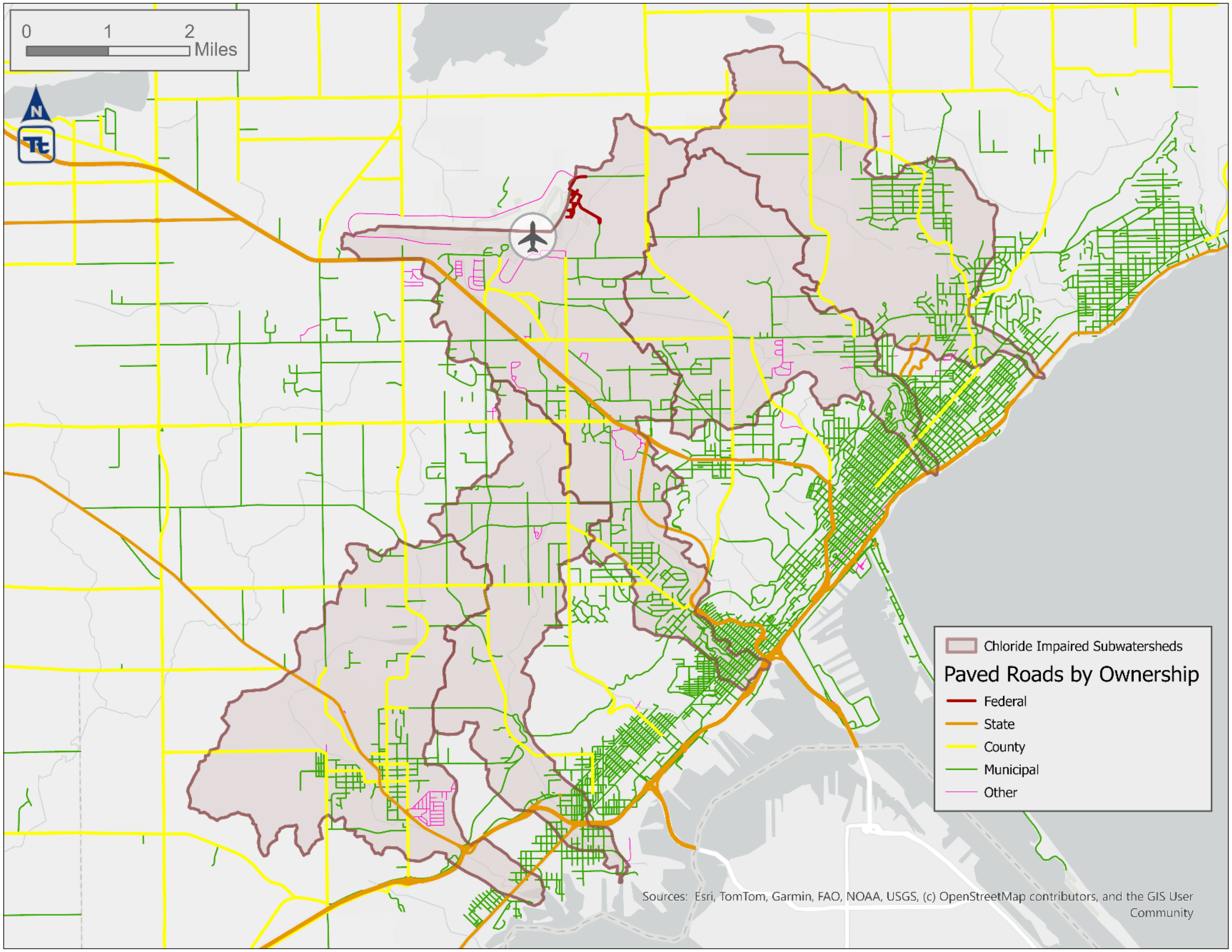
- **Planning**: Many organizations have winter maintenance plans that were recently updated and require annual training for equipment operators.
- **Road operations**: Most organizations apply a chloride-based de-icing or anti-icing agent to roads owned by the organizations using their own staff and plow trucks. Some organizations routinely calibrate their equipment. Most organizations also use sand as a traction agent.
- **Sidewalk operations**: Some organizations plow their sidewalks and some organizations apply a chloride-based de-icing or anti-icing agent.
- **De-icing/anti-icing agent storage**: Some organizations store de-icing/anti-icing agents at their own properties, while other organizations store such agents at properties owned by St. Louis County. All organizations store de-icing/anti-icing agents at covered facilities.
- **Snow storage**: Many organizations temporarily store snow. Organizations that do, do so at their own properties.

Recent efforts to reduce chloride loading to impaired streams are summarized in Sections 6.2 and 6.4.

Figure 33. Road salt application using a plow truck and spinner.

Source: MPCA

Figure 34. Paved roads in the DUAW and chloride impairment subwatersheds.



Source: *MnDOT Road Centerlines* (MnDOT 2025a) and *Roadway Details in Minnesota* (MnDOT 2025c)
Note: Both *MnDOT Road Centerlines* and *Roadway Details in Minnesota* contain some errors.

Municipal separate storm sewer systems

A MS4 is 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 the state, cities, townships, counties, or other public body having jurisdiction over disposal of stormwater)
- Designed or used for collecting or conveying stormwater
- Not a combined sewer
- Not part of a publicly owned treatment works

MS4s in Minnesota must satisfy the requirements of the MS4 general permit if they are located in an urban area with a population of 50,000 or more people as determined by the latest Decennial Census by the Bureau of the Census or owned by a municipality with a population of 10,000 or more, or a population of at least 5,000 and the system discharges to specially classified bodies of water. Minnesota state rule (Minn. R. 7090) establishes criteria and a process for designating MS4s. The MS4 general permit (MNR040000) is designed to reduce the amount of sediment and other pollutants entering state waters from stormwater systems. Entities regulated by the MS4 general permit must develop a stormwater pollution prevention program and adopt best practices.

The Phase II general NPDES/SDS Municipal Stormwater Permit for MS4 communities has been issued to nine entities in the DUAW. Permitted MS4s can be a source of chloride to surface waters through the impact of urban systems on stormwater runoff. Stormwater runoff, which delivers and transports pollutants to surface waters, is generated in the watershed during precipitation events.

Table 18. Regulated MS4s in chloride impairment subwatersheds

Regulated MS4s and impairment subwatersheds are sorted alphabetically top to bottom and left to right, respectively.
MnDOT = Minnesota Department of Transportation.
a. The University of Minnesota-Duluth is in the process of selling its property in the Chester Creek subwatershed.

Regulated MS4	Chester Creek (04010102-545)	Keene Creek (04010201-627)	Kingsbury Creek (04010201-626)	Miller Creek (04010201-512)	Tischer Creek (04010102-544)
Duluth, city of (MS400086)	X	X	X	X	X
Hermantown, city of (MS400093)	--	X	X	X	--
Lake Superior College (MS400225)	--	--	--	X	--
Midway Township (MS400146)	--	--	X	--	--
MnDOT – Outstate District (MS400180)	X	X	X	X	X
Proctor, city of (MS400114)	--	--	X	--	--
Rice Lake, city of (MS400151)	X	--	--	X	X
St. Louis County (MS400158)	X	X	X	X	X
University of Minnesota – Duluth (MS400214)	X [a]	--	--	X	X

Industrial Stormwater Covered by General NPDES Permits

Ten industrial operations across the five impaired subwatersheds are authorized to discharge stormwater associated with industrial activity through Minnesota's general NPDES permit for industrial stormwater (MNR05000). Chloride is not a benchmark for this general permit and no chloride information is available for stormwater at these industrial operations.

An additional 12 industrial operations have no exposure certification through this general permit. These 12 industrial operations are not a source of chloride in industrial stormwater because industrial stormwater is contained on-site.

Smart Salting Tool

The MPCA used the Smart Salting Tool to estimate chloride loading from winter maintenance activities. The MPCA also encourages the communities and permitted MS4s to run the Smart Salting Tool on their own because the communities and permitted MS4s can customize the Smart Salting Tool using local data. For example, local road authorities can input their own application rates and lane-miles.

Chloride loads derived from winter road maintenance activities were estimated for each impairment subwatershed (i.e., DNR Level 08 catchments). Results are presented for roads (Table 19 on Page 50) and nonroad pavement (Table 20 on Page 51) separately. An example of winter maintenance activities on nonroad pavement areas is shown in Figure 36.

The Smart Salting Tool was run with both default and local data and assumptions for roads[21] and default data and assumptions for non\road pavement[22]. The local data and loading results are presented in Appendix D. Using default data, the Smart Salting Tool estimated that winter maintenance activities are the predominant (91% to 94%) source of chloride in each of the five impairment subwatersheds. Municipal and county roads were typically the largest sources of chloride from winter maintenance activities. The chloride loads that were estimated using the higher application rates provided by the several road authorities in the DUAW were considerably larger than the chloride loads estimated using the tool's defaults (Figure 35). This may indicate that the Smart Salting Tool defaults are not representative of conditions in the DUAW. During Core Team meetings, representatives of the road authorities explained that more anti-icing/de-icing agent application is often needed in the DUAW due to the steeper slopes of many roads.

[21] The local data and assumptions are presented in Appendix D.
[22] The default nonroad pavement winter maintenance application is 0.036 tons of salt per acre. The default percents of area treated for open space, low-intensity, medium-intensity, and high-intensity development are 0.25%, 4.375%, 16.25%, and 22.5% (respectively).

Figure 35. Chloride loads from winter maintenance activities (Smart Salting Tool)

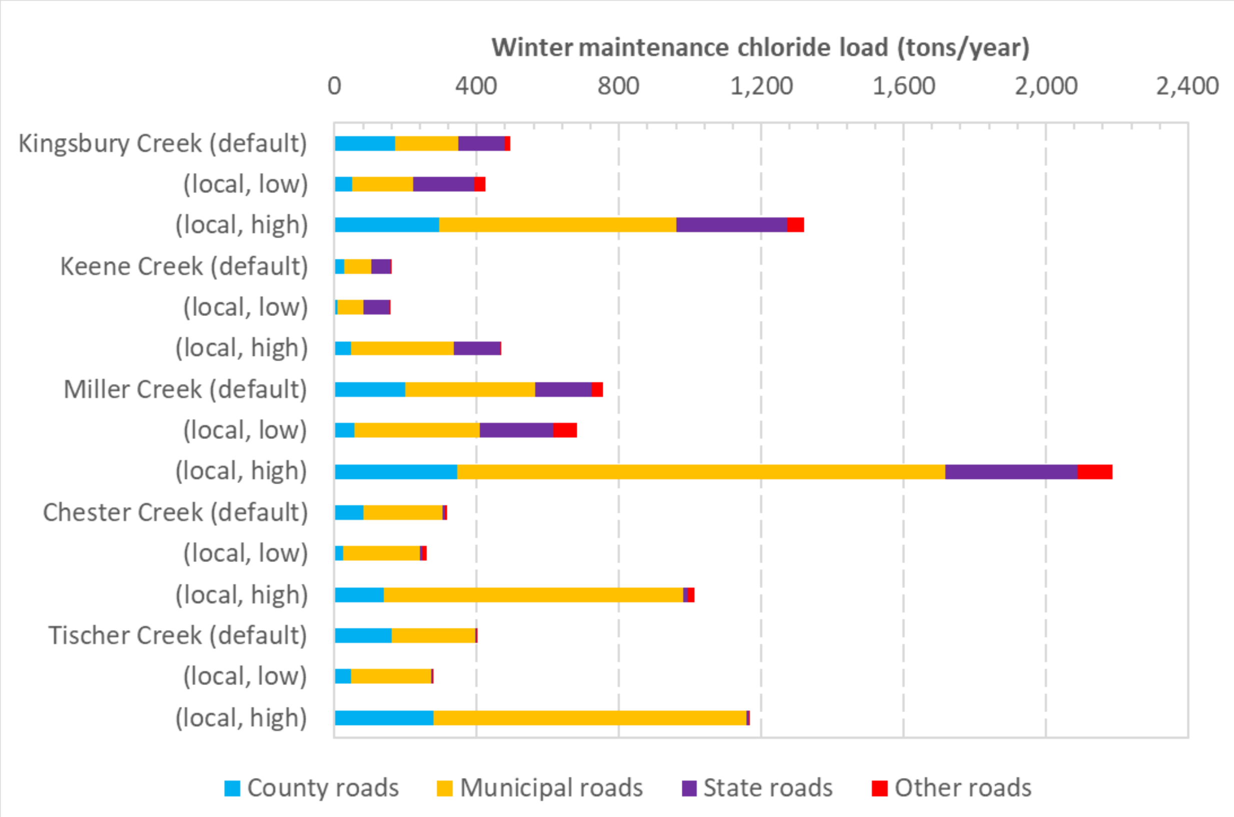


Table 19. Estimated chloride loads from winter road maintenance activities using local data (Smart Salting Tool)

Subwatershed	County	Municipal	State	Other	Total
Lane miles					
Chester Creek	10.4	57.5	0.7	3.3	71.8
Keene Creek	3.3 [a]	20.0 [a]	7.0 [a]	0.5 [a]	30.8
Kingsbury Creek	21.7	45.8	16.9	8.5	92.9
Miller Creek	25.6	93.9	20.2	17.5	157.2
Tischer Creek	20.7	60.2	0.4	0.2	81.4
Chloride load (tons/year)					
Chester Creek	23 to 140	216 to 841	7 to 13	12 to 18	258 to 1,012
Keene Creek	8 to 45 [a]	75 to 292 [a]	71 to 128 [a]	2 to 3 [a]	156 to 468
Kingsbury Creek	50 to 293	172 to 669	173 to 311	32 to 48	426 to 1,321
Miller Creek	58 to 346	352 to 1,373	206 to 371	66 to 99	682 to 2,189
Tischer Creek	47 to 279	226 to 880	4 to 7	1	277 to 1,167

Subwatersheds are sorted alphabetically from top to bottom for each section (i.e., Lane miles, Chloride load).

Estimated chloride loads using local data and assumptions (provided by the Core Team) presented in Appendix D to run the Smart Salting Tool.

Lane miles are rounded to the nearest one-tenth mile, and loads are rounded to the nearest ton.

a. The Keene Creek subwatershed is approximately 14% of the Level 08 catchment 03189000. As such, the lane miles and chloride load for Keene Creek are estimated by calculating 14% of the lane miles and chloride load for catchment 0318900.

Table 20. Estimated chloride loads from winter nonroad pavement maintenance activities (Smart Salting Tool)

Subwatershed	Developed, open	Developed, low-intensity	Developed, medium-intensity	Developed, high-intensity	Total
Pavement area (acres)					
Chester Creek	633	490	345	101	1,567
Keene Creek	289	172	128	34	623
Kingsbury Creek	636	452	377	105	1,570
Miller Creek	1,103	867	940	616	3,526
Tischer Creek	1,055	630	264	58	2,006
Chloride load (tons/year)					
Chester Creek	<0.1	0.8	2.0	0.8	3.7
Keene Creek	<0.1	0.3	0.7	0.3	1.3
Kingsbury Creek	<0.1	0.7	2.2	0.8	3.8
Miller Creek	<0.1	1.4	5.5	5.0	11.9
Tischer Creek	<0.1	1.0	1.5	0.5	3.1

Subwatersheds are sorted alphabetically from top to bottom for each section (i.e., Pavement area, Chloride load).

Estimated chloride loads using default data and assumptions to run the Smart Salting Tool.

Pavement areas are rounded to the nearest acre, and loads are rounded to the nearest one-tenth ton.

a. The Keene Creek subwatershed is approximately 14% of the Level 08 catchment 03189000. As such, the lane miles and chloride load for Keene Creek are estimated by calculating 14% of the lane miles and chloride load for catchment 0318900.

Figure 36. Winter maintenance activities on a nonroad pavement area.

Source: MPCA.

3.5.2.10 Natural background sources

"Natural background" is defined in both Minnesota statute and rule. The Clean Water Legacy Act (Minn. Stat. § 114D.15, subd. 10) defines natural background as "characteristics of the waterbody resulting from the multiplicity of factors in nature, including climate and ecosystem dynamics, that affect the physical, chemical, or biological conditions in a waterbody, but does not include measurable and distinguishable pollution that is attributable to human activity or influence." Minn. R. 7050.0150, subp. 4 states, "'Natural causes' means the multiplicity of factors that determine the physical, chemical, or biological conditions that would exist in a waterbody in the absence of measurable impacts from human activity or influence."

Natural background sources are inputs that would be expected under natural, undisturbed conditions. Natural background sources can include inputs from natural geologic processes such as soil loss from upland erosion and stream development (for chloride-rich soils), groundwater in contact with naturally chloride-bearing strata, atmospheric deposition, and wildlife. However, for each impairment, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment, and therefore natural background is accounted for and addressed through the MPCA's waterbody assessment process. Natural background conditions were evaluated within the source assessment portion of this study. These source assessment exercises indicate that natural background inputs are generally very low compared to winter anti-/de-icing agents, dust suppressants, and other human-created sources**.**

Natural background was quantified using a reference stream approach. The MPCA identified four rivers along the north shore of Lake Superior that are used as reference streams: the Gooseberry River, Split Rock River, East Split Rock River, and Big Sucker Creek (also known as Sucker River)[23]. All four rivers are in the Lake Superior South Watershed, which also includes Chester and Tischer creeks. The four reference stream subwatersheds contain low levels of human development, and in-stream chloride levels are very low. Post-2000 chloride concentrations at monitoring sites on these four rivers are summarized in in Table 21 and Figure 37. Of the 217 results, only seven (3%) exceed 3.5-mg/L. Based on the analyses of chloride concentrations at these reference streams, the natural background chloride concentration for this TMDL study is set to 3.5-mg/L.

Based on the MPCA's waterbody assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest that natural background sources are a major driver of any of the impairments and/or affect the waterbodies' ability to meet state water quality standards.

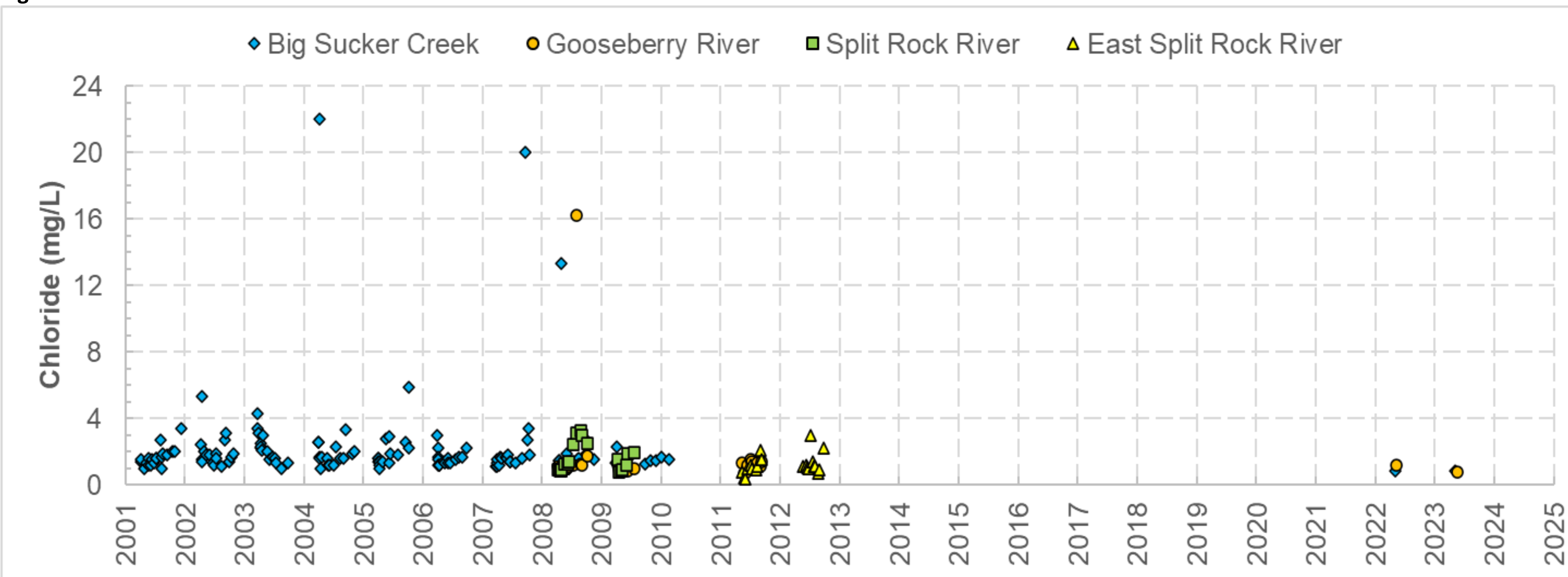
[23] In a study chloride contamination in Amity, Kingsbury, and Tischer creeks, NRRI observed in-stream chloride concentrations of 10 to 20 mg/L in Amity Creek at Lester Park in February 2020 through January 2021 (Chun et al. 2021). Much of the Amity Creek Subwatershed immediately upstream of the Lester Park monitoring site is forested to the east and residential to the west, and the authors believed that this monitoring site may be minimally impacted by winter road salt application. Furthermore, MPCA (Anderson et al. 2000) has found Amity Creek to be one of the least urbanized streams in the DUAW. However, since Amity Creek is likely impacted by winter road salt application from adjacent residential developments, MPCA did not include Amity Creek as a reference stream in the quantification of natural background for this TMDL study.

Table 21. Summary of chloride levels at the reference streams

River	WID (04010102)	Site	Period of record	No. of chloride records	Min. (mg/L)	Max. (mg/L)	Average (mg/L)
Big Sucker Creek	-555	S001-756	2001-2010, 2022, 2023	144	0.81	22.00	2.12
Gooseberry River	--	S000-256	2008, 2009, 2011, 2022, 2023	32	0.68	16.20	1.58
Split Rock River	-519	S000-263	2008, 2009	20	0.80	3.27	1.58
East Split Rock River	-A44	S006-605	2011, 2012	21	0.34	3.00	1.19

Waterbodies are sorted from top to bottom as west to east (i.e., closest to farthest from the DUAW).

Figure 37. Chloride levels at the reference streams.



3.5.2.11 Western Lake Superior Sanitary District

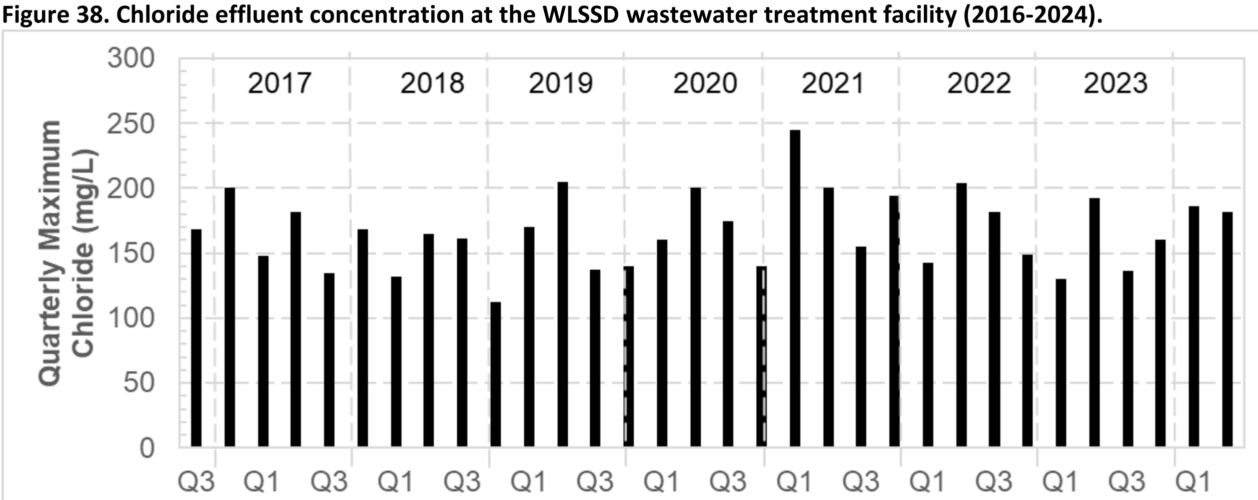
No permitted municipal or industrial[24] wastewater treatment facilities are within the five impairment subwatersheds. Municipal wastewater generated within the five impairment subwatersheds is transported to the WLSSD wastewater treatment facility that discharges treated effluent to the St. Louis River Estuary (the WLSSD wastewater treatment facility is the green symbol on Figure 39). Much of each of the five impairment subwatersheds is within the WLSSD sanitary sewer service area (Figure 39).

Municipal wastewater transported to the WLSSD wastewater treatment facility may contain chloride derived from multiple sources: human excreta (Section 3.5.2.3), chloride-rich industrial process water (Section 3.5.2.6), private drinking water from groundwater (Section 3.5.2.5), public drinking water from Lake Superior (Section 3.5.2.7), water softeners (Section 3.5.2.8), and chloride-rich groundwater or stormwater via inflow and infiltration[25]. Septage disposal at WLSSD is another source of chloride.

WLSSD does have inflow and infiltration in its approximately 100-miles of sanitary sewers, especially after larger precipitation events. Much of the inflow and infiltration that enters the WLSSD sanitary sewers is from upstream communities that connect to WLSSD sanitary sewers (e.g., the city of Duluth with 400-miles of sanitary sewers)[26].

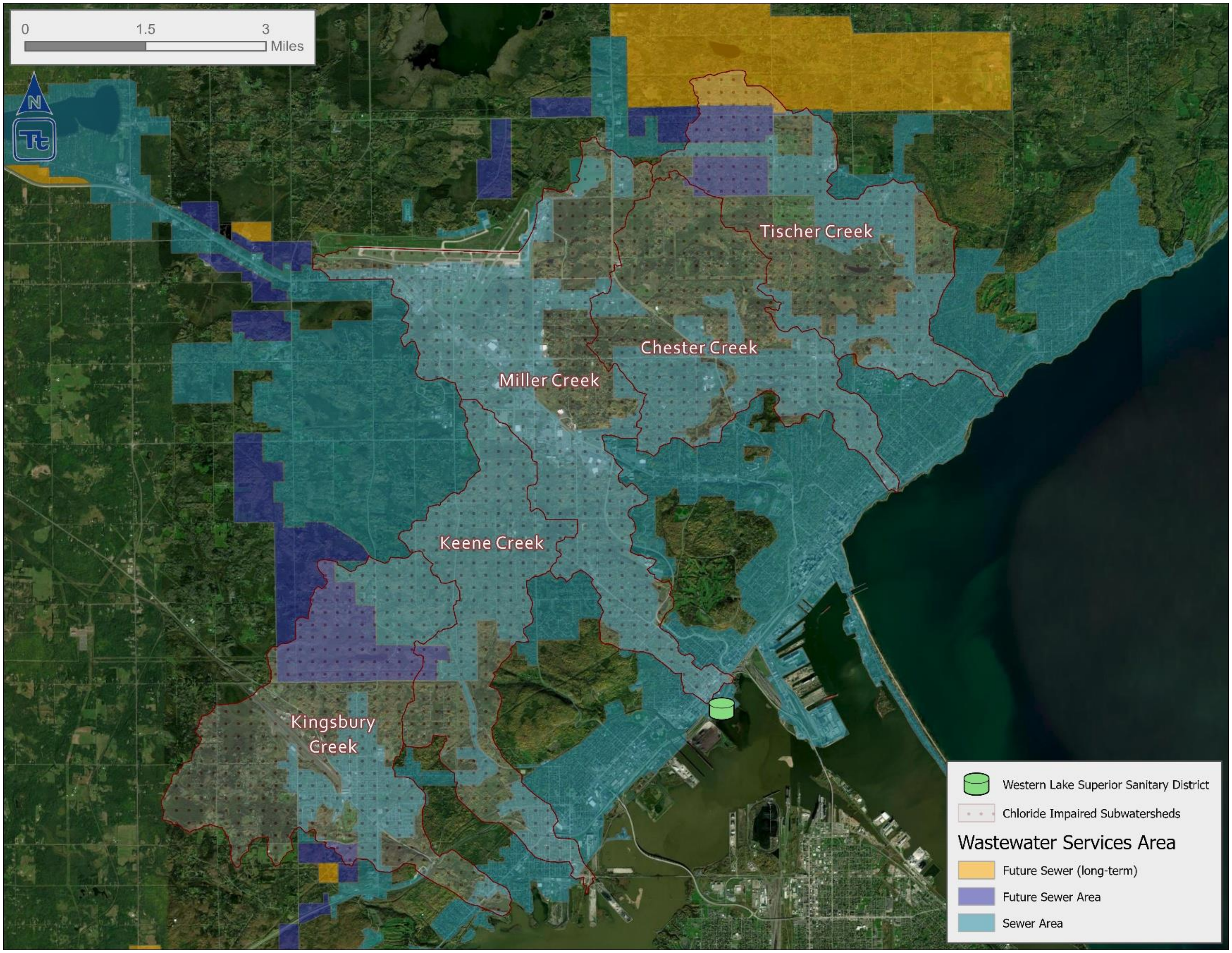
Since WWTPs do not treat chloride, chloride levels in the effluent from the WLSSD wastewater treatment facility are likely representative of influent chloride levels. The maximum reported chloride concentration per quarter at the WLSSD ranged from 211 to 245 mg/L, with a median of 167 mg/L, over the period from mid-2016 through mid-2024 (Figure 38).

Figure 38. Chloride effluent concentration at the WLSSD wastewater treatment facility (2016-2024).



[24] Three significant industrial users in the impairment subwatersheds do have WLSSD pretreatment requirements and standards.
[25] In their WWTP chloride budget, Overbo et al. (2019) found that inflow and infiltration "of road salt to sanitary sewer pipes was a small fraction of total chloride discharged" by WWTPs, but the authors acknowledge that inflow and infiltration "may be more important to individual WWTPs".
[26] Peter Douglas, Planner, WLSSD, electronic communication, January 7, 2025.

Figure 39. WLSSD service areas.



Source: WLSSD 2023

3.5.2.12 Nonpermitted wastewater

Nonpermitted wastewater from SSTS may contain chloride derived from multiple sources: human excreta (Section 3.5.2.3), private drinking water from groundwater (Section 3.5.2.5), public drinking water from Lake Superior (Section 3.5.2.7), and water softeners (Section 3.5.2.8). The statewide, annual chloride mass balance estimated that 3.4% of chloride generated in the state was discharged by residential SSTS (Overbo et al. 2019). Additionally, this study attributed 89% of the residential SSTS chloride load to water-softening, 5.4% to human excreta, 3.3% to drinking water, and 1.8% to household products (Overbo et al. 2019).

Like municipal wastewater treatment facilities, SSTSs do not treat nonpermitted wastewater for chloride (i.e., chloride within the influent passes through the septic tank and is discharged in the effluent to the leach-field). As such, chloride-loading from fully functioning and properly sited SSTSs is likely about the same as loading from malfunctioning or poorly sited SSTSs.

Other potential wastewater sources of chloride in the watershed may include straight pipe discharges, earthen pit outhouses, and land application of septage. Straight pipe systems are unpermitted and illegal sewage disposal systems that transport raw or partially treated sewage directly to a lake, stream, drainage system, or the ground surface. Straight pipe systems are required to be addressed within 10 months after discovery (Minn. Stat. § 115.55, subd. 11). Outhouses, or privies, are legal disposal systems and are regulated under Minn. R. 7080.2150, subp. 2F, and Minn. R. 7080.2280. Septage disposal is regulated under Minn. R. 7080, as well as in local and federal regulations.

Individual subsurface sewage treatment systems

In the DUAW, chloride in nonpermitted wastewater treated by SSTS (outside of the WLSSD sanitary sewer service area) is likely mostly derived from water softening and sanitary waste. Public drinking water in the DUAW has low levels of chloride (Section 3.5.2.7). No industrial operations with chloride-rich process water are known to exist in the DUAW that are served by SSTSs. In a study of septic systems and groundwater in Baxter, Minnesota (in the Upper Mississippi River Basin), chloride concentrations in septic plumes in groundwater were typically two-or more-times the background groundwater concentration (MPCA 1999).

Much of the impairment subwatersheds is within WLSSD sanitary sewer service area; refer to Section 3.5.2.11 for discussion of the WLSSD service area and a map of the service area. Visual analysis of a map of sanitary sewer service area (WLSSD 2023) with aerial imagery indicates the following:

- **Chester Creek**: The subwatershed is fully within the WLSSD service boundary. Much of the subwatershed is in the WLSSD sanitary sewer service area. The headwaters of the east and west branches are outside of the sanitary sewer service area.
- **Keene Creek**: The subwatershed is fully within the WLSSD service boundary. All residences apparent in aerial imagery are within the sanitary sewer service area.
- **Kingsbury Creek**: Most of the residences apparent in aerial imagery in Midway Township are outside of the WLSSD service boundary. The cities of Hermantown and Proctor are within the WLSSD service boundary but considerable portions of these cities in this subwatershed are not in the WLSSD sanitary sewer service area.

- **Miller Creek**: The subwatershed is fully within the WLSSD service boundary. Much of the subwatershed is within the WLSSD sanitary sewer service area. A developed area southeast of the DIA is not within the sanitary sewer service area. Central Park and Enger Park (including the golf course) are not within the sanitary sewer service area.
- **Tischer Creek**: The subwatershed is fully within the WLSSD service boundary. Considerable portions of the headwaters and middle of the subwatershed are outside of the sanitary sewer service area.

Areas or communities with SSTS concerns

No areas or communities with SSTS concerns are within the chloride-impaired subwatersheds.

Septage Disposal

Septage and leachate from maintenance of SSTSs is pumped by septage haulers and can be temporarily stored in underground storage tanks before transport and disposal at a WWTP or through land application. The MPCA licenses septage haulers and septage maintainers (i.e., entities that temporarily store septage). Septage storage must comply with local ordinances, and septage land application must comply with EPA regulations and local ordinances.

Licensed septage haulers are located throughout northeast Minnesota, including the DUAW. WLSSD accepts septage and leachate for disposal from septage haulers at the Scanlon Pump Station (WLSSD 2023). WLSSD does not have information on where septage originate from but the septage haulers that do dispose of septage at WLSSD operate within the communities that the five impaired subwatersheds encompass[27]. WLSSD (2019) has adopted ordinance governing liquid waste disposal (including septage). Septage disposed at WLSSD is sent through the same treatment process as wastewater from the sanitary sewer service area. As such, chloride loads in septage disposed at WLSSD is discharged to the St. Louis River Estuary and is not a source of impairment to the five chloride-impaired streams.

Neither MPCA[28] nor St. Louis County[29] track the locations that septage haulers land-apply septage in St. Louis County. As only a few acres of cropland (formerly) and about 150-acres of pasture (71% in the Kingsbury Creek Subwatershed) are in the five impairment subwatersheds, likely little to no septage application occurs. As such, chloride from septage application in the five impairment subwatersheds is assumed to be negligible.

3.5.3 Summary

Winter road maintenance activities (application of de-icing and anti-icing agents) are the major source of impairment to the five impaired streams. Dust suppressant application may be a major source in isolated locations. Most of the rest of the sources are either not delivered to the impaired streams or likely contribute very small loads to the impaired streams (Table 22).

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[27] Peter Douglas, Planner, WLSSD, electronic communication, January 28, 2025.
[28] Tim Luedkte, Environmental Specialist, electronic communication, January 30, 2025.
[29] Ryan Logan, Planning and Zoning Director, St. Louis County, electronic communication, January 30, 2025.

Table 22. Summary of sources of chloride in the five impairment subwatersheds

Sources		Locations		Generated [b]	Delivered [c]	Importance [c]
Atmospheric deposition		Everywhere		●	●	○
Dust suppression		Roads and nonroad paved areas		●	●	○
		Cultivated crops (manure application)		○	--	--
		Feedlots		○	--	--
	Livestock	Pastures		●	○	○
		Biosolids application to agricultural fields		○	--	--
			SSTS [d]	●	○	○
		Homes and businesses	WLSSD [e]	●	--	--
	Human (sanitary)	Septage application to agricultural fields		●	○	○
Excreta	Wildlife	Wildlife		●	●	○
		Cultivated crops		○	--	--
Fertilizer	Potash	Athletic fields, grass lawns		●	○	○
Industrial operations		Industrial facilities	WLSSD [e]	●	--	--
	Shallow groundwater	Homes and businesses using private wells	SSTS [d]	●	○	○
			WLSSD [e]	●	--	--
			SSTS [d]	●	○	○
Drinking water	Lake Superior	Homes and businesses using public water	WLSSD [e]	●	--	--
			SSTS [d]	●	○	○
Water softening		Homes and businesses	WLSSD [e]	●	--	--
		Roads and nonroad paved areas (e.g., parking lots, driveways, sidewalks)		●	●	●
		Storage facilities		●	○	○
Winter maintenance		Snow piles		●	●	○

a. The source is generated (●) or not generated (○) in the five chloride impairment subwatersheds.

b. The source is delivered or likely delivered (●), possibly delivered (○), or not delivered (--) to the five impaired streams (Chester, Keene, Kingsbury, Miller, and Tischer creeks).

c. The source is a major (●) or minor (○) source of impairment or is not a source of impairment (--).

d. Chloride loads from homes and businesses served by subsurface treatment systems (SSTS) may be delivered to the five impaired streams via groundwater migration from the drain-field to the impaired streams.

e. Chloride loads from homes and businesses in the Western Lake Superior Sanitary District (WLSSD) sanitary sewer service are not delivered to the five impaired streams because treated effluent discharges to the St. Louis River.

4. TMDL development

A waterbody's TMDL represents the loading capacity, or the amount of pollutant that a waterbody can assimilate while still meeting water quality standards. The loading capacity is divided up and allocated to the waterbody's pollutant sources. The allocations include WLAs for NPDES-permitted sources, LAs for nonpermitted sources (including natural background), and an MOS, which is implicitly or explicitly defined. The sum of the allocations and MOS cannot exceed the loading capacity, or TMDL.

Chloride TMDL development for Chester, Keene, Kingsbury, Miller, and Tischer creeks in the DUAW follows the same methodology that MPCA (2016b) used for developing chloride TMDLs in the TCMA.

4.1 Loading capacity methodology

Chloride TMDLs are developed for Chester, Keene, Kingsbury, Miller, and Tischer creeks using a simple, zero-dimensional, steady-state modeling approach that was previously used to develop chloride TMDLs for the TCMA (MPCA 2016b). The reasons that MPCA (2016b) selected this simple, zero-dimensional, steady-state modeling approach for the TCMA are applicable to the DUAW:

- Chloride is a conservative substance and is in the dissolved phase in the water environment; therefore, complex fate and transport assessments are not needed.
- Determining the time for a system to respond to reduced chloride loads was not necessary to inform the TMDL.

In this approach, the loading capacity is based on Minnesota's chronic chloride standard (230 mg/L) and the amount of winter season runoff. Precipitation data and a runoff coefficient are used to determine the amount of winter runoff. As with the TCMA chloride TMDLs, "this approach assumes eventual complete flushing in an impaired waterbody over the long-term" (MPCA 2016b, Page 21).

A conceptual model of this approach is presented in Figure 41. The calculations of winter precipitation equivalent (Section 4.1.1), winter season runoff (Section 4.1.2), winter season runoff volume (Section 4.1.3), and allowable winter season runoff load (Section 4.1.4) are in the following four subsections.

Figure 40. Ice and snow on the Lakewalk in Duluth, MN.
Source: Tom Estabrooks (MPCA)

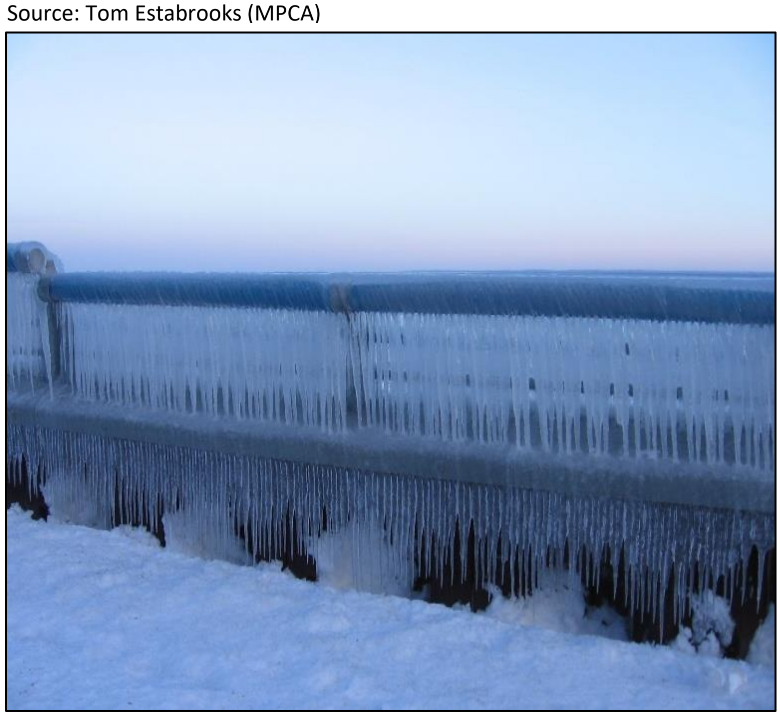
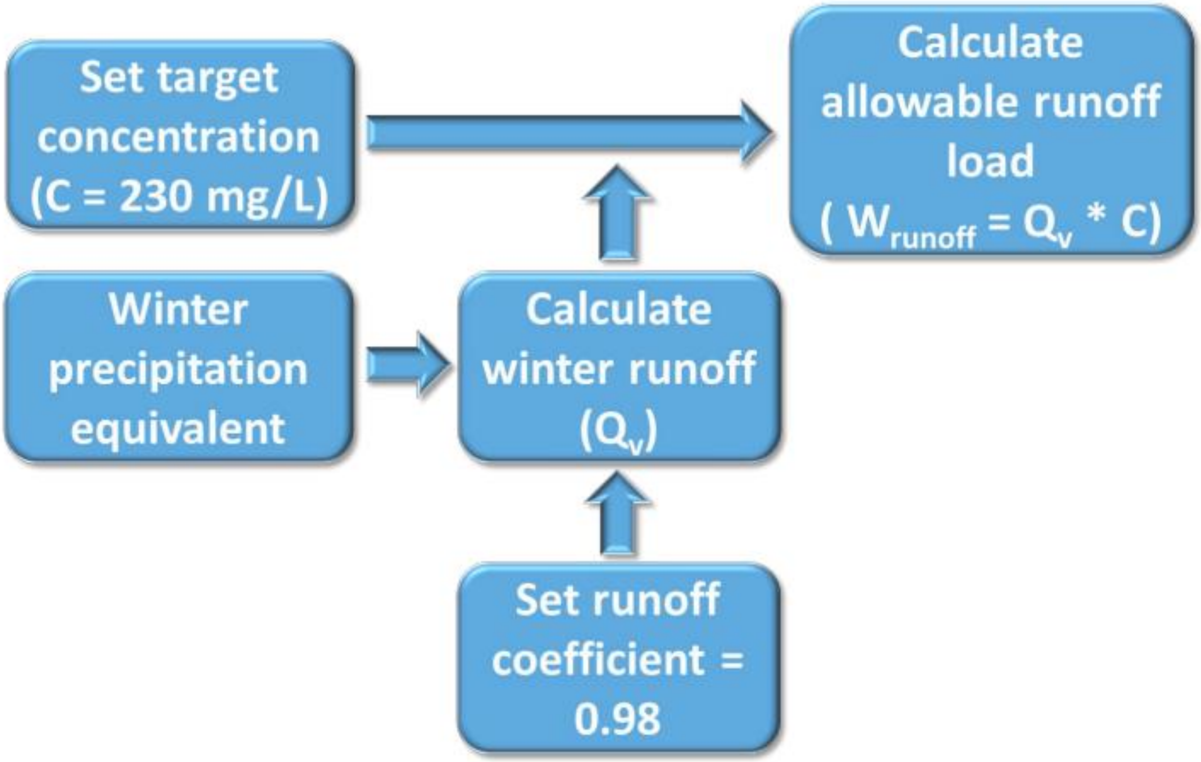


Figure 41. Conceptual model for allowable runoff load (i.e., loading capacity)



Source: MPCA 2016b, Figure 9

4.1.1 Precipitation

The simple, zero-dimensional, steady-state modeling approach requires the determination of the long-term average winter season precipitation (i.e., winter precipitation equivalent).

- **Winter season**: The MPCA (2016b) defined the winter season as November 1st through March 31st. "This period is typically when salt is being applied and is expected to accumulate and run off during the spring snowmelt (as well as occasional winter melts)" (MPCA 2016b, Page 24). The same winter season is used for the DUAW chloride TMDLs.
- **Long-term**: A long-term precipitation dataset is necessary to accurately represent the range of typical winter precipitation. The MPCA (2016b) selected long-term (1981-2010) climate data from the University of Minnesota to calculate the TCMA long-term average winter season precipitation.

Three data-sources for precipitation data were considered for developing the long-term average winter season precipitation for the DUAW chloride TMDLs:

- Gridded weather data for HSPF models for most watersheds across the state, including the DUAW and SLRW
- National Climactic Data Center
- WLSSD weather gages

The MPCA presented key information about these datasets to the Core Team. Besides representativeness, the Core Team was concerned with equity of approach (between TMDL subwatersheds) and ease of obtaining precipitation data. The Core Team requested that all five chloride TMDLs in the DUAW be calculated from the same long-term average winter season precipitation.

The MPCA considered five key characteristics of each dataset: proximity to the chloride-impaired subwatersheds, length of the period of record, length and frequency of data gaps, ease of obtaining the data, and level of effort and expertise needed to pre-process the precipitation data.

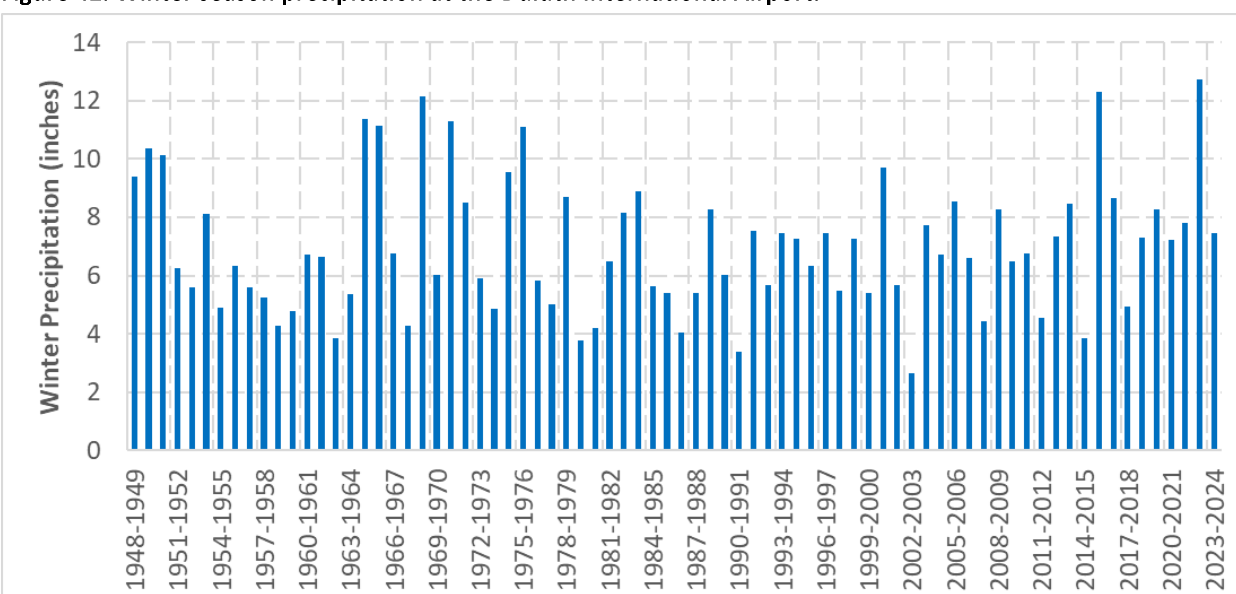
The MPCA and the Core Team agreed that the National Climatic Data Center's precipitation data for the DIA was the most suitable dataset for TMDL development. The National Climatic Data Center reports over 75 years of precipitation data for the DIA with 100% data coverage (i.e., no data gaps). The other datasets were generally deemed less suitable because they are short-term (less than 15 years), contain significant data gaps, or require significant pre-processing.

Winter season (November 1st through March 31st) precipitation at the DIA varied from about 4 inches to over 12-inches of water per year from the winter of 1948-1949 to the winter of 2023-2024 (Figure 42). Decadal winter season median precipitation at the DIA ranges from 5.61 to 7.34 inches, while decadal winter season average precipitation ranges from 6.13 to 7.45 inches (Figure 43).

The median and average winter season precipitation across the period of record (1948-2023) are 6.68 and 6.98 inches, respectively. The median and average winter precipitation for the past three decades (1994-2023) are 7.26 and 7.13 inches (respectively), which are 0.58 and 0.15 inch (respectively) larger than for the period of record.

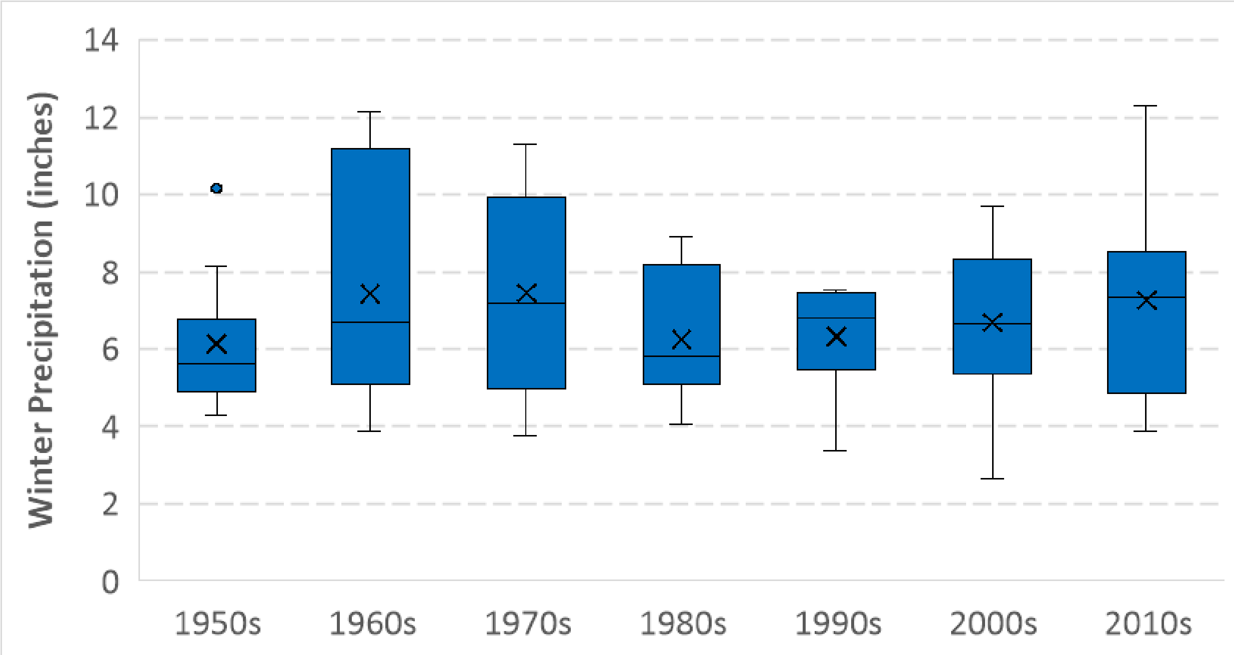
The long-term average winter season precipitation (i.e., the winter precipitation equivalent) is 7.26 inches for the DUAW chloride TMDLs.

Figure 42. Winter season precipitation at the Duluth International Airport.



Precipitation data are from the National Climatic Data Center (2024).
The winter season is November 1st through March 31st.

Figure 43. Decadal statistics of winter season precipitation at the Duluth International Airport.



Precipitation data are from the National Climatic Data Center (2024).
The winter season is November 1st through March 31st.

4.1.2 Winter Season Runoff

In the simple, zero-dimensional, steady-state modeling approach, winter runoff is calculated as the long-term average winter season precipitation multiplied by the runoff coefficient. The equation for winter season runoff is presented below.

$$R = P \times R_v$$

Where: R is the winter season runoff (inches)

P is the long-term average winter season precipitation (inches)

R_v is the runoff coefficient for frozen ground (unitless)

Winter season runoff for the five DUAW chloride TMDLs is 7.11 inches. The long-term average winter season precipitation is 7.26 inches for the five DUAW chloride TMDLs (Section 4.1.1). The runoff coefficient is 0.98. MPCA (2016b) selected a runoff coefficient of 0.98 to represent runoff over frozen ground; runoff over frozen ground occurs throughout the winter season (November 1st through March 31st). The calculation for winter season runoff for the four DUAW chloride TMDLs is presented below.

$$R = P \times R_v$$

$$R = (7.26) \times (0.98) = 7.11$$

4.1.3 Winter Season Runoff Volume

Winter season runoff volume is calculated as the winter season runoff multiplied by the drainage area of the TMDL subwatershed. The calculation for winter season runoff volume is presented below.

$$Q_v = A \times \frac{R}{12}$$

Where: Q_v is the winter season runoff volume (acre-feet)

A is the area of the TMDL subwatershed (acres)

R is the winter season runoff (inches)

The TMDL subwatershed areas for the five chloride-impaired streams in the DUAW are presented in Section 3.2. The winter season runoff is 7.11 inches for the DUAW chloride TMDLs. The winter season runoff volumes for the four DUAW chloride TMDLs are presented in Table 23 in Section 4.1.4.

4.1.4 Allowable Winter Season Runoff Load

As is discussed in Section 4.1, the loading capacity (i.e., allowable winter season runoff load) is calculated by multiplying the TMDL target concentration by the winter season runoff volume and then converting to appropriate units of measure. The calculation for allowable winter season runoff load is presented below.

$$L = Q_v \times C \times 2.72$$

Where: L is the allowable winter season runoff load (pounds [lbs])

Q_v is the winter season runoff volume (acre-feet)

C is the TMDL target concentration (mg/L)

2.72 is a conversion factor

The TMDL target for the five chloride-impaired streams in the DUAW is Minnesota’s chronic chloride standard (230 mg/L). The winter season runoff volumes for the five chloride-impaired streams in the DUAW are discussed in Section 4.1.3. As TMDLs must be reported at a daily timestep, the allowable winter season runoff loads can be divided by 151 (i.e., 151 days per winter season) to generate daily loads. The allowable winter season runoff loads and allowable daily loads for the five DUAW chloride TMDLs are presented in Table 23.

Table 23. Summary of loading capacity calculations

Impaired stream	WID	Drainage area (Acres) [a]	Winter season runoff volume (Acre-feet)	Allowable winter season runoff load (lbs)	Allowable daily load (lbs)
Chester Creek	04010102-545	4,309	2,555	1,597,813	10,582
Keene Creek	04010201-627	3,712	2,201	1,376,605	9,117
Kingsbury Creek	04010201-626	5,652	3,351	2,096,073	13,881
Miller Creek	04010201-512	6,387	3,787	2,368,375	15,685
Tischer Creek	04010102-544	4,658	2,762	1,727,315	11,439

Drainage areas, winter season runoff volumes, allowable winter season runoff loads, and allowable daily loads are rounded to the nearest integer.

a. Drainage areas (acres) are from DNR (2023).

4.2 Load allocation methodology

The LA is allocated to existing or future nonpermitted pollutant sources and natural background. The LA for nonpermitted sources is calculated as a percentage of the loading capacity based on the percentage of chloride load from residential SSTS relative the statewide total (Overbo et al. 2019). In the DUAW chloride TMDLs, like the TCMA chloride TMDLs (MPCA 2016b), the LA for natural background is calculated using a natural background concentration and runoff volume.

4.2.1 Nonpermitted Sources

The LA for nonpermitted sources is calculated as 3.4% of the loading capacity. The 3.4% represents the portion of chloride load generated by residential SSTS in the five chloride impairment subwatersheds, that is from areas served by SSTS (i.e., areas outside of the WLSSD sanitary sewer service area).

Because permitted MS4s and industrial stormwater facilities completely covers the chloride impairment subwatersheds, all surface runoff loads are included in the stormwater WLAs. However, these WLAs do not account for subsurface chloride loading from SSTS, inflow and infiltration, and leakage from buried water supply pipes through shallow groundwater. Refer to Section 3.5.2.5 for a discussion of chloride sources to shallow groundwater.

No data are available to calculate the subsurface chloride loads from SSTS, inflow and infiltration, and leakage from buried water supply pipes that are delivered to the impaired streams. Instead, the chloride loading generated from multiple sources (e.g., water-softening, human excreta, drinking water) in areas served by SSTS is used as a surrogate to represent all subsurface chloride loading. The value of 3.4% is from the statewide chloride mass balance (Overbo et al. 2019). The 3.4% represents the estimated statewide chloride load generated from residential SSTS (3,300 tons/year) relative to the statewide total generated chloride load (968,300 tons/year). This percentage of generated chloride load does not consider delivery to surface waters.

To account for subsurface chloride loading that may be delivered to the impaired streams, the LA for nonpermitted sources is calculated as 3.4% of the loading capacity in the DUAW TMDLs (Table 24). The use of 3.4% is conservative because the percentage is of SSTS load generated and does not consider delivery; a portion of the SSTSs chloride load may not be delivered to the impaired streams.

Table 24. Calculation of the load allocation for nonpermitted sources

Impaired stream	WID	Loading capacity (lbs./day) [a]	LA for nonpermitted sources (lbs./day)
Chester Creek	04010102-545	10,582	360
Keene Creek	04010201-627	9,117	310
Kingsbury Creek	04010201-626	13,881	472
Miller Creek	04010201-512	15,685	533
Tischer Creek	04010102-544	11,439	389

a. Section 4.1 discusses the methodology for calculating loading capacities.

4.2.2 Natural Background

Natural background conditions were evaluated within the source assessment portion of this study (Section 3.5.2.12). As discussed in that section, the natural background chloride concentration for this study is 3.5 mg/L. The natural background chloride load is calculated by multiplying the natural background chloride concentration by the winter season runoff volume. This approach is consistent with the TCMA chloride TMDLs (MPCA 2016b), where the natural background chloride load was calculated by multiplying the watershed runoff volume by 18.7 mg/L, which was the natural background concentration for TCMA streams that was estimated from a linear regression of winter chloride application (independent variable) and in-stream chloride concentration (dependent variable). The LA for natural background for each chloride TMDL is presented in Table 25.

Table 25. Summary of load allocations for natural background

Impaired stream	WID	Winter season runoff volume (Acre-feet) [a]	Natural background daily load (lbs)
Chester Creek	04010102-545	2,555	161
Keene Creek	04010201-627	2,201	139
Kingsbury Creek	04010201-626	3,351	211
Miller Creek	04010201-512	3,787	239
Tischer Creek	04010102-544	2,762	174

Winter season runoff volumes and natural background daily loads are rounded to the nearest integer.

a. Winter season runoff volumes are discussed in Section 4.1.3 and presented in Table 23.

4.3 Wasteload allocation methodology

The WLA is allocated to existing or future NPDES-permitted pollutant sources. WLAs were allocated to MS4s and industrial stormwater for one facility using an area-ratio approach.

4.3.1 Municipal separate storm sewer systems

The five chloride impairment subwatersheds span nine permitted MS4s (Figure 44 on Page 66); refer back to Section 3.5.2.9 for discussion of these MS4s. WLAs for the nine MS4s are allocated using an area-ratio approach based on the jurisdictional area of each permitted MS4. For each chloride TMDL, first the loading capacity is reduced by the summation of the natural background load (Section 3.5.2.10), nonpermitted load (Section 4.2.1), and MOS (Section 4.4), and then the remaining capacity was apportioned between permitted sources using a ratio of jurisdictional areas (Table 26 on Page 67).

This is essentially the same approach MPCA (2016b) used for the TCMA, which used runoff ratios for regulated and nonregulated areas. Since winter season runoff volumes are calculated as winter season runoff (7.11 inches; Section 4.1.2) multiplied by area, ratios of winter season runoff volumes are equivalent to ratios of areas.

Assigned WLAs will result in additional MS4 permit requirements per the next MS4 General Permit that MPCA anticipates issuing in 2026. Requirements in the current MS4 General Permit include documenting the amount of deicer applied each winter maintenance season, identifying existing BMPs, and assessing current and future opportunities to improve BMPs.

Figure 44. Regulated MS4s (2025a) based on 2020 Decennial Census.

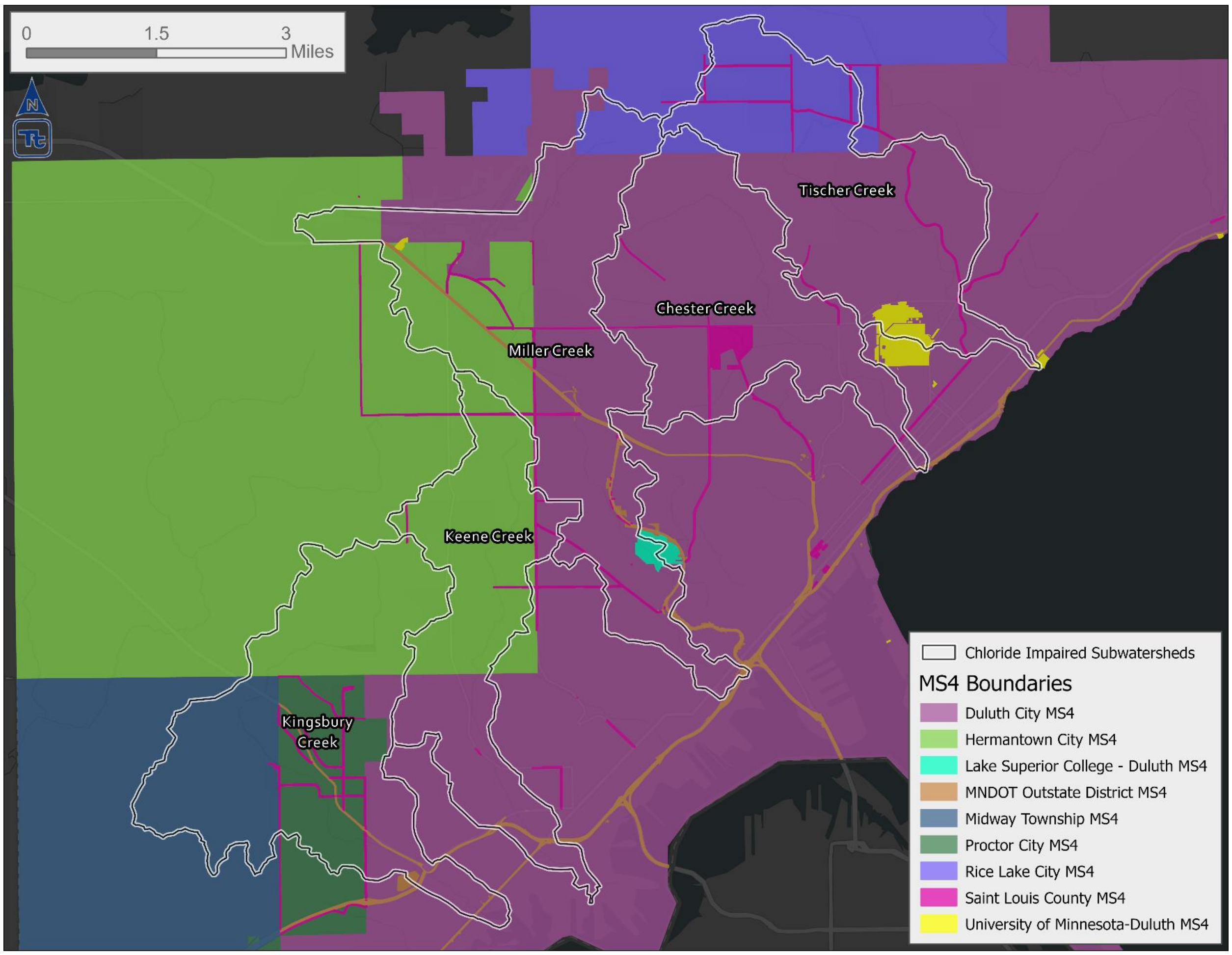


Table 26. Permitted MS4s and estimated jurisdictional areas for chloride TMDLs
Estimated jurisdictional areas are approximated using information available from MPCA and are rounded to the nearest acre.

MS4 name and permit number	Estimated jurisdictional area (acres)	Impaired waterbody	WID
Duluth, city of (MS400086)	4,068	Chester Creek	04010102-545
	1,461	Keene Creek	04010201-627
	848	Kingsbury Creek	04010201-626
	4,190	Miller Creek	04010201-512
	2,958	Tischer Creek	04010102-544
Hermantown, city of (MS400093)	2,195	Keene Creek	04010201-627
	1,691	Kingsbury Creek	04010201-626
	1,605	Miller Creek	04010201-512
Lake Superior College (MS400225)	54	Miller Creek	04010201-512
Midway Township (MS400146)	1,646	Kingsbury Creek	04010201-626
MnDOT – Outstate District (MS400180)	3	Chester Creek	04010102-545
	29	Keene Creek	04010201-627
	70	Kingsbury Creek	04010201-626
	156	Miller Creek	04010201-512
	1	Tischer Creek	04010102-544
Proctor, city of (MS400114)	1,146	Kingsbury Creek	04010201-626
Rice Lake, city of (MS400151)	91	Chester Creek	04010102-545
	303	Miller Creek	04010201-512
	1,497	Tischer Creek	04010102-544
St. Louis County (MS400158)	146	Chester Creek	04010102-545
	28	Keene Creek	04010201-627
	70	Kingsbury Creek	04010201-626
	70	Miller Creek	04010201-512
	72	Tischer Creek	04010102-544
University of Minnesota – Duluth (MS400214)	<1	Chester Creek	04010102-545
	8	Miller Creek	04010201-512
	130	Tischer Creek	04010102-544

4.3.2 Industrial stormwater

A categorical WLAs is allocated for industrial stormwater from operations covered by Minnesota's general permit (MNR050000) and an individual WLA is allocated for the WCL Proctor Rail Yard (MN0000361) that is covered by an individual permit.

The industrial stormwater categorical WLAs are calculated based on the area of operations authorized under the general permit (MNR050000) relative to the impairment subwatershed area. This relative area is less than 0.1% for the Chester, Keene, Kingsbury, and Ticher creeks' subwatersheds; as such, the industrial stormwater categorical WLA for the Chester, Keene, Kingsbury, and Ticher creeks' TMDLs is 0.1% of the loading capacity. The relative area for the Miller Creek Watershed is 5%, which includes regulated operations in the headwaters near the DIA. Therefore, the industrial stormwater categorical WLA for the Miller Creek TMDL is 5% of the loading capacity.

Table 27. Calculation of the categorical WLA for industrial stormwater

Impaired stream	WID	Loading capacity (lbs./day) [a]	Industrial stormwater categorical WLA (lbs./day)
Chester Creek	04010102-545	10,582	10.6
Keene Creek	04010201-627	9,117	9.12
Kingsbury Creek	04010201-626	13,881	13.9
Miller Creek	04010201-512	15,685	784
Tischer Creek	04010102-544	11,439	11.4

a. Section 4.1 discusses the methodology for calculating loading capacities.

The WLA for the WCL Proctor Rail Yard (MN0000361) is allocated using an area-ratio approach based on the regulated stormwater area for this operation (182-acres) that is within the Kingsbury Creek (-626) Subwatershed[30]. Just like with the MS4s, first the loading capacity is reduced by the summation of the natural background load (Section 3.5.2.10), nonpermitted load (Section 4.2.1), and MOS (Section 4.4), and then the remaining capacity was apportioned using a ratio of regulated stormwater areas.

4.4 Margin of safety

The MOS accounts for uncertainty concerning the relationship between water quality and allocated loads. The MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as a load set aside).

An explicit MOS of 10% was included in the TMDLs to account for uncertainty that the pollutant allocations will attain water quality targets. The use of an explicit MOS accounts for environmental variability in pollutant loading, variability in water quality monitoring data, uncertainty in modeling outputs, conservative assumptions made during the modeling efforts. This explicit MOS is considered to be sufficient given the robust datasets used and quality of modeling, as described below.

The precipitation dataset for the DIA has 75 years of daily records with 100% coverage. The MOS accounts for uncertainty associated with the calculation of the long-term average winter season precipitation. TMDL subwatersheds were defined as Level 08 catchments in the *DNR Watershed Suite* (DNR 2023). The MOS also accounts for uncertainty associated with the subwatershed boundaries.

4.5 Seasonal variation and critical conditions

Chloride loading to streams varies seasonally and thus critical conditions vary seasonally. Throughout the DUAW, in the winter and spring, chloride loading is driven by winter maintenance activities. Runoff, including spring snowmelt, via overland flow or storm sewers, transports residue from winter maintenance activities to the surface waterways, including the five impaired streams. During the winter

[30] WCL's Proctor Rail Yard (MN0000361) is 229-acres, with 182-acres in Kingsbury Creek (-626) Subwatershed and 47-acres in the Midway River (WID 04010201-541) Subwatershed.

and spring critical conditions, flows are high, chloride concentrations are high, and thus, chloride loads are high.

In the summer, chloride loading in certain locations (i.e., stream segments near dirt or gravel roads) is driven by dust suppression activities. Runoff transports dust suppressant residue to surface waterways, including the five impaired streams. During summer low-flow conditions, summer storms (even small storms) generate runoff with high chloride concentrations that can yield high chloride loads (relative to in-stream low-flow conditions).

The TMDLs have been developed to achieve compliance with the November through March period with the highest chloride loading. Since chloride does not readily break down, chloride loading from the winter and spring can persist in-stream throughout the year. As Minnesota's chronic chloride standard applies year-round, the TMDLs apply year-round.

4.6 Baseline year

The baseline year for all five impaired creeks is 2017. While the period of record varies by stream, most of the chloride data are available from 2016-2018, and 2017 is the midpoint of that period.

Any activities implemented during or after the baseline year that led to a reduction in pollutant loads to the waterbodies may be considered as progress towards meeting a WLA or LA. If a BMP was implemented during or just prior to the baseline year, the MPCA may consider evidence presented by the MS4 permit holder to demonstrate that the BMP should be considered as progress towards meeting a WLA.

4.7 Percent reduction

The estimated percent reductions provide a rough approximation of the overall reduction needed for the waterbody to meet the TMDL. The percent reduction is a means to capture the level of effort needed to reduce chloride concentrations in the watershed. The percentage reductions should not be construed to mean that each of the separate sources listed in the TMDL table needs to be reduced by that amount.

The estimated percent reduction needed to meet each TMDL was calculated by comparing the highest/maximum observed (monitored) sample concentration to Minnesota's chronic chloride standard (230 mg/L). The equation is:

Reduction = (Maximum monitored – Standard) / Maximum monitored.

4.8 TMDL summary

This section presents TMDL tables for each of the five streams impaired for their aquatic life use by high chloride levels. The impairments are presented from west to east: Kingsbury, Keene, Miller, Chester, and Tischer creeks. The daily loads are in lbs. of chloride and are reported to three significant digits (except for loads more than 1,000 lbs. that are reported as whole lbs.). Winter season (November through March) total loads are presented in Section 4.1.4.

Table 28. Kingsbury Creek (WID 04010201-626) chloride TMDL summary

- Listing year: 2022
- Baseline year: 2017
- Numeric standard used to calculate TMDL: 230 mg/L chloride
- Precipitation used to calculate TMDL: Long-term (1994-2023) November through March average
- TMDL and allocations apply January through December.

TMDL parameter		TMDL chloride load (lbs./day)
WLA	Duluth, city of (MS400086)	1,769
	Hermantown, city of (MS400093)	3,529
	Midway Township (MS400146)	3,434
	MnDOT – Outstate District (MS400180)	147
	Proctor, city of (MS400114)	2,391
	St. Louis County (MS400158)	145
	Wisconsin Central Ltd. – Proctor Rail Yard (MN0000361) *	381
	Industrial stormwater (MNR050000)	13.9
	Total WLA	**11,810**
LA	Nonpermitted aggregate	472
	Natural background	211
	Total LA	**683**
	MOS	**1,388**
	TMDL	**13,881**
	Maximum observed concentration (mg/L)	559
	Estimated percent reduction	59%

*Water Quality Based Effluent Limits (WQBELs) will be developed if discharges from the facility are found to have a reasonable potential to cause or contribute to excursions above the water quality standards. WQBELs may vary slightly from TMDL WLAs and may be expressed as concentration based effluent limitations.

Table 29. Keene Creek (WID 04010201-627) chloride TMDL summary

- Listing year: 2022
- Baseline year: 2017
- Numeric standard used to calculate TMDL: 230 mg/L chloride
- Precipitation used to calculate TMDL: Long-term (1994-2023) November through March average
- TMDL and allocations apply January through December.

TMDL parameter		TMDL chloride load (lbs./day)
WLA	Duluth, city of (MS400086)	3,048
	Hermantown, city of (MS400093)	4,580
	MnDOT – Outstate District (MS400180)	61.1
	St. Louis County (MS400158)	57.8
	Industrial stormwater (MNR050000)	9.12
	Total WLA	**7,756**
LA	Nonpermitted aggregate	310
	Natural background	139
	Total LA	**449**
	MOS	**912**
	TMDL	**9,117**
	Maximum observed concentration (mg/L)	874
	Estimated percent reduction	74%

Table 30. Miller Creek (WID 04010201-512) chloride TMDL summary

- Listing year: 2022
- Baseline year: 2017
- Numeric standard used to calculate TMDL: 230 mg/L chloride
- Precipitation used to calculate TMDL: Long-term (1994-2023) November through March average
- TMDL and allocations apply January through December.

TMDL parameter		TMDL chloride load (lbs./day)
WLA	Duluth, city of (MS400086)	8,240
	Hermantown, city of (MS400093)	3,157
	Lake Superior College (MS400225)	107
	MnDOT – Outstate District (MS400180)	307
	Rice Lake, city of (MS400151)	596
	St. Louis County (MS400158)	138
	University of Minnesota – Duluth (MS400214)	15.4
	Industrial stormwater (MNR050000)	784
	Total WLA	**13,344**
LA	Nonpermitted aggregate	533
	Natural background	239
	Total LA	**772**
	MOS	**1,569**
	TMDL	**15,685**
	Maximum observed concentration (mg/L)	1,170
	Estimated percent reduction	80%

Table 31. Chester Creek (WID 04010102-545) chloride TMDL summary

- Listing year: 2022
- Baseline year: 2017
- Numeric standard used to calculate TMDL: 230 mg/L chloride
- Precipitation used to calculate TMDL: Long-term (1994-2023) November through March average
- TMDL and allocations apply January through December.

TMDL parameter		TMDL chloride load (lbs./day)
WLA	Duluth, city of (MS400086)	8,490
	MnDOT – Outstate District (MS400180)	6.09
	Rice Lake, city of (MS400151)	191
	St. Louis County (MS400158)	304
	University of Minnesota – Duluth (MS400214)	0.390
	Industrial stormwater (MNR050000)	10.6
	Total WLA	**9,002**
LA	Nonpermitted aggregate	361 [a]
	Natural background	161
	Total LA	**522**
	MOS	**1,058**
	TMDL	**10,582**
	Maximum observed concentration (mg/L)	277
	Estimated percent reduction	17%

a. A load of 1 pound per day is added to account for rounding in the other allocations.

Table 32. Tischer Creek (WID 04010102-544) chloride TMDL summary

- Proposed listing year: 2026
- Baseline year: 2017
- Numeric standard used to calculate TMDL: 230 mg/L chloride
- Precipitation used to calculate TMDL: Long-term (1994-2023) November through March average
- TMDL and allocations apply January through December.

TMDL parameter		TMDL chloride load (lbs./day)
WLA	Duluth, city of (MS400086)	6,173
	MnDOT – Outstate District (MS400180)	2.90
	Rice Lake, city of (MS400151)	3,124
	St. Louis County (MS400158)	150
	University of Minnesota – Duluth (MS400214)	271
	Industrial stormwater (MNR050000)	11.4
	Total WLA	**9,732**
LA	Nonpermitted aggregate	389
	Natural background	174
	Total LA	**563**
	MOS	**1,144**
	TMDL	**11,439**
	Maximum observed concentration (mg/L)	453
	Estimated percent reduction	49%

5. Future growth considerations

The DUAW is mostly composed of urban and suburban land, with the headwaters along the suburban-rural fringes. The impaired subwatersheds range from 28% to 56% developed land. Regulated industrial and MS4 stormwater span the entirety of each impaired subwatershed. Recent population estimates are presented in Table 33 for key jurisdictions overlapping the five impairment subwatersheds. From 2000 to 2023, Duluth (Figure 45), Hermantown, Proctor, and Rice Lake increased in population, while Midway Township decreased and St. Louis County's population remained relatively unchanged. The Minnesota State Demographic Center (2024) estimated the 2024 population of St. Louis County to be 198,364 people and projects the 2055 population to decrease to 172,328 people.

Table 33. Populations of key political subdivisions in the DUAW

Sources: Census Bureau 2021a, 2021b, 2024.

Political subdivision	2000 Census	2010 Census	2020 est.	2023. est.	2000-2023 change
Duluth	86,381	86,265	86,271	87,680	+1.5%
Hermantown	8,052	9,414	10,222	10,202	+26.7%
Midway Township	1,522	1,399	1,423	1,425	-6.4%
Proctor	2,821	3,057	3,121	3,087	+9.8%
Rice Lake	4,125 [a]	4,095 [a]	4,104	4,160	+0.8%
St. Louis County	200,586	200,226	200,233	200,514	< -0.1%

a. Rice Lake Township.

Figure 45. Lake Avenue and Buchanan Street at Canal Park in Duluth, MN.

Source: Tom Estabrooks (MPCA)

5.1 New or expanding permitted MS4 WLA transfer process

Future transfer of watershed runoff loads in this TMDL may be necessary if any of the following scenarios occur within the project watershed boundaries.

1. New development occurs within a permitted MS4. Newly developed areas that are not already included in the WLA must be transferred from the LA to the WLA to account for the growth.
2. One permitted MS4 acquires land from another permitted MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more nonpermitted MS4s become permitted. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of a U.S. Census Bureau Urban Area with population over 50,000 encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an urban area at the time the TMDL was completed but are now inside a newly expanded urban area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related source is identified and is covered under an NPDES/SDS permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL. Loads will be transferred on a simple land area basis. In cases where WLA is transferred from or to a permitted MS4, the permittees will be notified of the transfer and have an opportunity to comment.

Figure 46. Canal Park in Duluth, MN.

Source: Tom Estabrooks (MPCA)

6. Reasonable assurance

"Reasonable assurance" shows that elements are in place, for both permitted and nonpermitted sources, that are making (or will make) progress toward needed pollutant reductions.

6.1 Reduction of permitted sources

In the five chloride TMDLs, permitted sources are allocated 85% of the loading capacity; nonpermitted sources, 3.4%; MOS, 10%; and natural background, 1.6%. As the five impairment subwatersheds are completely covered by regulated MS4s, much of the chloride load reductions will need to be from regulated stormwater.

6.1.1 Permitted MS4s

The MPCA is responsible for applying federal and state regulations to protect and enhance water quality in Minnesota. The MPCA oversees stormwater management accounting activities for all permitted MS4 entities listed in this TMDL report. The MS4 General Permit requires regulated municipalities to implement BMPs that reduce pollutants in stormwater to the maximum extent practicable. A critical component of permit compliance is the requirement for the owners or operators of a permitted MS4 conveyance to develop a Stormwater Pollution Prevention Plan (SWPPP). The SWPPP addresses all permit requirements, including the following six measures:

- Public education and outreach
- Public participation
- Illicit discharge detection and elimination program

- Construction site runoff controls
- Post-construction runoff controls
- Pollution prevention and municipal good-housekeeping measures

A SWPPP is a management plan that describes the MS4 permittee's activities for managing stormwater within their regulated area. In the event of a completed TMDL study, MS4 permittees must document the WLA in their future NPDES/SDS permit application and provide an outline of the BMPs to be implemented that address needed reductions. The MPCA requires MS4 owners or operators to submit their application and corresponding SWPPP document to the MPCA for review. Once the application and SWPPP are deemed adequate by the MPCA, all application materials are placed on 30-day public notice, allowing the public an opportunity to review and comment on the prospective program. Once NPDES/SDS permit coverage is granted, permittees must implement the activities described within their SWPPP and submit an annual report to the MPCA documenting the implementation activities completed within the previous year, along with an estimate of the cumulative pollutant reduction achieved by those activities.

This TMDL report assigns WLAs to permitted MS4s in the study area. Depending on the pollutant, the MS4 General Permit either requires permittees to implement specific permit items or to develop compliance schedules for EPA approved TMDL WLAs not already being met at the time of permit application. A compliance schedule includes BMPs that will be implemented over the permit term, a timeline for their implementation, and a long-term strategy for continuing progress towards assigned WLAs. For WLAs being met at the time of permit application, the same level of treatment must be maintained in the future. Regardless of WLA attainment, all permitted MS4s are still required to reduce pollutant loadings to the maximum extent practicable.

The MPCA's stormwater program and its NPDES/SDS permit program are regulatory activities providing reasonable assurance that implementation activities are initiated, maintained, and consistent with WLAs assigned in this study.

The objective of the regulated MS4 stormwater entities' WLAs is to reduce chloride-laden stormwater that is delivered to impaired streams by reducing chloride application during winter maintenance and summer dust suppression activities. In lieu of percent reductions from baseline for each regulated MS4 stormwater entity, the TMDL establishes performance-based reductions. The regulated MS4 stormwater entities must develop winter maintenance and summer dust suppression plans, implement BMPs from the plans, and annually document progress toward plan and BMP implementation and chloride reduction.

6.1.2 Permitted industrial stormwater

Industrial stormwater from the WCL Proctor Rail Yard (MN0000361) is assigned an individual WLA in the Kingsbury Creek (WID 04010201-626) chloride TMDL. The objective of the regulated industrial stormwater WLA, similar to that of the regulated MS4 stormwater entities WLAs, is to reduce chloride-laden stormwater that is delivered to impaired streams by reducing chloride application during summer dust suppression activities. In lieu of a percentage reduction from baseline, the TMDL establishes performance-based reductions. WCL Proctor Rail Yard must include chloride reduction BMPs in their

SWPPP and monitor for chloride in their stormwater effluent. Representatives of the facility have indicated that they intend to use water only for future dust suppression.

A categorical WLA has been set for industrial stormwater general permittees (MNR050000) in the impaired subwatersheds. Permittees are required to store deicer/anti-icer agents properly, and document in their SWPPP how they will minimize runoff from the use de-icing/anti-icing materials on the facility property.

6.2 Reduction of nonpermitted sources

Several chloride reduction programs can be used to support nonpermitted source reduction; however, such reduction programs can also be used for permitted source reduction. These programs identify BMPs, provide means of focusing BMPs, and support their implementation via state initiatives, ordinances, and/or dedicated funding.

The following examples describe large-scale programs that have proven to be effective and/or will reduce pollutant loads going forward.

6.2.1 Statewide Chloride Management Plan

The MPCA developed the *Minnesota Statewide Chloride Management Plan* (MPCA 2020c; Figure 47) for effective management of salt use to protect Minnesota water resources responsibly and effectively. The MPCA collaborated with local partners, sister state agencies, and experts to identify solutions that “find a balance between clean water and salt use” (MPCA 2020c, Page 10). The plan discusses water quality conditions, typical sources of chloride, salt use reduction strategies, recommendations for future monitoring (in-stream and BMPs), and tracking and measuring progress. For each typical source of chloride in Minnesota, the plan presents comprehensive implementation strategies that generally follow a performance-based approach.

Figure 47. Minnesota Statewide Chloride Management Plan.

6.2.2 Statewide Chloride Resources

The MPCA provides an online repository of Statewide chloride resources (including reports, guidance, and educational materials) online.

6.2.3 Training For Efficient and Effective Salt Management

Smart salting trainings are offered by multiple organizations, including state agencies, nongovernment organizations, and private contractors. The RSPT is a bi-state organization that coordinates pollution prevention activities and facilitates trainings to reduce chloride pollution in both Minnesota and Wisconsin; see Section 6.6.2 for more information about RSPT.

The MPCA provides Smart Salting training for winter maintenance to three types of audiences:

- **Winter maintenance professionals** (5.5-hour training)
- **Property managers, business owners, and environmental professionals** (4-hour training)
- **Community leaders** (2-hour online workshops)

For winter maintenance professionals, the MPCA offers Level 1 certifications for *Smart Salting for Roads* and *Smart Salting for Parking Lots and Sidewalks*. The MPCA also offers Level 1 certification for property managers, business owners, and environmental professionals. Participants must pass a test to earn the Level 1 certification. The MPCA also provides refresher trainings (three-hour) for these certifications.

Organizations that use the Smart Salting Tool, implement the tool recommendations, and attend the semi-annual training can earn Level 2 organization certification.

Staff at several organizations in the project area, including regulated MS4s, hold Level 1 certification (Table 34).

Table 34. Staff with Smart Salting Level 1 certification

Organization	Roads	Parking lots and sidewalks	Property managers
Duluth (city)	101	1	1
Duluth Public Schools	--	2	1
Hermantown	1	--	--
Lake Superior College	14		1
Rice Lake	4	--	--
St. Louis County	2	--	--
UMD	--	7	1

MnDOT incorporates smart salting into its training programs. MnDOT collaborates with MPCA to include material from MPCA's Smart Salting Training for winter maintenance into MnDOT's smart salting training for plow operators. MnDOT has a goal of training all plow operators on a five-year cycle. Recently, 15 plow operators in MnDOT District 1 (Northeast, which includes the DUAW) underwent smart salting training. Additionally, MnDOT has incorporated smart salting content into the Getting Ready for Winter (GRFW) meeting presentations for plow operators, supervisors, and managers that MnDOT conducts in all eight districts every year[31].

6.2.4 Smart Salting Tool

The MPCA encourages communities and organizations to use the Smart Salting Tool to evaluate and reduce the communities' and organizations' salt use. This online tool allows users to evaluate current conditions (i.e., assess the existing sources of chloride) and to develop a chloride reduction action plan (with BMPs) to reduce chloride pollution.

[31] Rober Vasek, Maintenance Operations Engineer, MnDOT, electronic communications, October 31, 2025.

The Smart Salting Tool includes a mapping feature that allows users to evaluate salt use and develop a chloride reduction action plan at several scales (e.g., county, regulated MS4, watershed). The easy-to-use interface allows users to research sources of chloride, identify means to collect additional data, and input local data. The tool can even be run using default data for those communities or organizations without any local data.

6.3 Summary of local plans

Minnesota has a long history of water management by local government, which included developing water management plans along county boundaries since the 1980s. The Board of Water and Soil Resources (BWSR)-led One Watershed, One Plan (1W1P) program is rooted in work initiated by the Local Government Water Roundtable (Association of Minnesota Counties, Minnesota Association of Watershed Districts, and Minnesota Association of SWCDs). The Roundtable recommended that local governments organize to develop focused implementation plans based on watershed boundaries. That recommendation was followed by the legislation (Minn. Stat. § 103B.801) that established the 1W1P program, which provides policy, guidance, and support for developing CWMPs:

- Align local water planning purposes and procedures on watershed boundaries to create a systematic, watershed-wide, science-based approach to watershed management.
- Acknowledge and build off of existing local government structure, water plan services, and local capacity.
- Incorporate and make use of data and information, including WRAPS.
- Solicit input and engage experts from agencies, residents, and stakeholder groups; focus on implementation of prioritized and targeted actions capable of achieving measurable progress.
- Serve as a substitute for a comprehensive plan, local water management plan, or watershed management plan developed or amended, approved, and adopted.

Figure 48. St. Louis River Watershed CWMP.

The *St. Louis River Watershed Comprehensive Watershed Management Plan* (Bomier et al. 2022) was developed by the Carlton, Lake, North St. Louis, and South St. Louis SWCDs, Fond du Lac Band, and St. Louis County. This CWMP covers the St. Louis River Subbasin (HUC 04010201), Cloquet River Subbasin (04010202), and the DUAW that includes a small portion of the Lake Superior South Subbasin (HUC 04010102).

The CWMP addresses chlorides in its goals and priority areas, and the CWMP targets participation in chloride TMDL development. For the *Surface Water Quality* issue category, the chloride goal is to ensure that "60% of municipalities have Smart Salt Certified Staff, 60% Communities achieved Level 2 Certified" and "education & outreach to 100% of priority landowners" (Bomier et al. 2022, Page 13). These goals are applicable in each of the five planning areas: St. Louis River North, St. Louis River South, Cloquet, Fond du Lac Reservation, and Duluth Urban.

In the Duluth Urban Planning Area, the CWMP identifies the Keene Creek Subwatershed as a priority area and the Kingsbury and Ticher creeks' subwatersheds as other important areas. In the Keene Creek Subwatershed, the 10-year and long-term goals are for three staff to be certified for Smart Salting and for three road authorities to be Level 2 certified for Smart Salting (Bomier et al. 2022, Page 173). The three targeted road authorities are the cities of Duluth and Hermantown and St. Louis County.

6.4 Examples of pollution reduction efforts

Organizations throughout the DUAW are implementing BMPs to reduce their chloride use. This section presents four examples of chloride reduction efforts.

6.4.1 City of Duluth BMPs[32]

Beginning in 2020, the City of Duluth took big steps towards reducing the city's chloride footprint. The city accomplished significant improvements through collaboration at the Streets Maintenance Division at the Department of Public Works and Utilities. The manager, operations coordinator, stormwater team, and division staff worked collectively to implement many chloride reduction BMPs in 2020 through 2024.

- **Storage**: All maintenance facilities that house salt or salted-sand were redesigned: all material is now stored under cover and BMPs contain any runoff from the storage areas.
  - Lund Toolhouse: Installation of a 1,000-ton material storage shed. Installation of a stormwater collection basin that was designed and constructed in-house. Native grasses were planted on all disturbed areas.
  - Riley Toolhouse: Installation of a 5,000-ton material storage shed (Figure 49). Installation of a

Figure 49. Salt shed at the Riley Toolhouse.
Source: Jake Mikna (Minnesota Green Corps, City of Duluth)

[32] Geoff Vukelich, Streets Maintenance Operations Coordinator, City of Duluth, electronic communication, March 4, 2025.

stormwater retention pond with sediment catch basin for overflow protection. Over 1 acre of pollinator species/plants and native grasses were planted in the disturbed area.

    - Mesaba Toolhouse: Installation of a 1,000-ton material storage shed.

- **Anti-Icing and De-Icing Agents**: In 2021 through 2023, the city purchased pre-wet tanks capable of spraying anti-icing liquids. In 2022, the city purchased a new brine generation system for each of the toolhouses. In 2023, the city installed brine stations capable of using de-icing additives.
- **Operations**: Beginning in 2021, winter road maintenance staff calibrate all spreaders on a maintenance schedule and staff track calibration and maintenance. In 2022, automatic vehicle location systems were installed in all plow equipment, which allows the city to track and analyze material usage.
- **Training**: Beginning in 2022, all winter maintenance staff are Smart Salting Level 1 Certified. Refer to Section 6.2.3 for information about Smart Salting Training.

6.4.2 St. Louis County BMPs (MPCA 2022b, St. Louis County 2019, 2023)

The St. Louis County Public Works Department has implemented many winter road maintenance BMPs over the past two decades and has reduced its salt use by about 30%. The county has found that investing in technology to reduce salt use pays off from an economic, as well as environmental standpoint.

- **Storage**: The county's sand and salt are stored in dome buildings or coverall type buildings that drain to stormwater retention ponds that capture sediment.
- **Anti-Icing Agent**: The county installed brine-making systems at multiple locations. One of the first areas where the county began using brine is the maintenance area covered by this TMDL.
- **Equipment**: The county's pre-2008 trucks were retrofitted with calibration controls and pre-wetting equipment. The county's trucks purchased in 2008 and later include pre-wetting equipment and global positioning system. New trucks have specialized equipment for brine pre-treatment.
- **Pre-treatment**: The county applies brine about 1-3 days before a forecast snowstorm (when the pavement is dry, temperatures are at least 15° F, and no rain is forecast). Once the brine dries on the roadways it inhibits snow and ice from binding to the road, which makes snow removal by the plow trucks easier.
- **Training**: Although personnel involved with winter road maintenance receive training, use of information technology has transferred the majority of salt-related decision making from plow drivers to management-level staff, which is more effective than relying on staff training and motivation.

6.4.3 MnDOT BMPs

MnDOT has over 1,800 staff that use over 800 snowplows trucks to plow over 30,400 miles of interstate and state routes in Minnesota (MnDOT 2025d). MnDOT practices described below are implemented statewide including the DUAW.

- **Planning**: MnDOT (2019) uses a Maintenance Decision Support System (MDSS) that integrates current and forecasted weather, maintenance, and road conditions to recommend treatment options that are presented to operators in their trucks. MnDOT (2025b) uses an automated information system to collect, process, and distribute weather forecasts and road surface information: Road and Weather Information System (R/WIS). This system provides information to plow drivers, fleet operators, and highway operations managers and allows MnDOT winter maintenance operations to adapt to changing weather and road conditions. MnDOT also uses a Winter Severity Index to facilitate comparison of winter maintenance activities (e.g., chloride use) between years; the Winter Severity Index is based on dew point/relative humidity, wind speed gusts and direction, frost/black ice, precipitation type and duration amounts, air temperature, road temperature, cloud cover, blowing snow, and surface pressure.
- **Equipment**: All MnDOT plow trucks use automatic vehicle location systems. MnDOT application equipment (rock salt spreaders and liquid application systems) are calibrated every year and within a season as needed.
- **Operations**: MnDOT tracks the application of salt, brine, sand, potassium acetate, and salt brine additives. Tracking includes the amounts and locations of material, as well as the application speed. MnDOT evaluates material usage and application speed for each route with industry recommendations to identify and mitigate any over-usage by operators and to ensure materials are kept on the road. MnDOT also measures performance using the Bare Lane Regain time to assess material application. MnDOT defines Bare Lane as all driving lanes are free of snow and ice between the outer edges of the wheel paths and have less than one inch of accumulation on the center of the roadway
- **Research**: MnDOT has funded research to identify chloride reduction BMPs and identify alternatives to chloride-based deicing/anti-icing materials (see Section 6.4.4 for two examples of studies funded by MnDOT).

6.4.4 Potassium Acetate Studies (Gulliver et al. 2022; Rehmann et al. 2022)

The University of Minnesota -Twin Cities, UMD-NRRI (in the DUAW), Valparaiso University, Iowa State University, Auburn University, Local Road Research Board, and MnDOT investigated the environmental impacts of potassium acetate as a road salt alternative. Potassium acetate is effective at lower temperature than other road salt alternatives and is less corrosive to steel than chloride-based road salt; however, it is more expensive than road salt and exerts biochemical oxygen demand as it is degraded by microorganisms.

Two teams of researchers studied the impacts and persistence of potassium acetate in two concurrent, companion research projects. Gulliver et al. (2022) focused on the toxicity of potassium acetate on aquatic and terrestrial indicator species, while Rehmann et al. (2022) focused on the persistence of potassium acetate in the environment and its impact on biochemical oxygen demand. The authors conducted a field study in the winters of 2019-2020 and 2020-2021, with potassium acetate applied as an anti-icing agent on three different types of roads in Duluth along with laboratory toxicological test. The authors collected stormwater samples and ambient samples from Lake Superior.

Gulliver et al. (2022): Potassium acetate applications did not have a significant influence on biochemical oxygen demand or microbiological quality in Lake Superior due to slow degradation at low temperature. Additionally, aquatic organisms were more sensitive to potassium acetate at lower levels than sodium chloride, primarily due to potassium. Observed potassium concentrations in Lake Superior generally did not reach toxic levels, but researchers concluded that smaller bodies of water are at greater risk. Field data were used to help develop a watershed model for Miller Creek. Based on the field study and modeling, the authors concluded that potassium acetate may be appropriate for limited use in hazardous winter driving locations (e.g., bridges and temperatures below which other deicers function) but not throughout the watershed or for all snowstorms.

Figure 50. Potassium acetate study.

Rehmann et al. (2022): Potassium acetate was not observed to biodegrade during the study period, which may indicate slow degradation in waterbodies. Modeling predicted that potassium acetate would have a small impact on oxygen levels. Modeling also indicated that potassium acetate concentrations in a lake would initially be high and then drop sharply. Rehmann et al. (2022) prepared detailed users manuals for two fate and transport models.

6.4.5 Outreach and education

In addition to facilitating smart salting trainings (e.g., for regulated MS4s), RSPT also conducts outreach and education for the public and key stakeholders. RSPT's online resources include websites with key information[33], Facebook posts, graphics (Figure 51), and videos (Figure 52).

Refer to Section 6.6.2 for more information about RSPT.

Figure 51. Example RSPT graphic.

33 https://www.poopfairy.university/learn/tackle-nacl

Figure 52. Examples of RSPT public service announcement.

6.5 Funding

Funding sources to implement TMDLs can come from local, state, federal, and/or private sources. MPCA's Statewide chloride resources presents funding programs that directly target chloride reduction and these funding programs are summarized in the subsections below.

Many major state and federal funding programs do not specifically address chlorides. For example, Farm Service Agency and Natural Resources Conservation Service competitive and noncompetitive grants are for agricultural operations and target nutrient and sediment reduction and wildlife habitat improvement.

Additionally, while not directly focusing on chloride, BWSR's Clean Water Fund Watershed-based Implementation Funding (WBIF) and Clean Water Fund competitive grants (e.g., Projects and Practices) can be used to fund chloride reduction projects.

6.5.1 Chloride Reduction Grants

The MPCA provides competitive chloride reduction grants to reduce chlorides in sources that contributed to elevated chloride loads in wastewater or surface waters. The MPCA awards grants of $200,000 to $500,000, with a 25% local match, and funding originates from the Clean Water Land and Legacy Amendment's Clean Water Fund. Grant applicants must propose a project that is either a whole community project or an industrial facilities project. Grant recipients must develop and implement chloride reduction action plans. MPCA encourages grant recipients to use the Smart Salting Tool.

6.5.2 Clean Water Partnership Loans

The MPCA provides competitive, low-interest loans on a rolling basis to local government units for implementing nonpoint source BMPs that restore or protect water resources. The MPCA awards seven-year loans up to $750,000 at an interest rate of 1.5%. Loans are awarded on a rolling-basis depending on the available funds; the program has a loan capacity of $3,500,000. Funding originates from the Clean Water State Revolving Fund. While the loans do not specifically target chloride, local government units can propose projects to address nonpoint sources of chloride. Examples of eligible projects include purchases of deicing and anti-icing equipment, snow removal equipment, upgrading water softeners, and for developing ordinances, education, and outreach.

6.5.3 Small Business Environmental Improvement Loans

The MPCA provides zero-interest loans on a rolling basis to small businesses for capital equipment purchases to help the small businesses meet environmental regulations and for investigation and cleanup of contaminated sites. The MPCA awards seven-year loans of $1,000 to $75,000 at a 0% interest rate. The MPCA established specific criteria for companies that qualify as small businesses. While the loans do not specifically target chloride, small businesses can propose equipment upgrades to reduce salt use. Examples of eligible projects include purchases of snow removal equipment (e.g., new technology snow blades, plows, pushers, power brooms, and blowers), along with deicing and anti-icing equipment (e.g., brine makes, deicing sprayers, and salting equipment).

6.5.4 Watershed-Based Implementation Funding

WBIF is a noncompetitive process to fund water quality improvement and protection projects for lakes, rivers/streams, and groundwater. This funding allows collaborating local governments to pursue timely solutions based on a watershed's highest priority needs. The approach depends on the completion of a CWMP developed under the 1W1P program to provide assurance that actions are prioritized, targeted, and measurable. The SLRW 1W1P includes actions that would be eligible for implementation funding related to chloride management, training and certification of municipalities, and education and outreach to targeted landowners.

BWSR has been moving more of its available funding away from competitive grants and toward WBIF to accelerate water management outcomes, enhance accountability, and improve consistency and efficiency across the state. This approach allows more clean water projects identified through planning to be implemented without having to compete for funds, helping local governments spend limited resources where they are most needed.

WBIF assurance measures summarize and systematically evaluate how WBIF dollars are being used to achieve clean water goals identified in comprehensive watershed plans. The measures will be used by BWSR to provide additional context about watershed plan implementation challenges and opportunities. The following assurance measures are supplemental to existing reporting and on-going grant monitoring efforts:

- Understand contributions of prioritized, targeted, and measurable work in achieving clean water goals.
- Review progress of programs, projects, and practices implemented in identified priority areas.
- Complete Clean Water Fund grant work on schedule and on budget.
- Leverage funds beyond the state grant.

More than $43,801,000 has been spent cumulatively on watershed implementation projects in SLRW from 2004 through 2023. About 81% of this funding was spent on upgrading municipal WWTPs and about 14% was spent on agricultural projects. None of the funding has been for chloride reduction but such funding could be used for chloride reductions in the future.

6.6 Other partners and organizations

6.6.1 Duluth Urban Watershed Advisory Committee

The Duluth Urban Watershed Advisory Committee (DUWAC) is composed of municipalities[34] in the DUAW that seek to exchange information and coordinate project development and implementation in a shared urban watershed management framework. DUWAC was established in 2015, with the vision to ensure "our water resources and associated ecosystems become healthier and more resilient through public engagement and local government collaboration." Fundamental to DUWAC is the shared responsibility for protecting and maintaining water resources located within and beyond individual jurisdictional boundaries. The memorandum of understanding states "Protection and management objectives are advanced through agency and community collaboration, knowledge and resource sharing, ordinance and policy review, and project prioritization." Jointly, DUWAC members worked to develop a prioritized list of projects and activities of shared interest for implementation. Focus areas include education, stormwater management, streambank stabilization, stream crossing and culvert improvements, forest and wetland management, waste management, and land use planning and ordinances. A recent project supported by DUWAC was the green infrastructure code audit project, which evaluated local government codes and ordinances and identified barriers to implementing green stormwater infrastructure. A future outcome of this project will be to update ordinances to remove barriers to implementing green stormwater infrastructure projects.

Figure 53. Example RSPT outreach graphic.
Source: RSPT

6.6.2 RSPT

RSPT is composed of regulated MS4s[35] and partnering agencies and organizations[36]. RSPT's (2024) "mission is to protect and enhance the region's shared water resources through stormwater pollution prevention by providing coordinated educational programs and technical assistance". RSPT coordinates and facilitates smart salting training and conducts outreach and education for the public, and key stakeholders, which includes developing outreach material (Figure 53).

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[34] DUWAC represents the following communities: the cities of Duluth, Hermantown, Proctor, and Rice Lake; Gnesen, Lakewood, Midway, Normanna, and Thompson townships; and St. Louis County.

[35] The following entities are regulated MS4s that participate in the RSPT: the cities of Cloquet, Duluth, Hermantown, Proctor, Rice Lake, Superior (WI); Lake Superior College; MnDOT; St. Louis County; St. Louis County townships of Duluth and Midway; the Town of Thompson; the University of Minnesota - Duluth; the villages of Oliver (WI) and Superior (WI).

[36] The following entities are non-MS4, nonvoting members that participate in the RSPT: Canosia Township (St. Louis County), DNR Coastal Program, Lake Superior National Estuarine Research Reserve, Minnesota Sea Grant, MPCA, NRRI, North St. Louis SWCD, South St. Louis SWCD, St. Louis River Alliance, University of Wisconsin – Lake Superior Research Institute, University of Wisconsin – Superior, and WLSSD.

6.6.3 St. Louis Estuary

Lake Superior Headwaters Sustainability Partnership

The Lake Superior Headwaters Sustainability Partnership seeks to achieve a thriving estuary landscape and community into the future through natural resources management that is guided by sustainability, resiliency, and equity. The Partnership uses a collaborative, holistic approach for protection and restoration of the estuary and tributary watersheds.

The Forum at the Partnership is composed of representatives of the cities of Duluth, Minnesota, and Superior, Wisconsin; DNR; Fond du Lac Band of Lake Superior Chippewa; Lake Superior National Estuarine Research Reserve; Minnesota Land Trust; MPCA; EPA; U.S. Fish and Wildlife Service; and Wisconsin Department of Natural Resources.

The Partnership has developed a *Landscape Conservation Design* process for the estuary and its tributary watersheds. This process includes a metrics dashboard, mapping tool, and documentation online[37].

St. Louis River Alliance

The St. Louis River Alliance is a membership organization committed to supporting the resiliency of the St. Louis River. The Alliance was initially formed, under a different name, to support the St. Louis River Area of Concern through development of a remedial action plan, which is a required plan for all Great Lakes areas of concern. The goal of the Alliance is a clean and healthy St. Louis River with a thriving ecology, economy and community.

In addition to supporting the St. Louis River Area of Concern, the Alliance also works on the St. Louis River Estuary National Water Trail, to protect the piping plover (an endangered shorebird), and to protect and restore wild rice resources. The Alliance conducts stewardship events that include clean-ups, invasive species management, tours, safety events, socials, and such.

The Alliance partners with federal, state, local, and tribal governmental agencies. Funding is derived from business and individual member donations.

6.7 Reasonable assurance conclusion

In summary, federal and state agencies and local governments, organizations, and partnerships have devoted significant time and resources to identifying the best strategies and BMPs, providing means of focusing them in DUAW, and supporting their implementation via state, local, and federal initiatives and dedicated funding. The DUAW WRAPS and TMDL process engaged partners to arrive at reasonable scenarios of BMP combinations that attain pollutant reduction goals. Minnesota is a leader in watershed planning and implementation, as well as monitoring and tracking progress toward water quality goals and pollutant load reductions.

[37] https://headwaterspartnership.org/

7. Monitoring

This section provides an overview of what monitoring is expected to occur at many scales in multiple subwatersheds within the DUAW, subject to availability of monitoring resources. The aquatic life designated use will be the ultimate measures of water quality. Improving the state of this designated use depends on many factors, and improvements may not be detected over the next 5 to 10 years. Consequently, a monitoring plan is needed to track shorter- and longer-term changes in water quality and land management. Monitoring is also a critical component of an adaptive management approach and can be used to help determine when a change in management is needed.

7.1 Water Quality Monitoring Programs

Minnesota's Water Quality Monitoring Strategy 2021 through 2031 (MPCA 2021) establishes three types of monitoring:

- **Condition monitoring**: This type of monitoring is used to identify overall environmental status and trends by examining the condition of individual waterbodies or aquifers in terms of their ability to meet established standards and criteria.
- **Problem investigation monitoring**: This monitoring involves investigating specific problems or protection concerns to allow for the development of a management approach to protect or improve the resource. It is also used to determine the actions needed to return a resource to a condition that meets standards or goals.
- **Effectiveness monitoring**: This type of monitoring is used to determine the effectiveness of a specific regulatory or voluntary management action taken to improve impaired waters or remediate contaminated groundwater.

There are monitoring efforts in place to address each of the types of monitoring.

7.2 Optional Monitoring for Chloride Source Investigation

Optional monitoring could be used to investigate the sources of chloride delivered to the five impaired streams.

7.2.1 Kingsbury Creek (WID 04010201-626)

Kingsbury Creek flows through WCL's Proctor Rail Yard (MN0000361), and dust suppressants are applied to gravel roads at the rail yard during the summer. WCL is not required to monitor stormwater or Kingsbury Creek for chloride concentration but is required to record and report dust suppressant application information to MPCA.

To determine if dust suppressant application at the rail yard is significant, as compared with winter road maintenance, a synoptic study could be designed to sample in-stream chloride concentrations upstream, within, and downstream of the rail yard. To determine if future monitoring is needed, the monitoring entity should coordinate with MPCA and WCL since WCL (2025) intends "to use water only for dust control activities at the Proctor Rail Yard in the future". If monitoring is deemed necessary, six monitoring stations could be considered:

- **S007-720**: This station is on Kingsbury Creek at Ugstad Road, which is downstream of Mogie Lake and upstream of the Proctor Rail Yard. Chloride monitored at this station would represent sources upstream of the Proctor Rail Yard.
- **S007-272**: This station is on Kingsbury Creek at North Ugstad Road adjacent to the Proctor Rail Yard. Chloride monitored at this station would represent both sources upstream of the Proctor Rail Yard and runoff from the Proctor Rail Yard.
- **New station**: This station could be created on the unnamed tributary to Kingsbury Creek near the intersection of North 8th Avenue and 5th Street. Chloride monitored at this station would represent the unnamed tributary, with a watershed that is primarily single family residential.
- **New station**: This station could be created on Kingsbury Creek at 2nd Street. Chloride monitored at this station would represent sources upstream of the Proctor Rail Yard, runoff from the Proctor Rail Yard, and sources in Proctor west of Kingsbury Creek (e.g., the unnamed stream).
- **S007-051**: This station is on Kingsbury Creek along Pionk Drive, which is downstream of the Proctor Rail Yard and adjacent to the Proctor Golf Course and athletic fields. Chloride monitored at this station would represent sources upstream of the Proctor Rail Yard, runoff from the Proctor Rail Yard, and runoff from Proctor.
- **S007-104**: This station is on Kingsbury Creek at South Boundary Avenue, which is downstream of the Proctor Rail Yard and at the Proctor municipal boundary. Chloride monitored at this station would represent sources upstream of the Proctor Rail Yard, runoff from the Proctor Rail Yard, and runoff from Proctor.

Chloride contributions from much of the Proctor Rail Yard could be evaluated by comparing results from stations S007-720 and S007-272. Chloride contributions from the southern portion of the Proctor Rail Yard could be evaluated by comparing results from station S007-272 and the two new stations.

Chloride contributions from Proctor could be evaluated by comparing the new station on Kingsbury Creek at 2nd Street with station S007-104. Chloride contributions from the Proctor Golf Course and athletic fields could be evaluated by comparing station S007-051 and S007-104.

Synoptic samples should be collected multiple times under different conditions (e.g., baseflow, following a summer storm, following a winter storm, spring snowmelt).

7.2.2 Winter Maintenance Targeted Monitoring

The MPCA has monitored in-stream chloride levels (Section 3.4) and chloride loads generated from winter maintenance activity can be estimated using the Smart Salting Tool (3.5.2.9). However, the chloride loads from winter maintenance activities that are actually delivered to the impaired streams has not been quantified. To quantify chloride loads delivered to the impaired streams, a synoptic study could be designed to monitor in-stream chloride concentrations (and instantaneous flow) in the impaired streams, from stormwater outfalls along the impaired streams, and at the mouths of tributaries to the impaired streams. Synoptic monitoring could be performed before a winter precipitation event, after winter road maintenance, and again later after winter road maintenance.

Winter water quality monitoring is often a challenge[38,39]. For example, snow and ice conditions can prevent monitoring staff from reaching the monitoring locations and monitoring locations can freeze over, especially smaller creeks and stormwater outfalls with less flow. Another option could be to deploy in situ, continuous conductivity monitors and use a regression of conductivity and chloride concentration to estimate continuous chloride concentrations from continuous conductivity. The City of Duluth began this type of monitoring in 2024-2025 at several streams and stormwater outfalls.

Given the size of the five chloride-impaired stream subwatersheds, it may be necessary to perform individual synoptic studies for each of the impaired streams or segments of the impaired streams. Different monitoring efforts could target different types of areas (e.g., a tributary flowing through a residential area, stormwater outfalls from a commercial complex). In the past, NRRI has setup networks of monitoring sites and conducted monitoring at a network of sites in the DUAW (Chun et al. 2021).

The results of such synoptic studies may help identify areas with higher chloride loads that could be targeted for BMP implementation.

8. Implementation strategy summary

The *Minnesota Statewide Chloride Management Plan* (MPCA 2020c) presents comprehensive implementation strategies for the sources of chloride that are produced in the DUAW and that are delivered to and impair Chester, Keene, Kingsbury, Miller, and Tischer creeks. The MPCA provides Statewide chloride resources (including reports, guidance, and educational materials) online.

8.1 Permitted sources

Stormwater from regulated MS4s and industrial facilities are the only permitted sources of chloride whose chloride load is delivered to the chloride-impaired streams. Construction stormwater and nonmetallic mining discharges covered by general NPDES permits are present in the impairment subwatershed but are not considered to be significant sources of chloride. No NPDES/SDS-permitted feedlots are in the impairment subwatersheds.

8.1.1 Municipal separate storm sewer systems

The MS4 General Permit has instituted performance-based requirements for MS4s with chloride WLAs requiring reductions. Currently, MS4s are expected to document the amount of deicer applied to permittee owned/operated surfaces and conduct an annual assessment of the permittee's winter maintenance operations. Nine MS4s (Table 26) have chloride WLAs in this TMDL requiring reductions. They did not have chloride WLAs prior to this, so this TMDL will result in additional permit requirements.

[38] Chan Lan Chun, Senior Research Program Manager, UMD NRRI, Core Team meeting, March 13, 2025.
[39] Ryan Granlund, Utility Programs Coordinator, City of Duluth, Core Team meeting, March 13, 2025.

Further information and up to date guidance can be found at Guidance for meeting chloride TMDL MS4 permit requirements - Minnesota Stormwater Manual (state.mn.us).

TMDLs are developed using DNR Level 08 catchments, and the spatial geometry of the catchments may not exactly align with storm sewersheds. As the WLAs are performance based (i.e., implementation of BMPs), any issues with TMDL subwatershed areas that could affect the calculation of the loading capacity or numeric load of the WLAs will not impact compliance with the WLAs. The recommended BMPs for the management of dirt and gravel roads and winter maintenance is the same for permitted sources and nonpermitted sources. Refer to Section 0 for discussion of BMPs for the dirt and gravel road management strategy and Section 8.2.4 for discussion of BMPs for the winter maintenance strategy. This implementation strategy summary presents a wide array of BMPs, and several winter road maintenance BMPs are already being implemented by MnDOT, St. Louis County, and the City of Duluth. Each regulated MS4 will need to determine which BMPs are suitable for their jurisdiction. BMP feasibility is especially important for winter road maintenance, where public safety is the primary concern.

8.1.2 Industrial stormwater

Several industrial facilities covered by Minnesota's industrial stormwater general permit (MNR050000) are in the five impairment subwatersheds. In the headwaters of the Miller Creek impairment subwatershed, such industrial facilities are clustered near the DIA. The industrial stormwater general NPDES permit does not currently include monitoring or limits for chloride in the industrial stormwater effluent but does have requirements for proper salt storage and documenting how the facility will minimize runoff from salt and other de-icing and anti-icing materials.

One permitted facility (WCL's Proctor Rail Yard [MN0000361]) has an individual WLA for industrial stormwater runoff. The NPDES permit does not currently include monitoring or limits for chloride in the industrial stormwater effluent. The NPDES permit requires development and implementation of a SWPPP to address the specific conditions at the facility and the submission of a Chemical Dust Suppressant Annual Report for each year that a chemical dust suppressant is applied. The Chemical Dust Suppressant Annual Report must identify the composition of the chemical dust suppressant and when the chemical dust suppressant was applied. These permit requirements are necessary because WCL uses a chloride-based dust suppressant; however, WCL (2025) has stated that they intend "to use water only for dust control activities at the Proctor Rail Yard in the future".

The current reporting requirements do not provide sufficient information to determine if WCL's Proctor Rail Yard is a significant source of chloride to Kingsbury Creek. Should WCL continue to use a chloride-based dust suppressant, then data from the following activities will allow the MPCA to determine if the permittee is a significant source of chloride to Kingsbury Creek:

- Documenting the chloride load of the dust suppressant applications.
- Monitoring stormwater effluent for chloride concentration and load.

Chloride deposited on unpaved roads from dust suppressant application may remain on the road surface until a wet weather event when stormwater runoff will transport the chloride load to Kingsbury Creek. Stormwater effluent monitoring shall occur once per calendar month when stormwater is discharged from the facility (i.e., during or after wet weather events). If no stormwater is discharged in a calendar month, then no stormwater monitoring needs to occur.

An industrial stormwater chloride concentration limit may need to be incorporated into the individual NPDES permit if chloride loading from dust suppressant application migrates to Kingsbury Creek via industrial stormwater and significantly impacts chloride levels in Kingsbury Creek.

Industrial activity must also meet all local government stormwater requirements.

The recommended BMPs for the management of dirt and gravel roads and for winter maintenance are the same for permitted sources and nonpermitted sources. Refer to Section 0 for discussion of BMPs for the dirt and gravel road management strategy and to Section 8.2.4 for discussion of winter maintenance management.

8.2 Nonpermitted sources

Implementation of the chloride TMDLs for the five streams in the DUAW for nonpermitted sources will primarily consist of a variety of BMPs across four strategies. Generally, each strategy encourages a reduction in chloride use; however, each strategy focuses on different chloride sources and recommends different BMPs (Table 35). Each of the four strategies presented in Table 35 is further discussed in a subsection below and the final subsection discusses education and outreach for private landowners.

Table 35. Example BMPs for nonpermitted sources

Strategy	BMP examples	Target audiences
Dirt and gravel road management	Use of nonchloride dust suppressants Calibrate and maintain application equipment Lower speed limits	Homeowners Property owners/managers Road maintenance authorities
Turf management	Soil-testing to identify where and how much fertilizer is needed Use of nonchloride potassium fertilizers Calibrate and maintain fertilizer equipment Separate weed control from fertilizer application	Athletic complexes and golf courses Educational complexes Homeowners Lawncare contractors Park systems Property owners/managers
Water-softening optimization	Upgrade to more efficient water-softening equipment Regularly inspect, calibrate, and maintain water-softening equipment	Duluth municipal government Homeowners Plumbing professionals Property owners/managers
Winter maintenance management	Use liquid products instead of granular products Calibrate and maintain application equipment Store salt indoors on an impermeable pad	Homeowners Property owners/managers Snow removal contractors

8.2.1 Dirt and gravel road management

Typically, dirt and gravel roads are not directly regulated through NPDES or SDS permits (the WCL Proctor Rail Yard is a notable exception). As such, voluntary implementation will be necessary for public and private owners of unpaved roads. Entities that apply dust suppressants (e.g., road authorities, businesses) should evaluate the frequency, volume, and composition of the dust suppressants they use and implement strategies to reduce dust suppressant application (MPCA 2020c, Page 151).

The *Minnesota Statewide Chloride Management Plan* (MPCA 2020c) identifies eight key BMPs:

Structural

- Implement physical or structural controls to reduce the need for dust control (e.g., grading)
- Install roadside, structural barriers (e.g., fences, trees)

Nonstructural

- Develop an unpaved roads maintenance plan
- Train dust suppressant applicators
- Replace chloride-based dust suppressants with nonchloride-based dust suppressants
- Calibrate and maintain dust suppressant application equipment
- Lower the speed limits
- Inform landowners that they can opt-out of dust suppression at or near their property

Several of these BMPs can reduce the frequency and volume of dust suppressant application. Fewer applications may reduce wear-and-tear on equipment and may reduce maintenance costs. Less application volume will require less chloride solution to be purchased. As such, these BMPs can reduce costs for the road authorities.

8.2.2 Turf management

Turf management generally occurs at three scales for residential, commercial, and institutional properties:

- yards at individual structures (e.g., home, grocery store, church)
- athletic or grass fields at complexes (e.g., apartment building, shopping mall, high school)
- athletic or grass fields at multiple complexes (e.g., condominium complex, series of shopping plazas, municipal park system)

As such, BMPs will vary based on scale and land use. Generally, the objective for the turf management strategy is to reduce or eliminate chloride-based fertilizers. The *Minnesota Statewide Chloride Management Plan* (MPCA 2020c) identifies 10 key nonstructural BMPs:

- Develop a turf management plan
- Train lawncare contractors
- Implement soil testing to determine potassium needs at each location and apply the 4Rs[40] for fertilizer application often promoted for cultivated crops fertilizer application
- Calibrate and maintain fertilizer equipment (e.g., spreaders)
- Replace potash or other chloride-based potassium fertilizers with a nonchloride-based fertilizer
- Avoid fertilizer application to frozen ground
- Avoid fertilizer application to hard surfaces (e.g., sidewalks, roads)
- Separate weed control from fertilizer application
- Leave grass clippings on lawns and mowed fields, to reduce fertilizer use
- Mow grass to higher heights

8.2.3 Water-softening optimization

"There is no single best approach to meet softening needs for localized industrial uses and residential preferences" (MPCA 2020c, Page 120). The level of water-softening varies based on multiple factors including taste and smell preferences and manufacturing and industrial processes requirements. The *Minnesota Statewide Chloride Management Plan* (MPCA 2020c) identifies five key BMPs:

Structural

- Upgrade in-home and on-site softening equipment to equipment with a salt efficiency rating of no less than 4,000 grains of hardness removed per pound of salt used in regeneration
- Centralized municipal hardness reduction (in lieu of water-softening at individual homes and businesses)
- Replace the water-softening equipment with an iron-filter, if iron-removal is the primary objective

Nonstructural

- Inspect, calibrate, and maintain water-softening equipment regularly
- Train plumbing professionals

The City of Duluth (public water supply) along with other public entities is recommended to collaborate with plumbing professionals in the DUAW to optimize water-softening and reduce chloride loads from water-softening. The City of Duluth, other public entities, and plumbing professionals should refer to the *Minnesota Statewide Chloride Management Plan* (MPCA 2020c) for implementation strategies to reduce chlorides from water-softening.

[40] Right source, right rate, right time, and right place.

8.2.4 Winter maintenance management

Winter maintenance management for nonpermitted sources is generally the same as for permitted sources. The objective of the TMDLs is to reduce chloride-loading to the impaired streams. Generally, the objectives of implementation are to reduce the amount of chloride applied that can be transported to streams, to limit the dispersion (scatter, broadcast) of the product during application, and to contain and prevent spills of the product. The *Minnesota Statewide Chloride Management Plan* (MPCA 2020c, Page 116) has five primary strategies for winter maintenance:

- Shift from granular products to liquid products
- Improve physical snow and ice removal
- Prevent snow and ice bonding with pavement
- Train road maintenance professionals
- Educate the public and elected officials on chloride problems and reduction strategies

Winter maintenance BMPs

The *Minnesota Statewide Chloride Management Plan* (MPCA 2020c, Page 117-118) also identifies more specific BMPs:

Structural

- Upgrade to equipment that can deliver low application rates
- Install chutes or skirts on the application equipment
- Install impermeable pads and berms to contain product spills
- Install low-salt-use pavement

Nonstructural

- Planning BMPs
    - Develop a winter maintenance plan and share it with supervisors, crew, and customers
    - Smart Salting training, education, and professional development
    - Record and refine application rates (adaptive management)
- Operations BMPs
    - Apply anti-icing agents before winter events (when conditions are appropriate) to reduce bonding of snow and ice to pavement

Figure 54. Plow truck with liquid application equipment.
Source: Jake Mikna (Minnesota GreenCorps, City of Duluth)

    - Begin mechanical removal as soon as possible and continue mechanical removal throughout the winter event
    - Use liquid products (in lieu of granular products; example in Figure 54)
    - Use a higher liquid-to-granular ratio
    - Use ground speed controllers and reduce vehicle speed
    - Lower the spinner elevation
    - Target the road centerline
- Maintenance BMP: Inspect, calibrate, and maintain equipment regularly
- Storage BMP: Store granular products indoors on an impermeable pad

When paved surfaces need to be replaced, homeowners and property owners should evaluate lower-salt-use pavement. The following paved surfaces can be replaced with low-salt-use pavement: sidewalks, parking lots, roads, bridges, trails, parking ramps, and steps (MPCA 2020c, Page 157). Lower-salt-use pavement include:

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

Cost benefits

Many of these BMPs can increase efficiency or reduce the volume of de-icing and anti-icing agent application. More efficient applications may reduce wear-and-tear on equipment and may reduce operations and maintenance costs. More efficient applications may also lead to quicker applications that maintain safe driving conditions. Less application volume will require less chloride solution to be created or purchased. As such, these BMPs can reduce costs for the regulated MS4s.

Challenges for BMP implementation

The *Minnesota Statewide Chloride Management Plan* (MPCA 2020c) and this section present a catalogue of winter maintenance BMPs that may be feasible for the regulated communities and stakeholders in the DUAW. However, not all BMPs listed herein are feasible or practical for every community and stakeholder. For example, with the operations BMP of reducing vehicle speed (to reduce bounce and scatter), this BMP may be feasible for MnDOT and St. Louis County that apply anti-icing and de-icing agents on roads with higher speed limits, but this BMP is not feasible for the city of Duluth, especially in the downtown area, where application occurs at slow speeds (e.g., 15 miles per hour). As another example, with the BMP of targeting the road center line for application (to reduce bounce and scatter), this BMP is more practical for adjustable spreading equipment (e.g., where the tailgate auger spreader can be moved along the back of the truck) but is less practical for fixed spreading equipment (e.g., where the spreader is fixed at the center of the back of the truck).

A significant challenge to BMP implementation is cost. Several BMPs will require capital investment (e.g., purchasing new trucks) that may be beyond the fiscal capacity of some communities and stakeholders. This challenge becomes more significant after lower cost BMPs are implemented, leaving only higher cost BMPs. Finally, a few entities have already implemented several BMPs and have significantly reduced their anti-icing and de-icing agent application volumes. Communities and stakeholders often target the most cost-effective BMPs for implementation first (i.e., the so-called "low-hanging fruit"). As more BMPs are implemented, the dwindling pool of remaining BMPs tends to be composed of less cost-effective BMPs.

8.2.5 Outreach and Education to Private Landowners

Significant chloride loads are generated by commercial, residential, and institutional properties that are privately owned. Public entities (including the municipalities, RSPT, St. Louis County, and St. Louis South SWCD) should continue to target outreach and education to such private landowners. As different strategies and BMPs should be implemented at different types of private property, public entities will need to tailor the outreach and education to each type of private property. Table 36 presents recommended priorities for outreach and education to private landowners. Priorities vary by land use, type of wastewater treatment (i.e., WLSSD sanitary sewer service or SSTS), and the types of pervious or impervious surfaces typical for the specific land use. Priorities may need to be adjusted for specific properties.

The MPCA provides outreach and education material that public entities in the DUAW can use to develop their programs. The Minnesota Statewide Chloride Management Plan (MPCA 2020c) identifies the need for education, guidance, and training resources. The Statewide chloride resources website provides hyperlinks to educational resources, including:

- The *Low Salt, No Salt Minnesota* program
- A salt mini-course program
- Educational videos
- Posters, postcards, and other printables

A key focus of any outreach and education program for private landowners should be that reducing and optimizing chloride application not only benefits the environment but also saves the landowner money (MPCA 2020c). Private landowners can directly save money by purchasing less chloride product.

Table 36. Targeted education and outreach to private land owners

Type	Target audience	Dirt and gravel road management	Turf management	Water-softening optimization	Winter maintenance management
Residential	Single family, duplexes, and triplexes				
	Within WLSSD sanitary sewer service area	--	○	--	●
	Served by SSTS	--	○	●	●
	Apartment or condominium complexes	--	○	--	●
Commercial	Businesses [a] in downtown or dense urban areas	--	--	--	●
	Businesses [a] in suburban or light urban areas				
	Within WLSSD sanitary sewer service area and dense	○	○	--	●
	Served by SSTS	○	○	●	●
	Golf courses	○	●	--	●
Institutional	Athletic complexes	○	●	--	○
	Cemeteries	--	○	--	○
	Educational institutions				
	with amenities that are paved surfaces (e.g., tennis court)	--	--	--	●
	with athletic fields or turf grass	○	○	--	○
	with only buildings and parking lots	--	--	--	○
	Hospitals				
	in downtown or dense urban areas	--	--	--	●
	in suburban or light urban areas	--	○	--	●
	Parks				
	with amenities that are paved surfaces (e.g., tennis court)	--	--	--	●
	with athletic fields and turf grass	○	●	--	--
	with natural areas	○	--	--	--
	Religious institutions				
	standalone	--	○	--	○
	complexes	--	●	--	●

Priority for education and outreach: ● = High priority; ○ = Low priority; -- = not applicable.

a. Businesses include restaurants, stores, and offices (e.g., medical, professional) at individual locations or in complexes (e.g., shopping plaza, mall).

8.3 Minnesota Green Corps

The Minnesota Green Corps program places AmeriCorps members with host site organizations with the objectives of training a new generation of young professionals and preserving and protecting Minnesota's environment. Green Corps Members serve 11-months with the host site organization and implement environmental projects to increase resilience to climate change. Such projects can include efforts to reduce stormwater runoff and improve water quality. The MPCA identifies reducing salt use and minimizing chloride pollution as a potential effort that Green Corps members can implement.

8.4 Water quality trading

Water quality trading can help achieve compliance with WLAs or water quality-based effluent limits. Water quality trading can also offset increased pollutant loads in accordance with antidegradation regulations. Water quality trading reduces pollutants (e.g., TP or total suspended solids [TSS]) in rivers and lakes by allowing a point source discharger to enter into agreements under which the point source "offsets" its pollutant load by obtaining reductions in a pollutant load discharged by another point source operation or a nonpoint source or sources in the same watershed. The MPCA must establish specific conditions governing trading in the point source discharger's NPDES/SDS permit or in a general permit that covers the point source discharger. The MPCA implements water quality trading through permits. See MPCA's *Water Quality Trading Guidance* (MPCA 2022c) for more information.

8.5 Cost

Implementation of the CWMP in 2023 through 2032 is estimated to cost about $30 million, with about $9 million for the *Duluth Urban Planning Area* (Bomier et al. 2022, Page 217); however, these costs are to address multiple pollutants. The estimated cost for BMPs to address chloride across the five planning zones is $720,00, and the estimated cost for the BMPs to address chloride in the Duluth Urban Planning Area is $145,000 (Bomier et al. 2022).

8.5.1 Winter road maintenance cost methodology

Costs for addressing winter road maintenance are for the labor for municipal employees to implement three sets of BMPs:

- Development of a winter road maintenance plan and annual updates
- Training for equipment operators, managers, and political officials
- Inspection, calibration, and maintenance of equipment

Costs for capital purchases (e.g., new equipment, upgrading existing equipment, upgrading storage facilities) will be unique for each community, and thus, are not estimated herein.

8.5.2 Dust suppressant application cost methodology

Since most communities with regular dust suppressant application programs use contractors, costs for addressing dust suppressant application are for the labor for municipal employees to develop chloride dust suppressant application management plans. Costs for capital purchases (e.g., new equipment, upgrading existing equipment) will be borne by the contractors.

8.5.3 Water-Softening cost methodology

Cost for addressing chloride loads from residential water softening are for the optimization of existing water-softeners and replacement of outdated water-softeners. Three key assumptions are

- The number of residential properties in the five impairment subwatersheds: 8,000
- The relative number of residential properties that use water-softeners in the DUAW: 15%

- The relative number of water-softeners in the DUAW that fully function for 20 years: 50%

8.5.4 Public outreach cost methodology

Costs for public outreach for all sources of chloride, to be shared amongst the communities in the DUAW, assume one or two employees (full-time equivalents).

8.5.5 Cost references

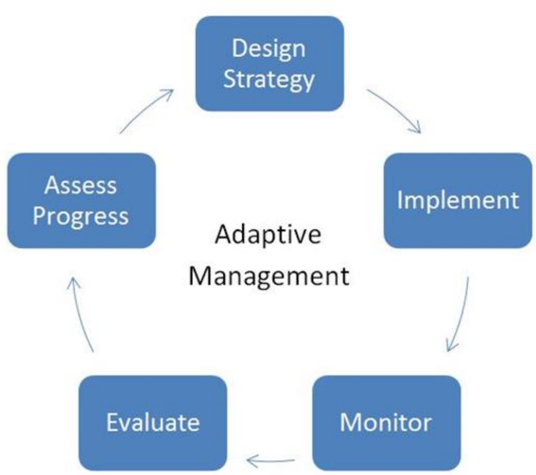
The costs to implement the activities outlined in the strategy relied on the following assumptions:

- Equipment costs for water-softener optimization and replacement (Overbo and Heger 2019)
- Hours for the various Smart Salting trainings (MPCA 2025)
- Inflation (U.S. Bureau of Labor Statistics 2025)
- Labor costs for state and municipal government workers (U.S. Bureau of Labor Statistics 2024)

8.6 Adaptive management

The implementation strategies in this TMDL report and the WRAPS report (MPCA 2020b) are based on the principle of adaptive management (Figure 55). Continued BMP and possible water quality monitoring and “course corrections” responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL report. Management activities will be changed or refined as appropriate over time to efficiently meet the TMDL and lay the groundwork for de-listing the impaired waterbodies.

Figure 55. Adaptive management.



9. Public participation

A Core Team was assembled and MPCA regularly held meetings with the Core Team to support development of the TMDL study. The Core Team was composed of representatives from the following organizations:

- DNR
- MnDOT
- Minnesota State College and University System
- UMD and NRRI
- Lake Superior College
- St. Louis County
- City of Duluth
- City of Hermantown
- City of Proctor
- City of Rice Lake
- South St. Louis SWCD

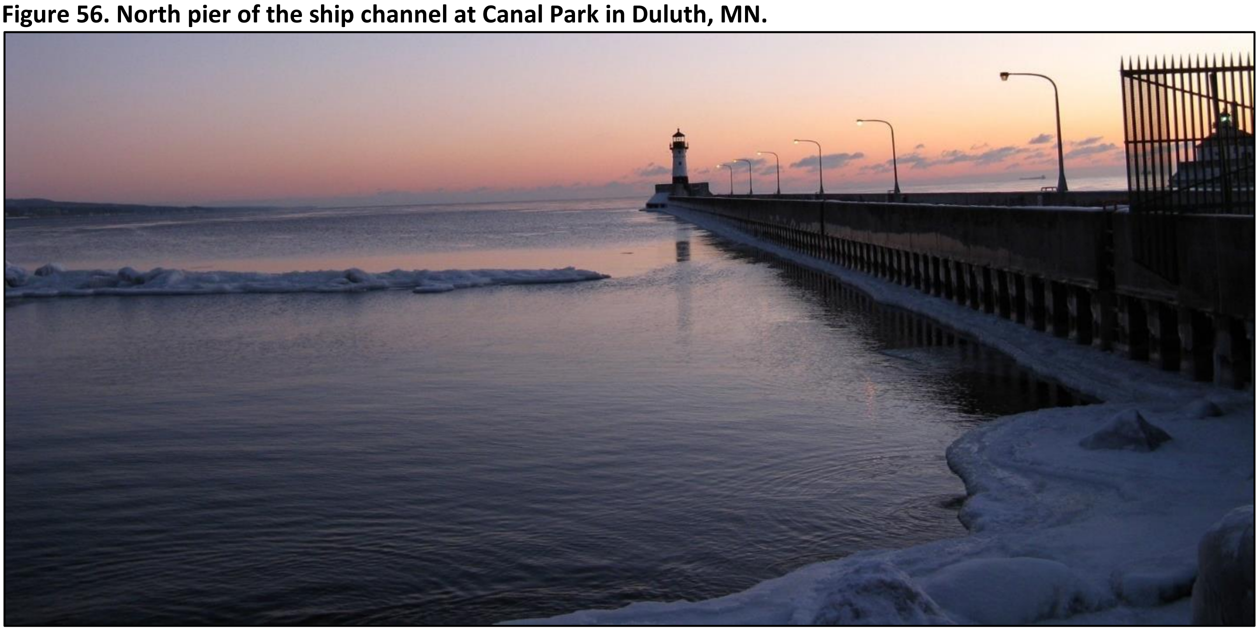
Meetings were held virtually, in-person, or hybrid on the following five dates:

- September 16, 2024
- December 4, 2024
- January 16, 2025
- March 13, 2025
- September 2, 2025

The Core Team also reviewed a preliminary draft TMDL report and provided comments and recommendations to MPCA to improve the report.

An opportunity for public comment on the draft TMDL report was provided via public notice in the State Register from February 17, 2026, through March 19, 2026. There were xx comment letters received and responded to as a result of the public comment period.

Figure 56. North pier of the ship channel at Canal Park in Duluth, MN.



Source: Tom Estabrooks (MPCA)

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Figure 57. Ice breakup on Lake Superior.

Source: Tom Estabrooks (MPCA)

Appendix A

This appendix lists all the impairments in the DUAW along with the TMDL status of each impairment (Table 37). Planned recategorizations are provided for listings that have been further assessed and for which recategorization will be considered. Recategorizations will not be final until they are approved by EPA as part of Minnesota's list of impaired waterbodies; therefore, this table represents a snapshot in time, and the EPA category or planned recategorization may change.

Table 37. Impaired waterbodies in the DUAW

Waterbody name	Waterbody description	WID	Use class [a]	Affected designated use [b]	Year added to list	Listing parameter	Stressors to bioassessment impairments: Confirmed	Stressors to bioassessment impairments: Inconclusive	EPA category in next impaired waters list [c]	TMDL developed in this report
Lake Superior South Watershed (HUC 04010102)										
Lester River	Headwaters to T52 R14W S14, south line	-548	2Bg	AQC	2014	Mercury (in fish tissue)	n/a	n/a	4A	No: TMDL completed in 2014
Lester River	T52 R14W S23, north line to Lk Superior	-549	1B, 2Ag	AQC	2014	Mercury (in fish tissue)	n/a	n/a	4A	No: TMDL completed in 2014
				AQC	1998	Mercury (in water column)	n/a	n/a	4A	No: TMDL completed in 2014
				AQL	1996	Turbidity	n/a	n/a	4A	No: TMDL completed in 2020
Amity Creek, East Branch	Unnamed cr to Amity Cr	-540	1B, 2Ag	AQL	2014	Turbidity	n/a	n/a	4A	No: TMDL completed in 2020
Amity Creek	Unnamed cr to Lester R	-511	1B, 2Ag	AQL	2004	Turbidity	n/a	n/a	4A	No: TMDL completed in 2020
Tischer Creek	Unnamed cr to Lake Superior	-544	1B, 2Ag	AQL	2026	Chloride	n/a	n/a	4A	Yes: Chloride
				AQR	2014	*E. coli*	n/a	n/a	4A	No: TMDL completed in 2020
Chester Creek	E Br Chester Cr to Lk Superior	-545	1B, 2Ag	AQL	2024	Chloride	n/a	n/a	4A	Yes: Chloride
				AQR	2014	*E. coli*	n/a	n/a	4A	No: TMDL completed in 2020
St. Louis River Watershed (HUC 04010201)										
Miller Creek	Headwaters to St Louis R	-512	1B, 2Ag	AQC	2002	Mercury (in fish tissue)	n/a	n/a	5	No: TMDL is under development.
				AQC	2024	PFOS (in fish tissue)	n/a	n/a	5	No: Deferred
				AQL	2012	Benthic macroinvertebrates	Elevated water temperature, chloride toxicity & SpCo	Altered hydrology	5	No: Temperature TMDL completed in 2018
				AQL	2010	Chloride	n/a	n/a	4A	Yes: Chloride
				AQR	2012	*E. coli*	n/a	n/a	4A	No: TMDL completed in 2020
Unnamed creek (Merritt Creek)	Unnamed cr to St Louis R	-987	1B, 2Ag	AQR	2012	*E. coli*	n/a	n/a	4A	No: TMDL completed in 2020
Kingsbury Creek	Mogie Lk to St Louis R	-626	1B, 2Ag	AQL	2012	Benthic macroinvertebrates	TSS	n/a	4A	No: TMDL completed in 2020
				AQL	2022	Chloride	n/a	n/a	4A	Yes: Chloride
				AQL	2012	Fish	TSS	n/a	4A	No: TMDL completed in 2020

Waterbody name	Waterbody description	WID	Use class [a]	Affected designated use [b]	Year added to list	Listing parameter	Stressors to bioassessment impairments		EPA category in next impaired waters list [c]	TMDL developed in this report
							Confirmed	Inconclusive		
Keene Creek	Headwaters to St Louis R	-627	1B, 2Ag	AQL	2022	Chloride	n/a	n/a	4A	Yes: Chloride
				AQR	2012	*E. coli*	n/a	n/a	4A	No: TMDL completed in 2020
Stewart Creek	T49 R15W S21, west line to St Louis R	-884	1B, 2Ag	AQR	2012	*E. coli*	n/a	n/a	4A	No: TMDL completed in 2020
Sargent Creek	Headwaters to St Louis R	-848	1B, 2Ag	AQC	2024	PFOS (in fish tissue)	n/a	n/a	5	No: Deferred
				AQR	2012	*E. coli*	n/a	n/a	4A	No: TMDL completed in 2020

Waterbodies are sorted from top to bottom as east to west.

DUAW: Duluth Urban Area Watershed; EPA: U.S. Environmental Protection Agency; HUC: hydrologic unit code; n/a: not applicable; PFOS: perfluorooctane sulfonic acid; SpCo: specific conductivity; TMDL: total maximum daily load; WID: waterbody identifier.

a. 1B: domestic consumption; 2Ag: aquatic life and recreation—general cold water habitat; 2Bg: aquatic life and recreation—general warm water habitat; 7: limited resource value water.

b. AQC: aquatic consumption; AQL: aquatic life; AQR: aquatic recreation.

c. 4A: Impaired and a TMDL study has been approved by USEPA. All TMDLs needed to result in attainment of applicable water quality standards for this impairment have been approved or established by EPA. For biological impairments, there are no remaining conclusive stressors for which TMDLs are needed.

4C: Impaired but a TMDL study is not required because the impairment is not caused by a pollutant.

4D: Impaired but a TMDL study is not required because the impairment is due to natural conditions with insignificant anthropogenic influence.

5: Impaired and a TMDL study has not been approved by EPA.

Appendix B

This appendix presents land use and land cover from the 2016 NLCD (Homer et al. 2020), pre-European settlement vegetation (DNR 2022), and road maps with permitted MS4s.

As much of the in-stream chloride data were collected in 2016 through 2018 (water quality data are discussed in Section 3.4), the 2016 NLCD may be more representative of land use and land cover during the monitoring period than the newer datasets presented in Section 3.3. No single land use or land cover comprises a majority of an impairment subwatershed (Table 38 on Page 111 and Figure 58 on Page 112). The largest individual land covers are deciduous forest (20% to 42%), woody wetlands (12% to 30%), and open developed (11% to 23%). The largest groupings are forest[41] (24% to 49%) and developed[42] (15% to 38%).

Pre-European settlement vegetation (DNR 2022) was plotted with the impairment subwatersheds (Figure 59 on Page 113).

Permitted MS4s were plotted with gravel (Figure 60 on Page 114) and paved (Figure 61 on Page 115) roads.

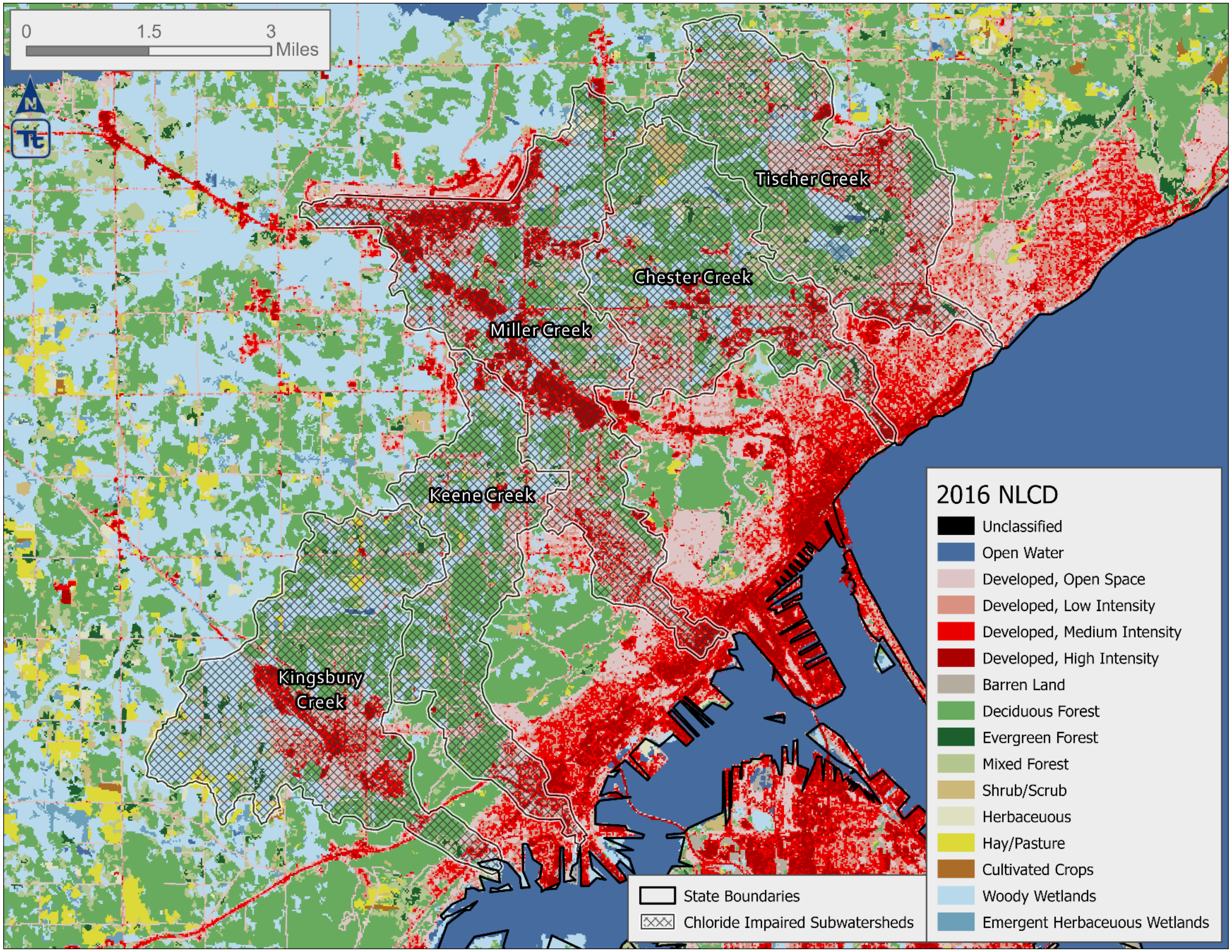
[41] The forest group is composed of deciduous forest, evergreen forest, and mixed forest.
[42] The developed group is composed of low-intensity, medium-intensity, and high-intensity developed.

Table 38. Land cover and land use by impairment subwatershed

Land cover	Kingsbury Creek		Keene Creek		Miller Creek		Chester Creek		Tischer Creek	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Open water	13	<1%	2	<1%	5	<1%	4	<1%	12	<1%
Developed, open space	634	11%	483	13%	1,100	17%	630	15%	1,054	23%
Developed, low-intensity	451	8%	318	9%	868	14%	489	11%	628	13%
Developed, medium-intensity	377	7%	215	6%	942	15%	346	8%	263	6%
Developed, high-intensity	105	2%	48	1%	619	10%	101	2%	58	1%
Barren	12	<1%	1	<1%	2	<1%	4	<1%	2	<1%
Deciduous forest	1,662	29%	1,559	42%	1253	20%	1,357	32%	1349	29%
Evergreen forest	89	2%	20	1%	21	<1%	46	1%	78	2%
Mixed forest	394	7%	230	6%	284	4%	327	8%	541	12%
Shrub/scrub	27	<1%	20	1%	61	1%	151	3%	40	1%
Grassland/herbaceous	40	1%	8	<1%	63	1%	30	1%	42	1%
Pasture/hay	108	2%	24	1%	3	<1%	15	<1%	2	<1%
Cultivated crops	2	<1%	1	<1%	--	--	--	--	--	--
Woody wetlands	1,702	30%	768	21%	1,112	17%	776	18%	538	12%
Emergency herbaceous wetlands	31	1%	11	<1%	47	1%	29	1%	46	1%

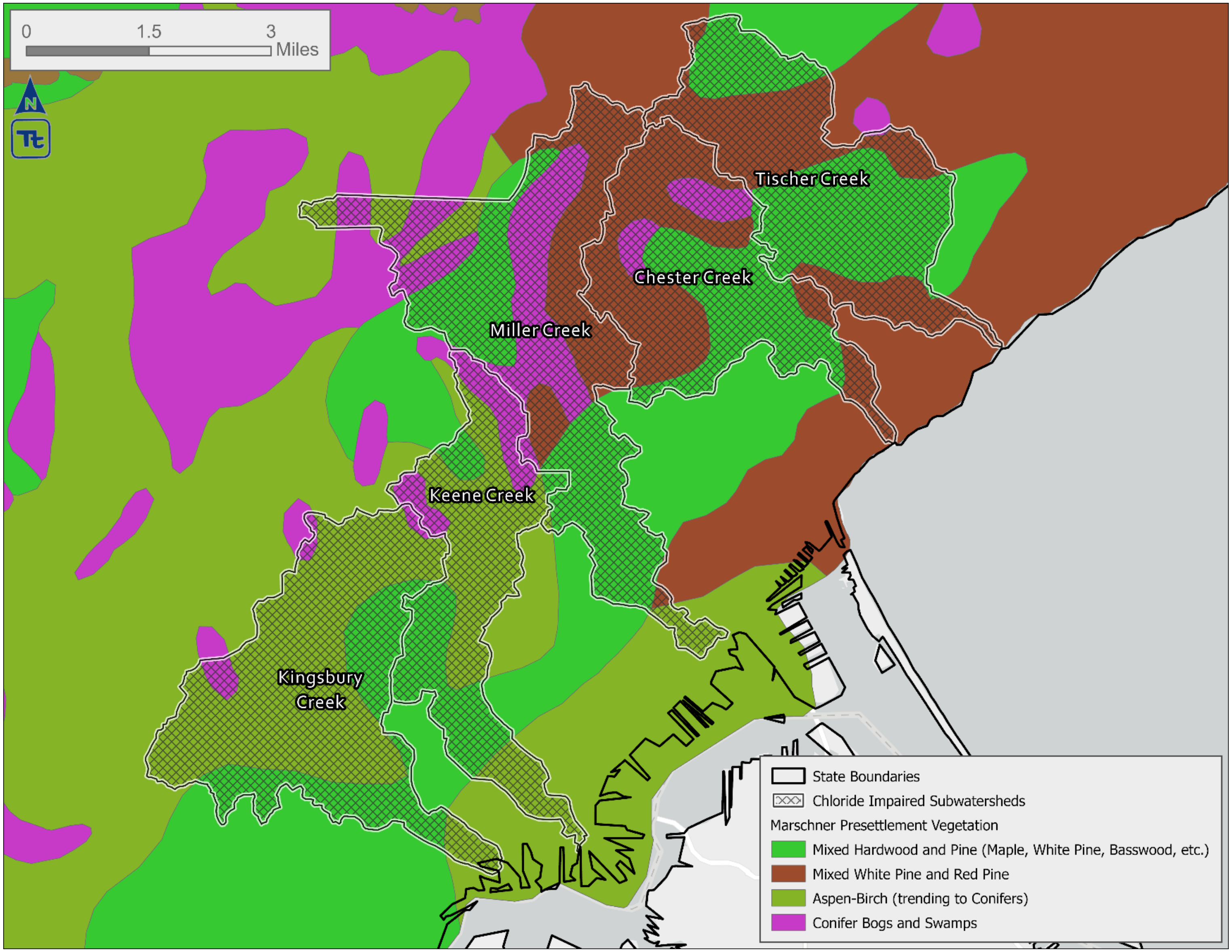
Source: 2016 National Land Cover Database (Homer et al. 2020)
Note: Areas are rounded to the nearest acre and nearest percentage point.

Figure 58. Land cover and land use



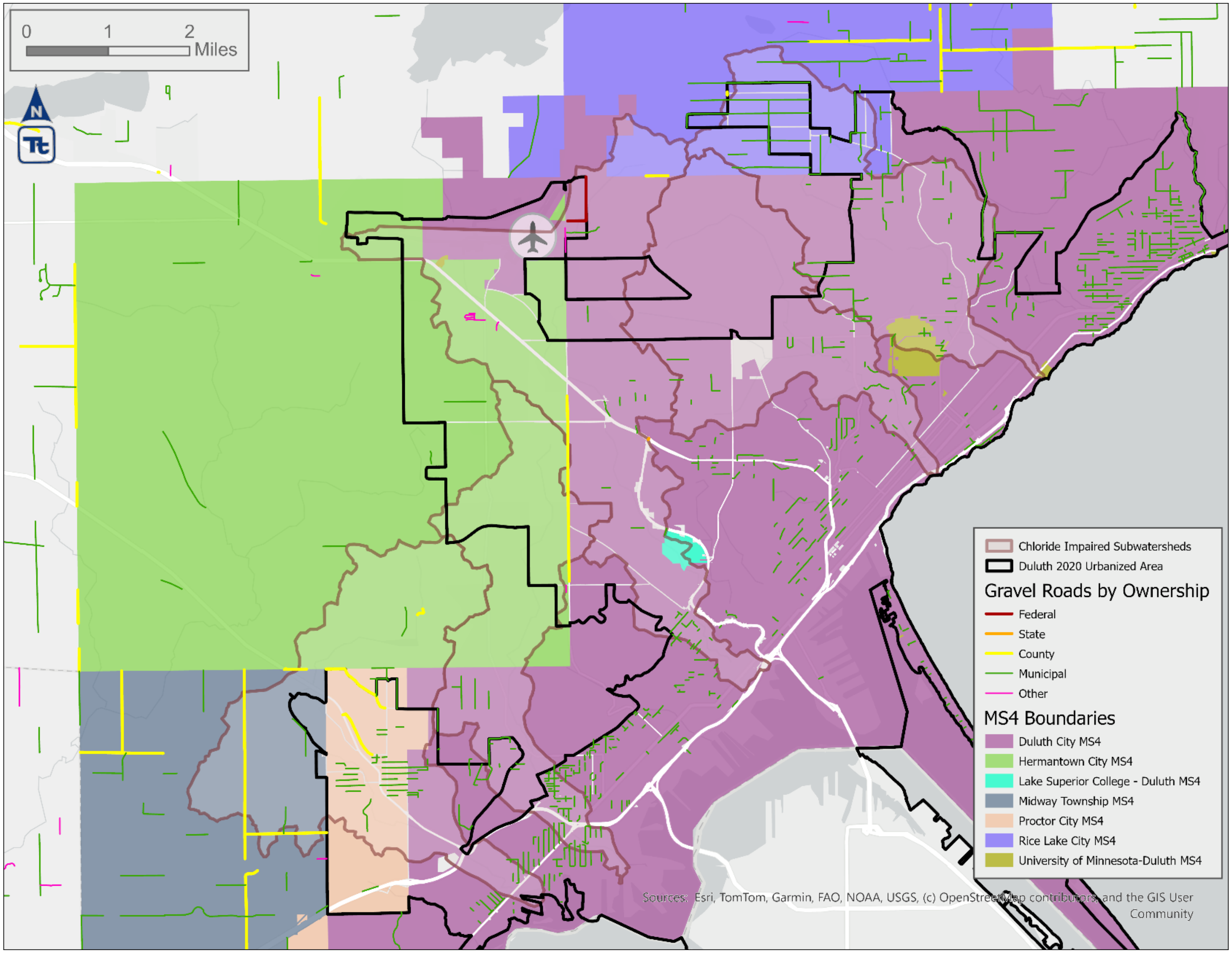
Source: 2016 National Land Cover Database (Homer et al. 2020)

Figure 59. Pre-European settlement vegetation and impairment subwatersheds



Source: *Native Vegetation at the Time of the Public Land Survey 1847-1907* (DNR 2022)

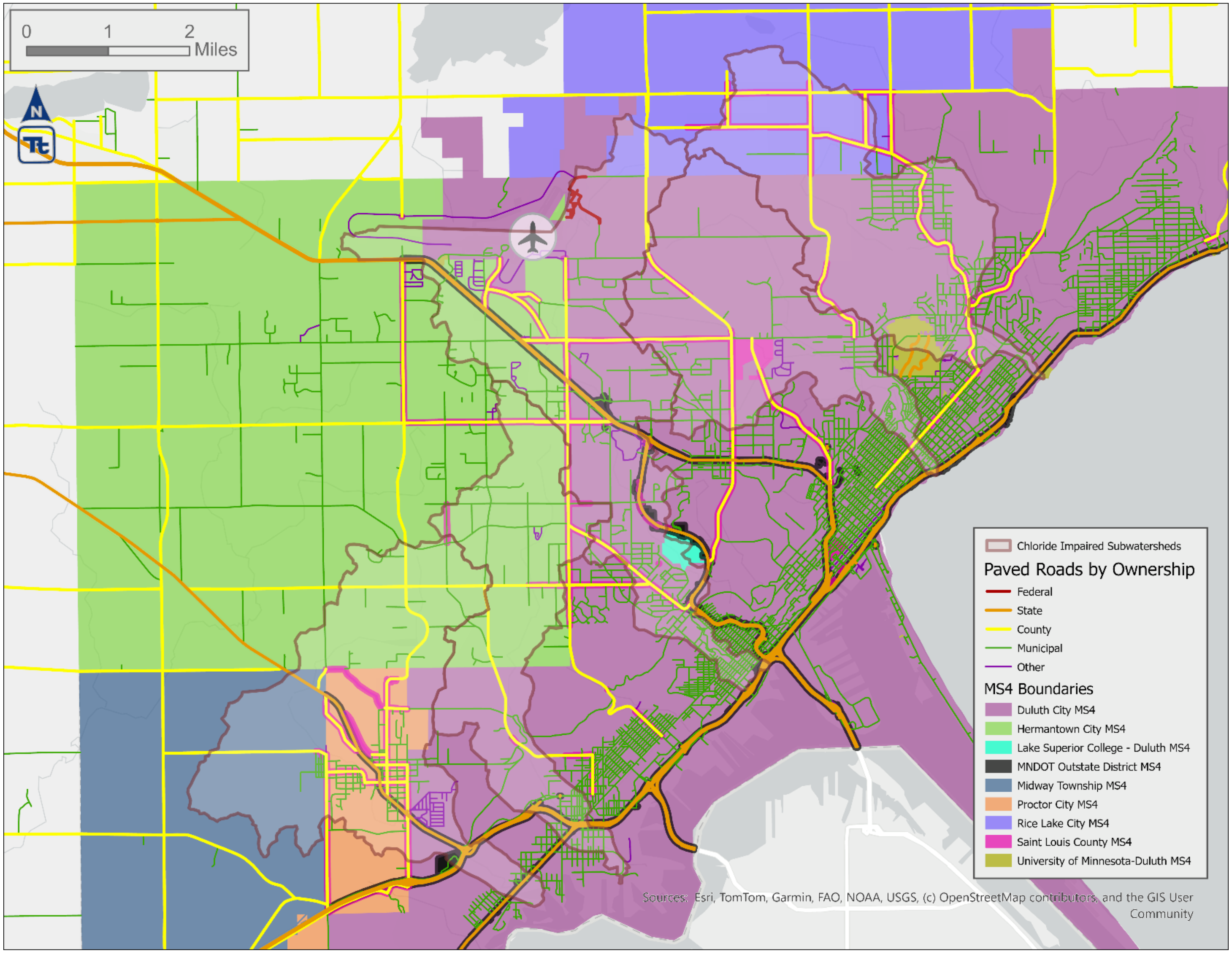
Figure 60. Gravel roads in the DUAW with chloride impairment subwatersheds, permitted MS4s, and the 2020 Census urbanized area.



Source: MnDOT 2025a,b

Note: Several roads shown in this map as gravel are actually paved roads.

Figure 61. Paved roads in the DUAW with chloride impairment subwatersheds and permitted MS4s.



Source: MnDOT 2025a,b

Appendix C

This appendix presents summaries of a questionnaire distributed to organizations involved with winter maintenance activities, summer dust suppression, and turf grass management. Summaries of winter maintenance activities and storage are presented in Table 39 and Table 40, respectively. Summaries of dust suppression are presented in Table 41.

Table 39. Summary of winter maintenance activities in the DUAW

Organization	Plan (Updated)	Operator training (Frequency)	Equipment calibration (Frequency)	Roads application	Sidewalks application
Duluth [a]	Yes (2024)	Yes (Annual)	Yes (Annual)	Road salt or brine are applied to city roads [b] and alleys using single axel dump trucks at rates of 100 to 900 lbs./LM. Washed sand for traction.	Salt is applied by hand to some city sidewalks and multi-use trails.
Hermantown	No	Yes (Annual)	Yes (Annual)	70% sand and 30% salt mix and brine are applied to city roads using plow trucks at a rate of 300 lbs./LM. Washed sand for traction.	*None*.
Midway Township	No	No	No	Road salt or brine are applied to township roads by St. Louis County.	*None*.
MnDOT	--	Yes (Annual & 5-year cycle)	Yes (Annual)	Road salt, brine, or potassium acetate are applied to state highways, U.S. routes, and interstate routes using single- or tandem axel plot trucks. Road salt rates of 6 to 19 tons/LM/year, and brine rates of 177 to 1,275 gallons/LM/year. Sand for traction.	*None*.
Proctor	No	No	No	Road salt or brine are applied to city roads and some county roads using a plow truck with sander. A 75% sand to 15% salt mix is applied.	Salt is applied by hand to sidewalks at public facilities.
Rice Lake	Yes (2024)	Yes (Annual)	No	Road salt is applied to city roads pre-storm. Sand for traction.	*None*. Chicken grit for traction.
St. Louis County	Yes	Yes (Variable)	Yes (Annual) [c]	Brine is applied (pre-wetting) to county and township roads using plow trucks at an average rate of 250 lbs./LM (range: 100-700 lbs./LM).	*None*.
UMD	Yes (2024)	Yes (Annual)	Yes	Road salt or liquid calcium chloride are applied to university roads using plow trucks at a rate of 250 lbs./LM. Sand for traction.	Road salt or bagged magnesium/calcium chloride blend are applied to university sidewalks using either a handheld spreader or spreader mounted to a Kubota at a rate of 3 lbs/1,000 sq. ft.

lbs: pounds; LM: lane mile; MnDOT: Minnesota Department of Transportation; sq. ft.: square feet; UMD: University of Minnesota – Duluth.

a. Historically, the city of Duluth plowed 573-miles of roads and applied 698 lbs. per mile per storm (Anderson et al. 2000). At the time, MPCA found this deicer application rate to be twice that of the national average and probably due to Duluth's topography (Anderson et al. 2000).

b. The city of Duluth has maintenance agreements with MnDOT and St. Louis County that maintain several roads within city limits.
c. St. Louis County also calibrates equipment when key parts are replaced.

Table 40. Summary of winter maintenance storage in the DUAW

Organization	De-icing/anti-icing agent storage	Snow storage
Duluth	Four covered locations	City properties (4 sites)
Hermantown	St. Louis County Public Works Facility	*None*
Midway Township	St. Louis County facility	*None*
MnDOT	--	Multiple locations under U.S. Route 53 and I-35 bridges
Proctor	Kirkus Street salt dome and St. Louis County facility	Proctor Fairgrounds
Rice Lake	St. Louis County Tool House	City property on Schultz Road
St. Louis County	--	County properties (2 sites) in the Chester and Miller creeks subwatersheds
UMD	Indoor storage facility	On campus (3 sites)

DUAW: Duluth Urban Area Watershed; MnDOT: Minnesota Department of Transportation; UMD: University of Minnesota – Duluth.

Table 41. Summary of dust suppression activities in the DUAW

Organization	Unpaved areas plan	Dust suppression plan (Updated)	Gravel roads application	Dust suppressant storage
Duluth	*No dust suppression at the city.*			
Hermantown	Yes	No	A private contractor applies liquid calcium chloride using a tanker truck once annually to municipal gravel roads.	The private contractor stores dust suppressant in the city of Superior, WI.
Midway Township	Yes	Yes (2024)	A private contractor applies a chloride solution (10,400 gallons) once annually in the spring after gravel roads are graded (9.59 miles).	--
MnDOT	*No gravel roads in the impairment subwatersheds, and no dust suppression in the DUAW.*			
Proctor	Yes	Yes	A private contractor applies liquid 38% calcium chloride solution (4,400 gallons) using a tanker truck with spray bars annually in July to two miles of gravel roads.	The private contractor stores dust suppressant at the Hallet Dock.
Rice Lake	Yes	Yes (2024)	A private contractor applies calcium chloride using a tanker truck annually in the spring to municipal gravel roads.	Storage tank on Garfield Avenue in Duluth, MN.
St. Louis County			A private contractor applies liquid 38% calcium chloride solution using a tanker truck with spray bars. Application timing and extent varies by the daily traffic on each unpaved road.	
UMD	*No dust suppression at the university.*			

DUAW: Duluth Urban Area Watershed; MnDOT: Minnesota Department of Transportation; UMD: University of Minnesota – Duluth.

Appendix D

This appendix presents the technical contents of a memorandum prepared by Tetra Tech and submitted to MPCA on June 27, 2025, that describes the inputs and outputs for the winter maintenance activities component of the *Smart Salting Tool*. The MPCA distributed a previous iteration of the memorandum (dated May 21, 2025) to the Core Team for review on June 3, 2025. The City of Duluth transmitted comments to MPCA on June 4, 2025, and Tetra Tech addressed those comments in the final memorandum dated June 27, 2025.

Tetra Tech will use the results from the *Smart Salting Tool* in the source assessment section of the TMDL report. The TMDLs (i.e., loading capacity) and associated allocations (e.g., the WLAs for regulated MS4s) for the five impaired streams will not be based on the results of the Smart Salting Tool. The TMDLs will be based on precipitation, runoff, and Minnesota's chloride water quality standard, and the WLAs will be based on the area of each regulated MS4 relative to the area of the impaired subwatersheds.

Background

The *Smart Salting Tool* calculates chloride load for winter maintenance activities using the chloride-based deicer/anti-icer application rate (tons per lane-mile per year) and the length of roadway (lane-miles) for four types of roads: county, municipal, state, and other. The chloride load (tons per year) is calculated by multiplying the application rate by the length. This salt load represents the salt applied to a roadway (i.e., the generated load) and does not consider fate-and-transport to area waterways (i.e., the delivered load).

User-Inputs

Users can run the *Smart Salting Tool* with local information, in lieu of the tool's defaults. Users can input the application rates and roadway lengths for each of the four types of roads.

To support the DUAW chloride TMDL project, Tetra Tech ran the *Smart Salting Tool* with the three sets of application rates: tool defaults and lower and higher application rates based on local information provided by regulated MS4s.

Limitations and Uncertainties

The *Smart Salting Tool* is run on an annual time-scale, and for winter road maintenance activities, this is essentially a winter season. As such, any user-inputs must be at the annual time-scale (i.e., the winter time-scale). If local data or information are at a nonannual time-scale, the user must convert the nonannual data or information into an annual input.

The *Smart Salting Tool* is a simple tool to estimate annual chloride loads. The tool cannot account for spatial- or temporal-variability. As such, all roadways in a road type (i.e., county, municipal, state, other) are assumed to be uniform within that road type. Additionally, all chloride-based deicer/anti-icer applications for a road type are assumed to be uniform across the winter season.

Local Information

To support the DUAW chloride TMDL project, several permitted MS4s provided deicer/anti-icer application rates by event (Table 42). Tetra Tech used this information to estimate local application rates for the four types of roads in the *Smart Salting Tool* (i.e., county, municipal, state, other).

Table 42. Summary of local information for winter maintenance salt application rates

Regulated MS4	Salt Application Rate(s) (lbs per lane-mile per event)
Duluth, city of (MS400086)	full range: 100 to 900 typical low and high rates: 250 and 650
Hermantown, city of (MS400093)	300
Lake Superior College (MS400225)	(no response to questions)
Midway Township (MS400146)	(St. Louis County applies salt to township roads)
MnDOT – Outstate District (MS400180)	five-year range: 322 to 913 [a]
Proctor, city of (MS400114)	(provided the annual tonnage of salt applied)
Rice Lake, city of (MS400151)	(city reports application rate is not known)
St. Louis County (MS400158)	full range: 100 to 700 average: 250
University of Minnesota – Duluth (MS400214)	250

a. MnDOT provided annual-rates of salt (tons/lane-mile/year) and brine (gallons/lane-mile/year) that are converted to event-rates by assuming 45 events per year. Brine (gallons) is converted to salt (tons) assuming a density of 10.26 pounds per gallon and that the brine solution is 23.7% salt by volume.

Smart Salting Tool Inputs

Using the information provided by regulated entities (see the previous section), Tetra Tech developed two sets of user-inputs for the deicer/anti-icer application rates in the *Smart Salting Tool*. The *Smart Salting Tool* uses application rates that are in tons per lane-mile per year; however, road authorities often operate using application rates of lbs./lane-mile per event. To convert between annual rates and event rates, Tetra Tech assumed that 30 events occur per year (i.e., essentially per winter) in the lower rate scenario and that 45 events occur per year in the higher rate scenario. The 30 events per year is based on a conversation with the City of Duluth Public Works and Utilities Department, and the 45 events per year is based on conversations with St. Louis County Public Works Department.

Table 43 presents the default and two scenarios of application rates at the annual-scale. These annual application rates are used in the *Smart Salting Tool*. Table 44 (Page 122) presents the application rates at the event-scale.

Table 43. Application rates at the annual-scale

Road type	Default	Lower rate scenario	Higher rate scenario
County	7.787	2.250 [a]	13.500 [c]
Municipal	3.894	3.750 [a]	14.625 [c]
State	7.787	10.215 [b]	18.371 [b]
Other	1.947	3.750 [a]	5.625 [c]

Application rates are in tons per lane-mile per year.

a. Application rates are calculated using event rates and assuming 30 events per year. These rates are rounded to the one-thousandth ton per lane-mile per year.

a. MnDOT provided annual-rates of salt (tons/lane-mile/year) and brine (gallons/lane-mile/year); the 25th and 75th percentile are presented as the lower and higher rates (respectively). Brine (gallons) is converted to salt (tons) assuming a density of 10.26 pounds per gallon and that the brine solution is 23.7% salt by volume.

c. Application rates are calculated using event rates and assuming 45 events per year. These rates are rounded to the one-thousandth ton per lane-mile per year.

Table 44. Application rates at the event-scale

Road type	Default	Lower rate scenario	Higher rate scenario
County	346 to 519 [a]	150	600
Municipal	173 to 260 [a]	250	650
State	346 to 519 [a]	450 [b]	1,200 [b]
Other	86.5 to 130 [a]	250	250

Application rates are in pounds per lane-mile per event.

a. The first event-scale application rate is calculated assuming 45 events per year, and the second event-scale application rate is calculated assuming 30 events per year. These rates are estimated to three significant digits.

b. MnDOT provided annual-rates of salt (tons/lane-mile/year) and brine (gallons/lane-mile/year) that are converted to event-rates by assuming 30 events per year or 45 events per year. Brine (gallons) is converted to salt (tons) assuming a density of 10.26 pounds per gallon and that the brine solution is 23.7% salt by volume. The lower rate scenario is the 25th percentile assuming 45 events per year and the high rate scenario is the 75th percentile assuming 30 events per year.

Smart Salting Tool Outputs

The length of roads, chloride loading, and relative loading are presented by road type for Kingsbury (Table 45), Keene (Table 46), Miller (Table 47), Chester (Table 48), and Tischer (Table 49) creeks.

Municipal roads contribute the highest loads in both the lower (40% to 84%) and higher (51% to 83%) rate scenarios and in the results from tool default settings (36% to 71%), which is expected since municipal roads are the largest lane-mileage in each subwatershed. MnDOT is the second highest source of loads (24% to 46%) in the Kingsbury, Keene, and Miller creeks subwatersheds, due to higher application rates and longer lengths of roads in these subwatersheds. MnDOT has far fewer roads in the Chester and Tischer creeks subwatersheds, and thus, lower relative loads (1% to 3%).

Table 45. Winter road maintenance chloride loads for Kingsbury Creek

Road type	Length (lane-mile)	Default		Lower rate scenario		Higher rate scenario	
		(tons/year)	(%)	(tons/year)	(%)	(tons/year)	(%)
County	21.7	169	34%	48.8	11%	293	22%
Municipal	45.75	178	36%	172	40%	669	51%
State	16.93	132	27%	173	41%	311	24%
Other	8.48	16.5	3%	31.8	7%	47.7	4%
Total	**92.86**	**496**	**100%**	**426**	**100%**	**1,321**	**100%**

Chloride loads are in tons per year and are reported to three significant digits or the nearest pound if the load exceeds 1,000 pounds.

Relative loads (across road types) are rounded to the nearest percentage point and may not sum to 100% due to rounding.

Table 46. Winter road maintenance chloride loads for Keene Creek

Road type	Length (lane-mile)	Default		Lower rate scenario		Higher rate scenario	
		(tons/year)	(%)	(tons/year)	(%)	(tons/year)	(%)
County	3.34	26.0	16%	7.52	5%	45.2	10%
Municipal	19.97	77.8	49%	74.9	48%	292	62%
State	6.97	54.2	34%	71.2	46%	128	27%
Other	0.53	1.04	<1%	1.99	1%	2.99	<1%
Total	**30.81**	**159**	**100%**	**156**	**100%**	**468**	**100%**

The Smart Salting Tool provides results for Level 08 catchment 0318900. The Keen Creek subwatershed is 14% of the land area of catchment 0318900. The results presented in this table are 14% of the results for catchment 0318900.

Chloride loads are in tons per year and are reported to three significant digits or the nearest pound if the load exceeds 1,000 pounds.

Relative loads (across road types) are rounded to the nearest percentage point and may not sum to 100% due to rounding.

Table 47. Winter road maintenance chloride loads for Miller Creek

Road type	Length (lane-mile)	Default		Lower rate scenario		Higher rate scenario	
		(tons/year)	(%)	(tons/year)	(%)	(tons/year)	(%)
County	25.64	200	26%	57.7	8%	346	16%
Municipal	93.89	365	48%	352	52%	1,373	63%
State	20.19	157	20%	206	30%	371	17%
Other	17.52	34.2	5%	65.7	10%	98.6	5%
Total	**157.24**	**756**	**100%**	**682**	**100%**	**2,189**	**100%**

Chloride loads are in tons per year and are reported to three significant digits or the nearest pound if the load exceeds 1,000 pounds.

Relative loads (across road types) are rounded to the nearest percentage point and may not sum to 100% due to rounding.

Table 48. Winter road maintenance chloride loads for Chester Creek

Road type	Length (lane-mile)	Default		Lower rate scenario		Higher rate scenario	
		(tons/year)	(%)	(tons/year)	(%)	(tons/year)	(%)
County	10.40	81.1	26%	23.4	9%	140	14%
Municipal	57.48	224	71%	216	84%	841	83%
State	0.68	5.30	2%	6.95	3%	12.5	1%
Other	3.27	6.38	2%	12.3	5%	18.4	2%
Total	**71.83**	**317**	**100%**	**258**	**100%**	**1,012**	**100%**

Chloride loads are in tons per year and are reported to three significant digits or the nearest pound if the load exceeds 1,000 pounds.

Relative loads (across road types) are rounded to the nearest percentage point and may not sum to 100% due to rounding.

Table 49. Winter road maintenance chloride loads for Tischer Creek

Road type	Length (lane-mile)	Default (tons/year)	Default (%)	Lower rate scenario (tons/year)	Lower rate scenario (%)	Higher rate scenario (tons/year)	Higher rate scenario (%)
County	20.66	161	40%	46.5	17%	279	24%
Municipal	60.20	234	59%	226	82%	880	75%
State	0.38	2.96	1%	3.88	1%	6.98	1%
Other	0.17	0.332	<1%	0.638	<1%	0.956	<1%
Total	**81.41**	**398**	**100%**	**277**	**100%**	**1,167**	**100%**

Chloride loads are in tons per year and are reported to three significant digits or the nearest pound if the load exceeds 1,000 pounds.

Relative loads (across road types) are rounded to the nearest percentage point and may not sum to 100% due to rounding.