# Smart Salting for Roads Manual


2023

MINNESOTA POLLUTION CONTROL AGENCY

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# Acknowledgements

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## Funding:

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Thank you to the following individuals for contributing their expertise to the production of this document.

## Project advisory committee:

Brooke Asleson – Minnesota Pollution Control Agency

Chandi McCracken-Holm – Minnesota Pollution Control Agency

Andy Kraemer – Hennepin County Highway Department

Ben Hershey – DTN

Bill Kern – Jefferson County, WI

Bob Ewert – Hennepin County Highway Department

Chuck Jacobus – City of Rosemount

Craig Eldred – City of Waconia

Dan Horvat – City of Altura

Dan Plizga – City of Rochester

Joe Keding – City of Shoreview

Joe Wiita – Scott County

John Wickenhauser – Carver County

Jory Danielson – Crow Wing County

Josh Dix – Cook County Highway Department

Justin Kurtz – City of Avon

Kevin Koetz – City of Grand Rapids

Kimberly Engle – Cryotech

Kory Johnson – Itasca County

Matt Morreim – City of Shorewood, City of St. Paul

Matt Zinniel – Stearns County

Michael Piacenti – Brown County, WI

Michael Wegner – City of Edina

Scott Koefod – Cargill

Scott Riley – City of Eden Prairie

Shannon McIntyre – Minnesota Department of Transportation

Tim Hanlin – Envirotech

Tom Zabinski – City of St. Cloud

## Training manual development:

Connie Fortin – Bolton & Menk, Inc.

Caralie Randolph – Bolton & Menk, Inc.

## Other contributors:

Steve Bytnar – Envirotech

Andy Kietzmann – Force America

Doug Klimbal – Bolton & Menk, Inc.

## Photos and graphics:

Photos and graphics are MPCA unless otherwise noted.

# 1. Introduction

All Minnesota Pollution Control Agency (MPCA) Smart Salting certification trainings advocate for smart salting best practices that reduce chloride pollution while providing public safety, based on the best science to inform decisions.

This manual is designed to supplement the MPCA "Smart Salting for Roads" level 1 certification training. The target audience is anyone involved in winter operations of roads (city streets, county roads, township roads, and state highways). Participants learn how to integrate science and innovation into their operations to deliver the level or service their customers expect with lower chloride strategies.

The manual may work as a stand-alone resource. However, users will miss the discussion, resources, and additional information brought to the training from the hosts, instructors, and attendees.

## Goal of Smart Salting program

In response to increasing levels of chloride pollution in Minnesota's waters, the MPCA created and continues to sponsor the Smart Salting Training & Certification Program. Smart Salting for Roads is just one of the Smart Salting certification trainings.

**Smart Salting certification courses:**

- Smart Salting for roads: Intended for city, county, township, and state winter maintenance professionals who maintain high and/or low speed roads. Learn how to reduce salt use, save money, and protect Minnesota 's lakes and streams.
- Smart Salting for property managers: Intended for property managers, environmental professionals, business owners, those who hire private winter maintenance professionals, MS4 and wastewater permit staff, and public works directors or other high-level management roles. Learn how to save money and protect water resources using less salt and still maintain safe paved surfaces.
- Smart Salting for parking lots and sidewalks: Intended for those who maintain private or public walkways, parking lots and service roads. Learn how to significantly reduce salt use, save money, and protect Minnesota's lakes and streams while maintaining safety.
- Smart Salting Level 2: Certification for all winter maintenance organizations that apply salt to help assess salt use and improve your understanding of average and below average winter maintenance practices. Intended for winter maintenance leadership, public works managers & supervisors, MS4 permittees, business owners, and other lead staff. Obtain certification by completing assessments using the Smart Salting tool and submitting results to the MPCA.

**Smart Salting Refresher Courses:**

Refresher courses are for those who are already Smart Salting certified. Trainings fulfill the MS4 Permit requirement for annual staff chloride training. They do not replace the certification trainings or renew certification.

- **Smart Salting 101:** Overview of the Smart Salting certification courses with a focus on municipal separate storm sewer system (MS4) requirement. Appropriate for roads/parking lots & sidewalk winter maintenance.
- **Smart Salting: Weather for winter maintenance:** Content focuses on weather prediction tools, in-time pavement conditions that provide winter maintenance crews a basis to develop strategies for product use frequency, and application rates, while also offering local success stories, environmental information, and resources.
- **Smart Salting: Liquid deicers:** Provides a closer look at liquids application, conditions, equipment maintenance, brine making and storage that provide winter maintenance crew a basis to understand benefits, troubleshoot issues and find opportunities for expansion of liquids.
- **Smart Salting: Salt & snow storage:** Content focuses on best practices of granular and liquid salt storage as well as snow storage, with an emphasis on MS4 permit requirements.

**Other Smart Salting opportunities:**

- Smart Salting for Community leaders workshop Intended for local and state elected officials, members of sustainability and environmental commissions, board members of housing associations, neighborhood associations, or watershed districts, and other local decision makers. Introduces attendees to the environmental, infrastructure, and monetary impacts of chloride in Minnesota and provides Smart Salting strategies and policies for chloride reduction. The workshop teaches how decision makers can play a role in supporting this reduction and provides tools, resources, and funding opportunities.

**Turfgrass Maintenance training:**

- Consider attending the MPCA Turfgrass Maintenance certification training. This course integrates science into cultural practice, irrigation, fertilizer, and pesticide use to protect water and meet level of service expectations.

# How to find a training class

For upcoming Smart Salting trainings near you, visit the MPCA Smart Salting training calendar. If current training dates or locations do not work for you, or if you need the efficiency of a more convenient training for your organization, you may host a private training.

For more about trainings and certifications contact: smartsalting.pca@state.mn.us.

The rest of this manual is dedicated to the MPCA Smart Salting for Roads certification training.

# Using the manual

This manual should accompany the MPCA Smart Salting for Roads Certification Training. It is a high-level reference for understanding the environmental impact of road salt and the science of winter maintenance.

## MS4 Permit

The MS4 General permit is designed to reduce the amount of pollutants entering state waters from stormwater systems. Public entities, including cities, towns, and villages, that are owned or operate in an MS4 area must develop a stormwater pollution prevention program and adopt best practices. MS4 permit requirements are detailed in Appendix A. Visit the interactive map to see if you work in an MS4 community.

## Symbols

Throughout the manual the following symbols will be shown to indicate tips and strategies for your operations:

**Represents environmental tips**

**Represents cost-saving tips**

**Represents new ideas**

**Represents time-savings tips**

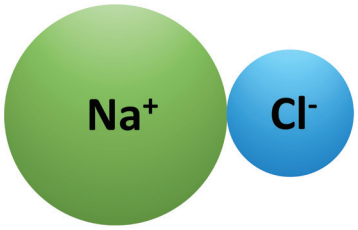

**Represents sections relevant to the MS4 general permit**

# Disclaimer

The MPCA provides instruction and guidance about the most current best management practices and technologies intended to provide safe surfaces while minimizing negative impacts on the environment and infrastructure. Clear policies that include maintenance considerations such as service level, reasonable professional care, and appropriate use and documentation of best practices may help to reduce potential liability risk. The class instruction or other MPCA resources provided in the Smart Salting trainings is not a substitute for professional legal advice. Always consult a legal professional before implementing a comprehensive liability risk reduction plan.

# 2. Impacts of chloride

**Figure 1:** Depiction of a sodium chloride (NaCl) compound (rock salt)




Minnesota has a growing salty water problem. Chloride is a permanent pollutant. It does not breakdown or degrade over time and will persist in our waters. Chloride is a pollutant of concern because it is toxic to freshwater fish, amphibians, insects, and plants. Once used, it seeps into lakes, streams, and groundwater. It is far too expensive and difficult to remove with current technologies (such as reverse osmosis). Salt is used widely and is an important public safety tool in winter conditions. The Smart Salting program is not about decreasing public safety, but instead is advocating for best salt use practices, based on the science to inform decisions.

## Salt and chloride

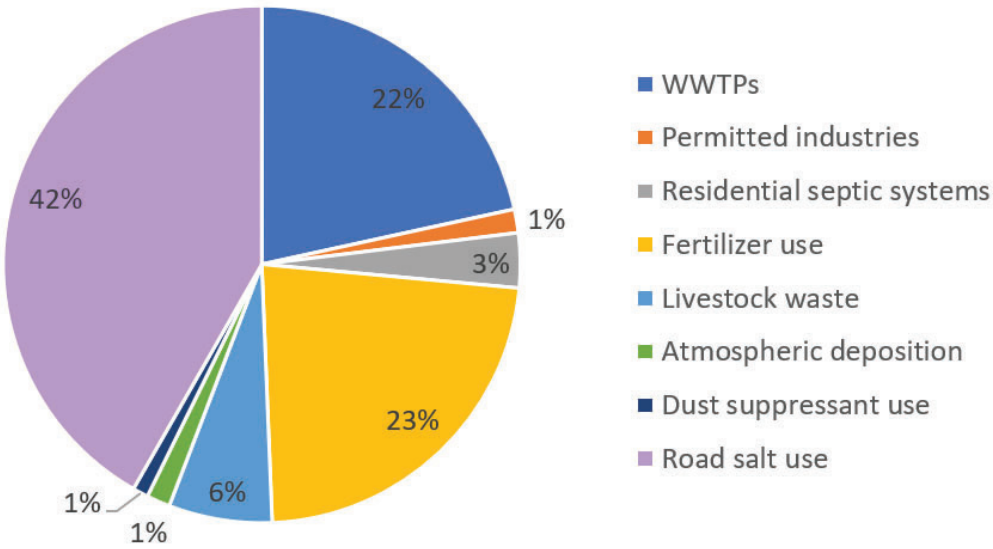
In this manual when referring to salt, we are talking about chemical compounds that contain a chloride ion (Figure 1). These compounds include sodium chloride (NaCl or rock salt), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$) and potassium chloride (KCl or potash).

"Salt" and "chloride" are often used interchangeably when referring to this type of pollution.

## Sources of chloride

Chloride pollution comes from several sources (Figure 2). In more populated areas, the largest sources are fertilizer, deicers, and water softening salt. Other chloride pollution getting into lakes, streams, and groundwater include industrial discharge, livestock waste, and dust suppressants.

**Figure 2:** Annual chloride contributions from major sources in the State of Minnesota




Annual chloride contributions from major point and nonpoint sources for the State of Minnesota (Overbo et al., 2019)

## Deicing salt

An estimated 403,600 tons of road salt is applied in Minnesota and 249,100 tons just in the Twin Cities metro area each year (Overbo et al., 2019). A study by the University of Minnesota found that about 78% of salt applied in the Twin Cities for winter maintenance is either transported to groundwater or remains in the local lakes and wetlands (Stefan et al., 2008).

**All the salt used to melt snow and ice flows into ditches, storm drains, lakes, streams, wetlands, and groundwater.**

## Water softener salt

People soften their water for a variety of reasons. In most communities, salty brine from water softeners drains to municipal wastewater treatment plants that do not have the technology to remove salt from that wastewater. The salt passes directly through the plant to a local water body. Septic systems do not remove salt; it likely ends up traveling toward private wells or through the soil to nearby water bodies. Refer to Appendix B for resources on reducing water softening salt.

## Fertilizer application

Potassium chloride, sometimes referred to as potash, is a common fertilizer ingredient. Agricultural fertilizer is a large chloride pollution source in Minnesota (Overbo et al., 2019). The chloride from potash applied on turfgrass and ornamental plants will also move to surface and groundwater. Chloride concentrations in animal manure also contribute to chloride loading.

## Dust suppressant/gravel road stabilization

Chloride products are commonly used to control dust on gravel roads. Application rates are often high and pose a threat to nearby surface and groundwater.

# Chloride trends in Minnesota

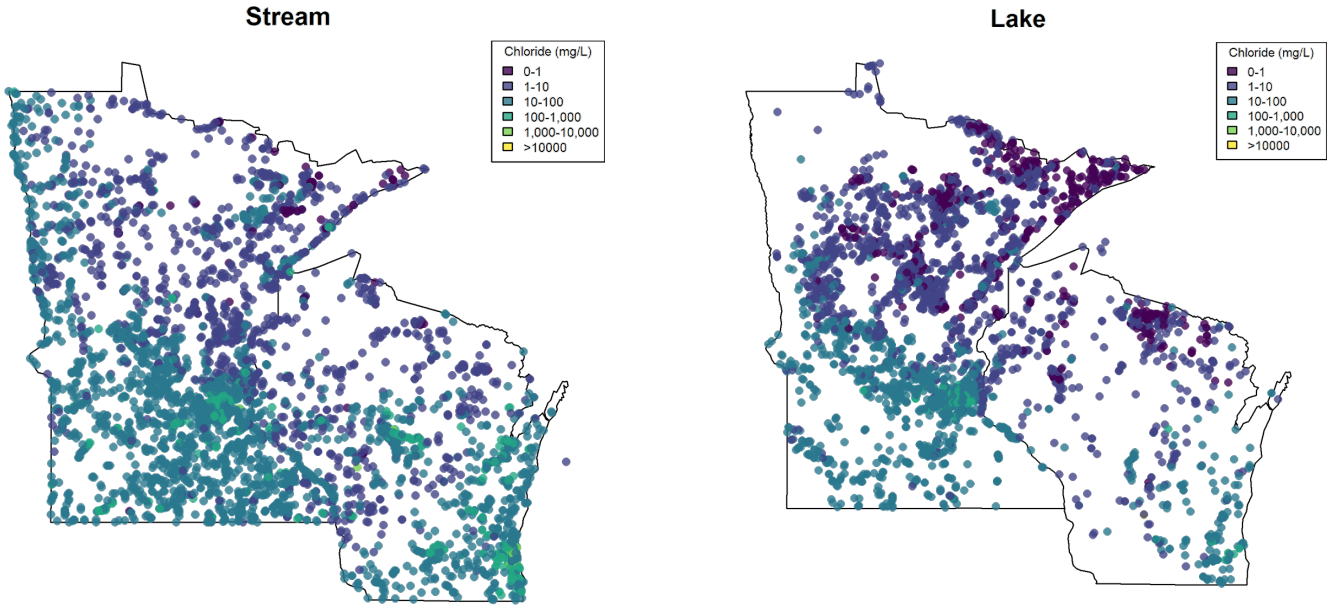
**Figure 3:** Water and teaspoon salt

Deicing salt is creating water quality problems especially in developed areas with many salted surfaces. There are currently nearly 100 communities in Minnesota that have high chloride in their wastewater discharge.

There are 54 impaired water bodies in Minnesota that exceed the chloride standard designed to protect fish and other aquatic life (MPCA, 2022). Minnesota follows federal water quality standards of 230 mg/L (chronic) and 860 mg/L (acute), to protect fish and other aquatic life from chloride pollution (EPA, 2022). There are also another 75 water bodies at high-risk for exceeding water quality chloride levels (within 10% of the standard). Minnesota has many lakes and streams that are testing for chloride (Figure 4). However, most of our surface and groundwater has not been tested or chloride has a very short record of monitoring results.

**It only takes one teaspoon of salt to permanently pollute five gallons of water.**

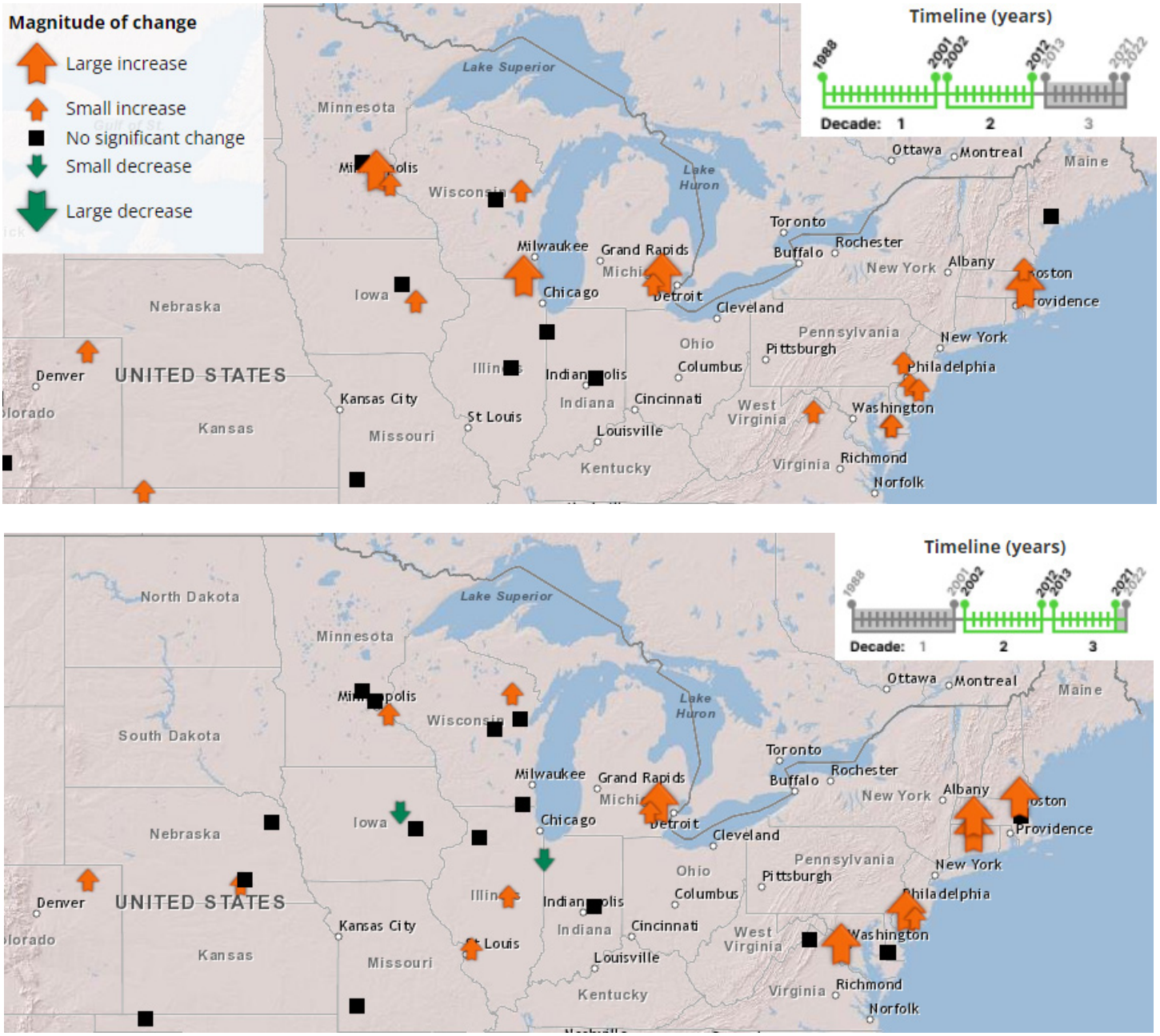
**Figure 4:** Chloride levels in streams (left) and lakes (right) in Minnesota and Wisconsin.




The lighter the dots, the saltier the water. www.waterqualitydata.us (Dugan, 2018)

According to USGS, between 1990 to 2010, the concentration of chloride in our ground water was on a steep incline. A report looking at trends between 2010 to 2020 showcased that Minnesota groundwater continued to increase in chloride concentration but at a slower rate (USGS, n.d.a). A recent report conducted by the Metropolitan Council assessed chloride concentration in regional streams and found that trends were flattening out, and not increasing as intensely as they once were. However, in water bodies with high groundwater input, the chloride contamination trend was steeper than those with less groundwater influence (Metropolitan Council, 2022). One possible explanation for this is that the salt accumulation over the years is working its way through soils and entering groundwater.

**Figure 5:** Decadal Change in Groundwater Quality, USGS, n.d.a.

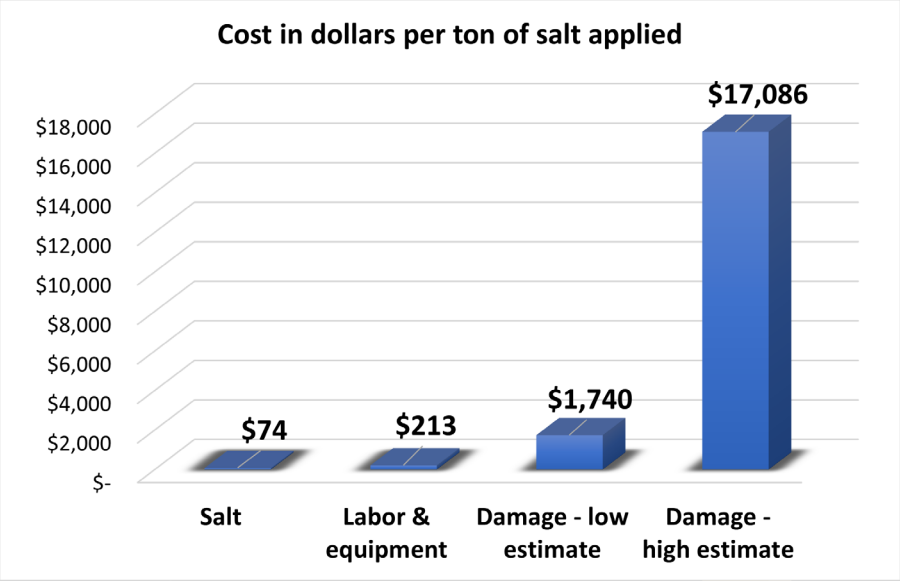


# Side effects of salt

## Cost

Salt costs much more than the initial purchase and application. Salt damages interior and exterior building infrastructure, walkways, vegetation, vehicles, and more. The total cost of damages from one ton of salt are estimated to be between 1,700 and 17,000 dollars (Figure 6).

**Figure 6:** Estimates of costs in dollars per tons for damage caused by road salt (Fortin, 2014)




Low estimate: repair and maintenance of roads and bridges, vehicle corrosion cost, and loss of aesthetic value due to roadside tree damage (Vitaliano, 1992) High estimate: damage to water supplies and health, vegetation, highway structures, vehicles, and utilities (Murray and Ernst, 1976; Murray and Brenner, 1977). Estimates are adjusted for inflation July 2023.

## Damages infrastructure

Salt negatively affects concrete, roads, guardrails, and bridge surfaces (MPCA, 2020). Due to the corrosive nature of chloride ions, leftover salt damages metal and concrete which over times weakens these structures.

**Figure 7:** Salt damaged guardrail

## Toxic to fish, aquatic insects, and amphibians

Elevated chloride levels are toxic to fish, aquatic bugs, amphibians, and plants. Chloride reduces fish and insect community structure, diversity, and productivity. Low levels of chloride are toxic to fish eggs. Amphibians have been shown to be more sensitive to salt-induced mortality and deformities (Tiwari and Rachlin, 2018). Amphibian eggs are permeable, making them especially sensitive to salt exposure, which results in their bodies drying out or death (Jones et al., 2015).

Further, there are indirect impacts to invertebrates beyond toxicity. It lowers their resiliency to outside biotic stressors. Developmental delays, changes in physiology, resistance to disease, altered food webs, and changes in predation pressures, further impact survivability and the whole freshwater ecosystem (Jones et al., 2017).

This allows non-native species to make their way into Minnesota waters. Unfortunately, many have shown a greater tolerance for chloride pollution and are destined to survive and overrun native species.

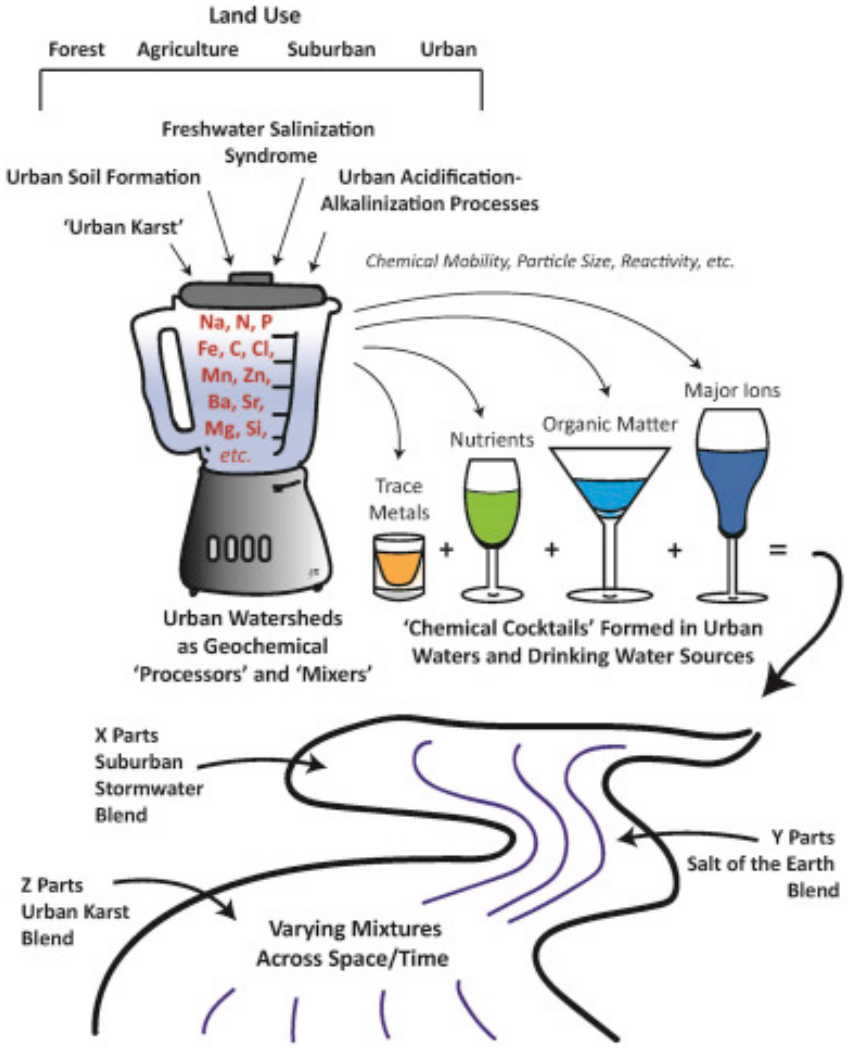
## Accumulates in lakes

Upward chloride concentration trends have been observed in North America's lakes region since 1985. The most important predictors of such increases have been found to be impervious land cover and road density surrounding the lake (Dugan et al. 2017). Dissolved chloride increases water density, which can prevent the natural, seasonal mixing of lake waters (Novotny et al. 2008). The natural mixing of lakes increases oxygen levels required by aquatic life to survive. Excess chloride concentrations can stratify lakes by density gradients, with denser chloride impacted water residing below less dense fresher water toward the surface. The impact of such persistent stratification in lakes has been suggested that oxygen may become depleted in the salt-dense layer near the sediments. This could result in increased phosphorus release into the water column from these anoxic sediments (Novotney and Stefan, 2012).

## Freshwater salinization

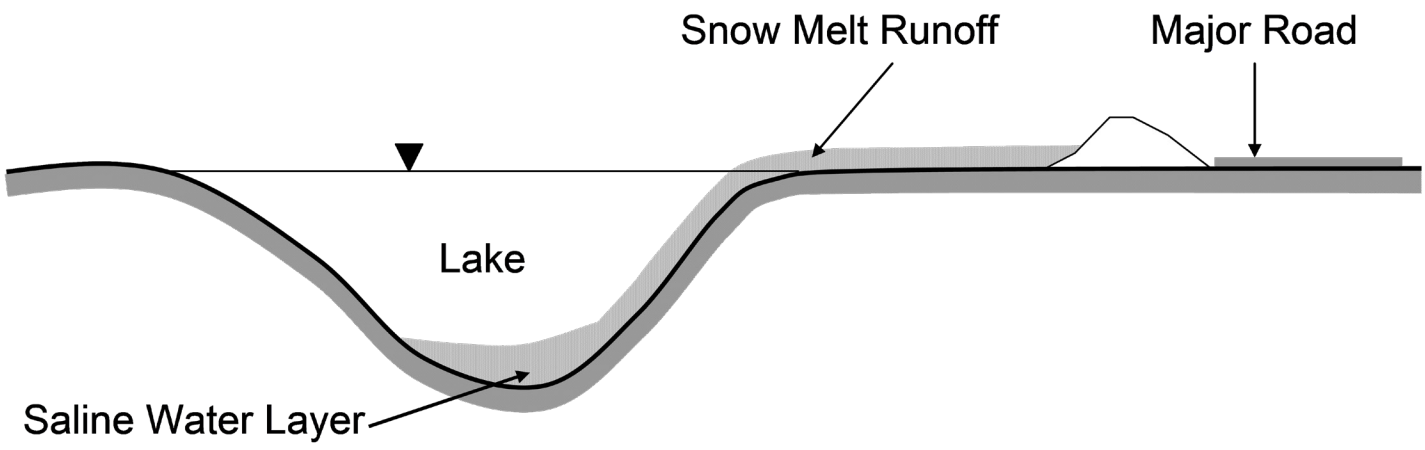
Salt can corrode metals and cause the release of heavy metals in drinking water systems, which also increases heavy metal and nutrient contamination in streams, lakes, and wetlands. The release of these materials creates a chemical cocktail with unknown toxic effects. Salts and the associated chemical cocktails build up in soils, surface water and ground water, which is not easily remediated.

**Figure 8:** How salts form chemical cocktails Kaushal et Al. 2020



## Inhibits stormwater pond function

**Figure 9:** Schematic of a saline water intrusion into a lake




This same stratification has been observed in stormwater ponds, where persistent layers of high chloride were found (Herb, 2017). Research suggests stormwater ponds release heavy metals and phosphorus stored in sediment in the presence of high chloride levels. (Finlay, 2018). The presence of increased phosphorus is known to cause increased algae blooms. There is ongoing research to determine the potential impacts of chloride loading and phosphorus release from stormwater ponds specifically.

## Damages vegetation

Road salt spray can damage and kill plants and trees near salted surfaces; plants that take up salty water through their roots also suffer. Many are familiar with the perennial 'vegetation burn' that commonly happens along sidewalks, parking partitions, even in rain gardens. Stunted tree growth indicators, like witches' broom, show an increase in chloride in the soil. The cost to replace dead grass, plants, and trees, particularly if it is an annual habit, can add up quickly in maintenance costs.

## Drinking water contamination

Salt has contaminated shallow groundwater in some areas of the state; 75% of Minnesotans rely on groundwater for drinking water. Excess salt could affect the taste and healthfulness of drinking water. Twelve percent of monitoring wells in the Twin Cities metro area's shallow aquifers have chloride concentrations that exceeded EPA drinking water guidelines (250 mg/L). Forty percent of the 35 wells analyzed by the MPCA had an upward trend in chloride concentrations from 2005-2017. Most of the wells with upward trends were deep well aquifers used for drinking water supplies. (Kroening and Vaughan, 2019)

### Soil impacts

Soil along roadsides and parking lots can be impacted by deicing salt (primarily the sodium) in several ways, including change in soil structure, effects on the nutrient balance, accelerated colloidal transport, mobilization of heavy metals, reduced hydraulic conductivity and permeability (Amundsen 2010; MDOT 1993). These changes can lead to reduced plant growth. Salt also can cause sodic soils, which is where soil loses its ability to retain water. This change in soil structure results in increased erosion and sediment transport to surface waters (Kelting and Laxson 2010).

# Impacts of non-chloride materials

### Non-chloride deicers

Chemicals often applied in winter maintenance that do not contain chloride include acetates, formates, and urea. All these chemicals have effects on the environment. The effects are generally shorter lived than chlorides but can be severe. These materials can deplete oxygen in water and soil and add nutrients, potentially causing algal blooms or fish kills. These non-chloride deicers typically biodegrade.

Non-chloride materials are typically less corrosive to metal and safer for vegetation. The environmental effects from these products may have the potential to be remediated by holding ponds, rain gardens and other nutrient traps.

### Deicer additives

Anti-caking additives and other impurities in deicers such as phosphorus, cyanide containing compounds, copper, and zinc cause additional stress and accumulate in the environment to a potentially toxic level (Wenck 2009). Ferro-cyanide is the most common additive to rock salt, it helps as an anti-clumping tool.

### Abrasives

Abrasives can be applied on surfaces that need temporary traction. Sand migrates off the roadway into ditches, storm drains, and roadside soils. It changes the drainage capacity and may form deltas in the receiving water. Once in the water, sand can irritate fish's gills, cover habitat and disrupt food chains in water bodies. Sand will also transport other pollutant's such as oil or grease from cars and rubber from tires, into the drainage system.

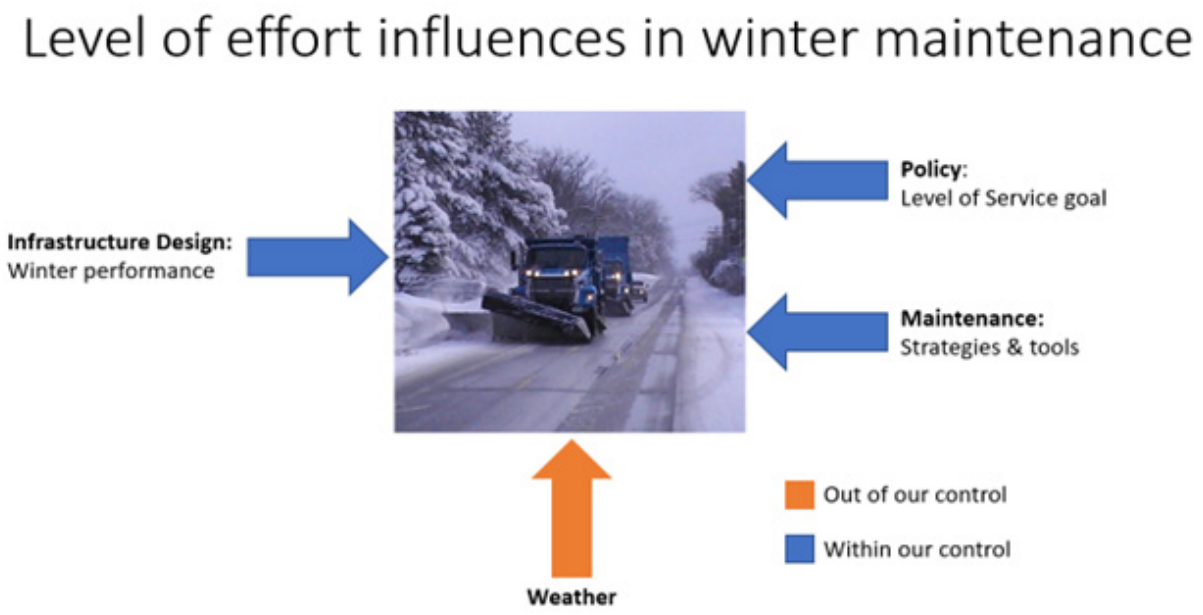
# Statewide Chloride Management Plan

The MPCA and many local partners developed a Statewide Chloride Management Plan in 2021 that creates a framework for all Minnesotans to implement changes and take action to reduce chloride pollution. It includes ways local government units, winter maintenance professionals, decision-makers, property managers, and more can work together preserve and protect Minnesota's water resources. We can all work together to lower our chloride use. Becoming Smart Salting certified is a great first step to reducing chloride pollution. Each community, organization, and individual can implement a variety of strategies to reduce salt use while still maintaining safety. Source reduction begins with you!

# 3. Preparing for winter operations

The figure below shows the influence of four factors on winter maintenances effort. Depending on your roadway network, these factors may exert a larger or smaller influence. Of the three factors that we can influence, winter performance strategies are seldom integrated into roadway design but offer the potential to significantly reduce the maintenance effort needed to reach safety goals. Winter design is at the top of the efficiency chart as it will make it easier to reach level of service goals. Reducing level of service goals, which may not be popular, has potential to reduce winter maintenance effort as will improved winter maintenance tools and strategies. All three factors should be considered in moving winter operations forward.

**Figure 10:** Winter maintenance operations influences (Fortin, 2023)[1]




# Design infrastructure to reduce the need for salt

In order to help winter maintenance professionals have easier operations with less salt, we challenge the engineers, architects, planners and designers to put more focus on winter infrastructure design. If they can design surfaces where the snow, rain, meltwater, and ice have both the smallest and briefest footprint (potential salting footprint),

1 Infographic courtesy of Bolton & Menk, Inc. from their Low Salt Solutions™ strategies

our need for salt will be reduced. If the meltwater footprint can be routed away from saltable surfaces, especially from critical areas such as intersections, ramps, curves, underpasses and other high-risk areas, the need for salt is minimized while safety is improved (Fortin, 2022). Basic Design Principles [2] include:

- Keep the winter angle of the sun in mind to make sure it reaches critical areas.
- Understand the direction of prevailing winter wind and design to prevent blowing snow
- Consider flow of meltwater and shorten its path, pay attention to super elevated surfaces.
- Design in adequate snow storage
- Consider pavement alternatives in areas where we cannot get easy, less expensive winter performance.

# Written policy vs. your operations

Often, bare pavement goals are not explicitly written into policy, but bare pavement is sought in operations. The tools for bare pavement are different than those needed for temporary traction. In this manual when we refer to bare pavement and non-bare pavement, we are referring to what you are trying to accomplish.

# Level of service

Defining the level of service required for a specific road type/stretch of road aids in determining the tools and amount of material needed to efficiently reach the desired result.

# Cycle time

Cycle time is a huge factor in creating and reaching level of service goals. For example, if you have a 2-hour cycle time and 24-hour coverage of a route your ability to use straight liquid deicers becomes a reality. If you have 12-hour coverage and 6-hour cycle time, the reality is you are providing spot treatments and friction for stopping and turning. As we look at crew size and availability, the hours of coverage, and the length of the routes, the tools we have available to us change as does level of service targets. Much work is being done to optimize routes to allow for better performance. Route optimization exercises can be intense but will likely change the way you operate and perform for the better. An interesting Clear Roads publication on this is the Tools for Improving Snowplow Route Optimization Projects.

## Optimizing the variables for low salt success

Our goal is to meet our level of service goal with the smallest amount of chemicals. This may mean more cycles, more coverage, different material, etc. Why should we try to optimize for the smallest amount of chemicals? To protect the future of our communities. We can provide a better future if we deliver less infrastructure damage, less drinking water contamination, lower impacts to our fisheries and the aquatic eco-system, less soil sterilization, and more success in erosion control and vegetation establishment. As we safely decrease salt use, we have the potential to improve quality of life for future generations.

2 Design principle excepts are reprinted with the permission of Bolton & Menk, Inc. from their Low Salt Solutions™ strategies

In winter operations we cannot change the infrastructure design, but we can explore, adjust, and refine many of these variables as we move towards a lower salt future:

- Level of service goal (i.e., bare pavement, non-Bare pavement)
- Period of route coverage (i.e., 12-hour, 18-hour, 24-hour)
- Route Cycle time (i.e., 6 hours, 4 hours, 2 hours)
- Physical removal tools for snow/ice
- Material selection
- Spread pattern
- Application rate

### Bare pavement & non-bare pavement

- Bare pavement: Goal is for no snow and ice on the road. Operations will not stop until this has been accomplished.
- Non-bare pavement: Goal is variable. It can mean many things from plow only, to providing traction on top of snow and ice, to melting some of the snow and ice. Since there is a wide range of acceptable levels of service within the non-bare pavement category it will be up to the user to define what are acceptable driving conditions within the non-bare pavement category.
- Mixed level of service within the same route: Your operations likely require a different level of service within a route. This gets complicated. We often use materials for a non-bare level of service in a bare pavement area but in greater quantities. We recognize this may be a less than optimal solution.

# Policies/plans

### Bare pavement target

Review Minnesota Model Snow and Ice Policy template.

### Non-bare pavement target

Review Minnesota Model Snow and Ice Management Policy template and in addition, consider putting a policy in place to restrict level of service creep to bare pavement. Any areas where you can do this will save on chloride loading. Since the highest salt use is found when we try to achieve bare pavement, most of the manual is directed at bare pavement level of service unless otherwise noted.

### A consideration for gravel roads

In rural areas, we have seen examples of highest annual chloride loading coming from the summer dust control of gravel roads vs the winter ice control of low volume paved roads. Use Table 3: Chloride Content in Liquid Deicers and the corresponding templates found in Appendix B to help you calculate the chloride contribution per lane mile per year of both practices. Anyone managing gravel roads with dust suppressants should examine their practices seeking advice on chloride reduction strategies.

Communities may consider chloride reduction through planning and policy. One area is to address level of service creep. Level of service creep has already happened in much of the metropolitan areas and the pressure to have instantly clear winter surfaces is growing. If a community can control this at a policy level; clearly stating their

interest in protecting their surface and ground water from chloride contamination, they may have more luck fending off the demand for more bare pavements. A good example of this in the metro area are communities that have a no salt on the city trails policy. It is easier to keep this goal than to change it to a bare trail goal and expect someday to go back to snow covered trails.

- Develop a maintenance policy or plan. Your level of service may be based on average daily traffic, environmental concerns, safety, mobility, economics, and other factors.
- Annually review and update policy.
- Inform crew and customers of your high-level plan.
- Follow your maintenance plan.
- Document that you followed your plan: what and how much material you apply on each shift. Throughout the winter, analyze and adjust your process based on what you learned.
- Review and update the maintenance policy and plan each year

**Reduce liability. Establish a maintenance policy, follow it, document your actions.**

## Tools and templates

The following tools and templates will give you a good start when developing your winter maintenance plan – you can follow these formats, or you can make your own.

### *Model policies*

The MPCA has a Minnesota Model Snow And Ice Management Policy template developed for use by organizations. This is a fill in the blank template to help you consider and plan for components such as budget, level of service and the environment. There are also example policies from various municipalities across the state. For background information on snow and ice policies, visit the Minnesota Model Snow and Ice Policy Guidance document.


**The MS4 permit requires a winter maintenance policy. Develop and keep a current maintenance policy or plan that guides winter operations. A little planning and communication up-front can help achieve better results throughout the season and reduce your risk. Detailed MS4 language and how it applies to policies is found in Appendix A.**

### *Model ordinances*

The MPCA worked with several local partners to develop a suite of model ordinances that can be adopted by municipalities to enforce. Example requirements include:

- Training for winter maintenance professionals
- Salt storage regulations
- Chloride management plan site (adapted from Nine Mile Creek Watershed District's Watershed Rules)
- Sweeping regulations for excess deicers on dry pavement

**Do you have an ordinance to keep grass clippings out of the street? How about an ordinance to keep excessive salt off the sidewalks? City of Madison ordinance to limit use of salt on sidewalks**

### *Model contracts*

Winter maintenance contracts encourage best practices. Never use a contract that bills by the ton, gallon, or pound of salt applied because it encourages over-application. If hiring subcontractors for winter operations, the City of Edina in partnership with Smith and Associates LLC law firm developed an adaptable model winter maintenance contract. This template encourages lower salt use but not lower level of service or safety agreement. It showcases other strategies to bill for services instead of billing by the ton or gallon of materials applied.

### *Winter maintenance management template (for sites)*

The intended use of this template is for entities who are just getting started in winter maintenance. The Hennepin County Chloride Initiative (HCCI), a partnership of organizations within Hennepin County, received Clean Water Funds (CWF) to develop resources to assist in addressing chloride pollution. That project developed a chloride site management plan template. These templates are best used by private properties at the introductory level on managing for lower salt use. Cities, watersheds, or others may require them as a part of development or redevelopment. They can also be used voluntarily by anyone training to take first steps on salt reduction and can be customized to meet specific needs. For example, The City of Minneapolis uses these templates as part of their stormwater credits program. Nine Mile Creek Watershed District requires a management plan for development. Three templates are available: basic, intermediate, advanced. The calculator tool in the template allows users to receive recommendations on which template best fits their needs by answering a few simple questions.

# Calibration

## Bare pavement target:

By calibrating trucks, the operator has confidence in accurate rates. Bare pavement goals require high salt use. In our effort to use only enough salt, calibration is key.

## Non-bare pavement target

Debugging equipment before winter operations is where calibration shines for those with non-bare pavement targets. Also, there may be stretches of bare pavement in mostly non-bare pavement routes and the accuracy calibration brings will optimize operations in these high level of effort areas.

Calibration is the process of running spreaders and recording how much material is discharged through catch tests. By calibrating equipment, you get two big benefits:

1. Debug your equipment
2. Have confidence in precision application rates

Organizations have reported up to a 25% overall salt saving after calibrating their equipment for the first time. This savings in salt, and by default money, improves efficiency of your operation.

During calibration, make sure your equipment is running at RPMs similar to what you experience on the roads.

**Imagine if your oven was not calibrated. You might bake a cake at 100 or 700 degrees instead of 350 degrees. The results would be frustrating and wasteful. The same with our spreaders!**

## Timing

Calibrate before you begin your winter operations. Calibrate again during winter operations if:

- Your equipment is acting up or you are discharging too much or too little material.
- You changed hydraulics, auger, conveyor, or any equipment that plays a key role in discharging material.
- Data shows an unusually high or low amount of material being discharged on a given route.

## What equipment?

- Calibrate every piece of equipment that will spread salt, sand, or liquid deicers

## What materials?

Calibrate for each product you intend to use, as they all flow differently.

- Liquids, granular salt, abrasives, mixes, pretreated salt
- Rock salt may come in different gradations. Recalibrate if graduation changes significantly

## What settings?

- Ground Speed controls: Calibrate for one setting using a salt catch test. Enter results into the computer. The computer will do the rest and will self-adjust if needed.
- Manual controls: Calibrate for every setting you intend to use (separate catch tests)
- The more catch tests, or a catch test with a longer catch time will give you more accurate results

**A collection box with a scale that can be zeroed out will save you time and effort**

## What units?

- Granular material should be measured in pounds per minute
- Liquids should be measured in gallons per minute

## Establish calibration experts

Select a small team of detailed orientated people to become your calibration experts. It is an important job and will affect how your operations run.

## Record your results

Keep a record of calibration dates for each vehicle. This can help protect you against lawsuits.

- Manual spreaders: put calibration results in the truck and keep a copy in your shop as well.

## Ground speed-controlled spreaders

Ground speed-controlled spreaders are run by a computer in the cab and are tied to the speedometer and an auger or conveyor sensor in the rear of the truck. Once the application rate is selected the computer regulates the amount of salt discharged in pounds per line mile (regardless of the speed traveled). These are more salt efficient than the manually controlled systems.

The equipment vendor will have specific calibration instructions based on the type and brand of equipment. Contact them; it is in their best interest to provide instructions to calibrate their equipment so it can be used to its full potential.

**Ensure that the spread control speed matches what the speedometer says.**

**Calibration debugs your equipment & allows accurate material use.**

## Manual controlled spreaders

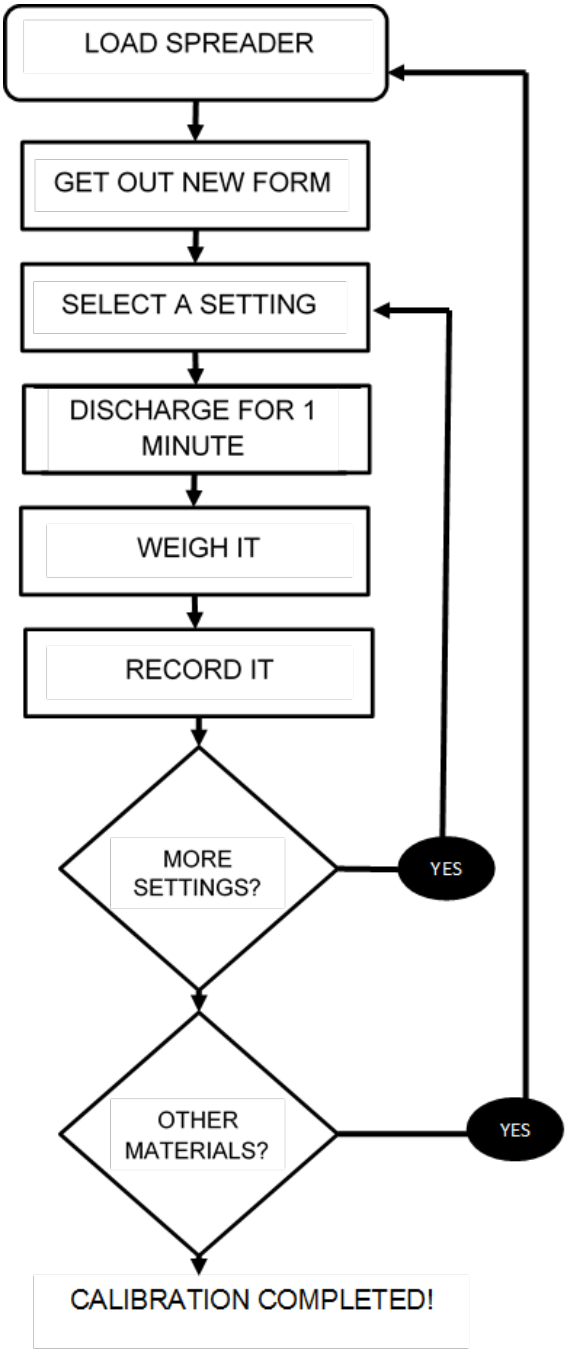
Manual controlled spreaders fall into two categories:

- Those that have an auger or conveyor
- Those that are gravity fed

They operate by selecting a setting that changes the size of the discharge opening and/or the auger or conveyor speed. More or less salt may be discharged depending on the speed of travel and the spreader setting.

The basic principle behind calibrating an auger/conveyor spreader is shown in the flow chart below.

**Figure 11:** Steps for calibrating an auger or conveyor system



# Calibration form

Fill out a calibration form to keep in trucks and in the office. During calibration, fill in the head information, start your truck, bring it to working RPM, and discharge material for 1 minute, collect and weigh the material, fill in pounds per minute for each setting you plan to use during the winter. Back in the office, do the calculations to fill in the rest of the blanks. Multiply the weight in column 2 with the multiplier in the top row, this provides pounds per mile.

**Table 1:** Blank calibration form

**Calibration chart for auger or conveyor systems**

| **Calibration date–**_____ **Truck number–** _____ **Material** _____–––––_____ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Setting** | **Pounds per minute** | **5 MPH (X 12)** | **10 MPH (X 6)** | **15 MPH (X 4)** | **20 MPH (X 3)** | **25 MPH (X 2.4)** | **30 MPH (X 2)** | **35 MPH (X 1.7)** |
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |

# 4. Materials

The more materials you have to choose from, the better your choice will be when the winter event hits. The days of one product fitting all our needs have vanished - winter maintenance has transitioned into a precision industry. Deicers are used to provide melting; however, abrasives are used to provide temporary traction on top of snow and ice. Abrasives never melt snow or ice. In areas of bare pavement, they are useful in extremely cold conditions when deicers are not effective.

## Chloride products

These are the most used products for melting snow and ice at the time of this publication:

- Granular Sodium Chloride, road salt (NaCl)
  - Least Expensive (typically sold in bulk)
  - Slower working – does not attract water from air
  - Most effective at temperatures greater than 15 degrees Fahrenheit
  - More melting power than other deicers
  - Leaves dry salt residue on pavement surfaces
- Liquid Sodium Chloride (Brine)
  - Faster acting than granular salt
  - Works in the same temperature range as road salt
  - Freezes at -6 °F (in tanks, hoses)
  - 23.3% optimal concentration
- Liquid Magnesium Chloride (MgCl2) & Calcium Chloride (CaCl2)
  - Naturally found as a liquid product
  - Hygroscopic – pulls moisture from the air to the pavement
  - Never leaves a dry residue, keeps pavements moist
  - Cold weather deicer: coldest working temperature -10 and -20 degrees
  - Can create a slippery surface if over applied, or used in warm/humid situations, or applied directly to a bare pavement.
  - Gallon to gallon have a higher chloride footprint as compared to NaCl
    - Chloride footprint could be smaller if significantly less amounts of these products are needed to accomplish the same results on cold days as compared to using straight NaCl.

## Additives

Liquid additives are mixed with salt brine to improve performance in a variety of ways. Additives can be categorized as deicers, organics, or dyes. Additives change the performance of salt brine. Below are some of the benefits you may see depending on the additive:

- Allow brine to stay on pavement longer before the storm
- Reduce the freeze point of brine
- Reduce corrosivity
- Soften ice crystal formation
- Speed up melting

## Chloride blends

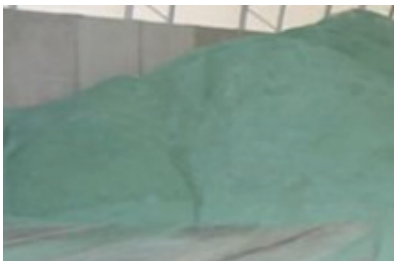
- Pre-treated salt piles
- Brine blends
- Offer a cold weather advantage over straight sodium chloride
- Offer a price advantage over straight $MgCl_2$ or $CaCl_2$
- Present a higher chloride footprint than straight NaCl
- Generally not needed in warm pavement conditions.

## Pretreated stockpiles

Stockpile additives are mixed with rock salt to improve performance. These additives create “pretreated” stockpiles. Additives are commonly one or more of the following:

- Magnesium chloride
- Calcium chloride
- Organics
- Dye

**Figure 12:** Pretreated stockpile



They are often mixed at 4-6 gallons/ton, depending on the wetness of the salt. Caution should be taken to use minimum but optimal amounts of liquids to reduce risk of leaching. Depending on what kind you choose to use, additives could:

- Minimally decrease bounce and scatter
- Improve cold weather performance
- Improve visibility

Pretreated granular materials contain a micro amount of liquid and are a good tool if there is no liquid available. It will give a better performance than plain rock salt. When it is coupled with prewetting, it increases cold weather effectiveness. It has a tendency for liquid to leach out of your stockpile easier than rock salt.

# Winter sand

The salt/sand mix should include only 5-10% salt into sand to keep the pile from refreezing. This is a common tool when bare pavement is not needed as it provides temporary traction on top of snow and ice. It is rarely a tool for bare pavement roads, exceptions are super cold pavements or an ice storm.

### Salt/sand mix (> 10)

It is better to choose the best material for your situation rather than create an all-purpose tool. Often Salt/Sand mixes are used as a blanket treatment no matter what the road or level of service, causing an overuse of both the salt and sand. This is also a tool that can be traced back to limited storage, limited equipment, limited budget, and a mix of levels of service within a route. To see if you might be better off with a lower application rate, straight salt, or a lower salt to sand ratio, check out Table 5: Pounds of Salt in Salt/Sand Mixes Per Lane Mile in Chapter 8: Granular Application.

# Non-chloride products

Manufactured products that are typically more expensive than rock salt, biodegradable, and less corrosive to metal. To learn more about the impacts on non-chloride deicers, read the Clear Road's study on the Efficacy, Cost, and Impacts of Non-Chloride Deicers.

- Acetates – most common non-chloride deicer used on roads today
  - Calcium Magnesium Acetate (CMA):
    - Granular
    - Gentler for new concrete
    - Works at about same pavement temperatures as NaCl
  - Potassium Acetate (KAc):
    - Liquid
    - Most commonly used acetate on roads
    - Works at very cold pavement temperatures, consider reading the MnDOT study on Assessing the Effectiveness of Potassium Acetate to Control Snow and Ice on Minnesota Highways. Note that while potassium acetate does not contain chloride, there are still negative environmental impacts associated with its use.
- Formates, Glycols, Urea, and other non-chloride products exist but are not seeing much road application at this time.

# Total chloride loading

If you want to understand your chloride footprint from various maintenance strategies including prewet applications, dry salt, salt/sand mix, direct liquid application, and dust suppressants. See Appendix B for templates and examples. Our goal is to understand our chloride footprint and adopt strategies to reduce it.

### Absolute quantity of chloride

**Table 2:** Chloride content in granular deicers

| Decicer chemical | Absolute quantity of chloride | Chloride in 1 lb. of deicer |
|---|---|---|
| NaCl | 60.66% | 0.6066 lbs. |
| $MgCl_2$ | 74.47% | 0.7447 lbs. |
| $CaCl_2$ | 63.89% | 0.6389 lbs. |

**Table 3:** Chloride content in liquid deicers

| Deicer chemical | Absolute quantity of chloride | Standard brine concentration | Calculation | Chloride |
|---|---|---|---|---|
| NaCl 9.84 lbs./gal | 60.66% | 23.3% | (0.233)x(9.84)x(0.6066) | 1.39 lbs. Cl per gallon |
| $MgCl_2$ 10.7 lbs./gal | 74.47% | 30% | (0.30)x(10.7)x(0.7447) | 2.39 lbs. Cl per gallon |
| $CaCl_2$ 10.8 lbs./gal | 30% | 30% | (0.30)x(10.8)x(0.6389) | 2.07 lbs. Cl per gallon |

You can adjust these calculations based on the percent of chloride product you are applying (i.e. if you use 28% $MgCl_2$ adjust the equation)[1]

# Ice melt capacity

The total amount of ice that one pound of dry, granular salt can melt and the speed it will melt decreases with temperature. There is nothing that can be done to increase ice melt capacity for any deicer, besides applying more chemicals. However, ice melting speed can be changed. A chemical does most of its ice melting action while in brine form, which is why ice melting from dry rock salt becomes so low, most notably at colder temperatures. The colder the temperature, the more time it takes for salt to form an initial brine layer. However, if we start by applying salt in brine form, ice melt can happen rapidly since the time-consuming part is already finished.

Yet we pay a price for this in ice melting capacity. Although brines melt ice faster than dry salt, they do not melt as much. You must also be aware that adding more brine to achieve the same amount of melting action as rock salt at colder temperatures puts you at risk of refreeze and slippery conditions from large amounts of liquid on the road. This can be addressed by applying both rock salt and brine simultaneously (e.g., prewetting).[2]

**Table 4:** Ice melt capacity of dry (solid) salt and standard 23.3% NaCl brine

Use 1.179 g/mL = 9.839 lbs./gal for 23.3% NaCl

| | | | | **Lbs. ice melted per lb. salt** | **Lbs. Ice melted per lb. brine** | **Lbs. ice melted per gallon brine** | **Gallons of brine equivalent to 100 lbs. dry NaCl LIn/mile** |
|---|---|---|---|---|---|---|---|
| *Temp. (°F)* | *Temp. (°C)* | *NaCl/100* | *% NaCl* | *NaCl* | *23.3% NaCl* | *23.3% NaCl* | *23.3% NaCl* |
| 30 | -1.11 | 0.01867 | 1.867 | 52.56 | 11.48 | 112.92 | 46.55 |
| 25 | -3.89 | 0.06279 | 6.279 | 14.93 | 2.71 | 26.66 | 55.98 |
| 20 | -6.67 | 0.1014 | 10.14 | 8.86 | 1.30 | 12.76 | 69.43 |
| 15 | -9.44 | 0.1344 | 13.44 | 6.44 | 0.73 | 7.21 | 89.27 |
| 10 | -12.22 | 0.1631 | 16.31 | 5.13 | 0.43 | 4.21 | 121.77 |
| 5 | -15 | 0.1881 | 18.81 | 4.32 | 0.24 | 2.35 | 183.99 |
| 0 | -17.78 | 0.21 | 21 | 3.76 | 0.11 | 1.08 | 349.85 |
| -5 | -20.56 | 0.2292 | 22.92 | 3.36 | 0.02 | 0.16 | 2088.82 |

*Data for NaCl taken from CRC Handbook of Chemistry and Physics, 77th edition, David R. Lide, editor in chief, CRC Press, NY, 1996*

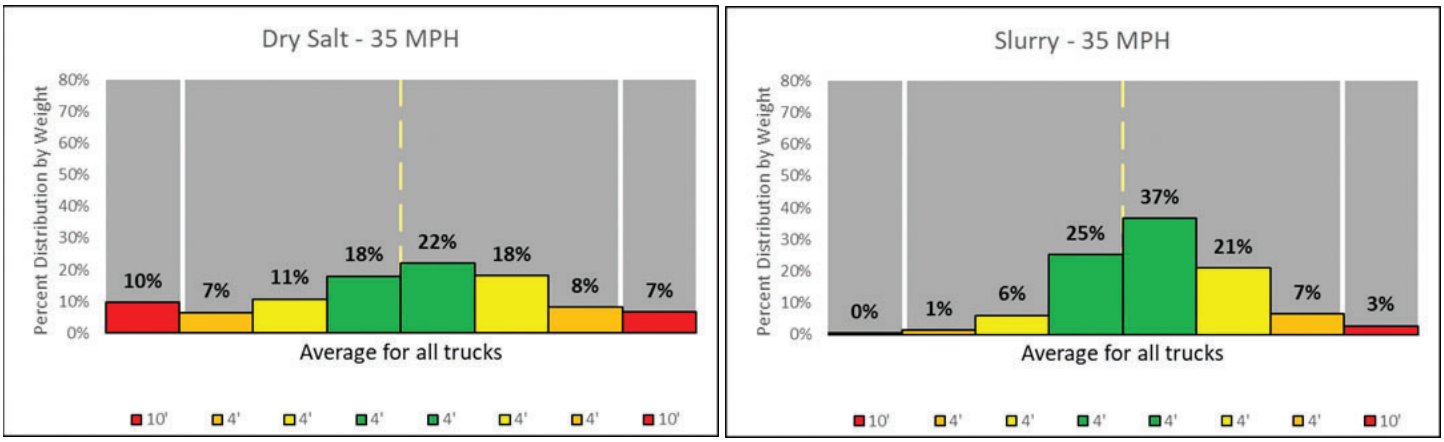
1 These values are representative of completely anhydrous (0% water content) compounds. Hydrate forms of these chemicals are more common than their anhydrous forms in typical solid calcium chloride and magnesium chloride ice melt products. As a result, the mass of chloride listed for the chemicals above will be greater than actual chloride content of packaged deicers. However, this is still a useful way to express relative chloride content.

Calculations provided and reviewed by Doug Klimbal, Bolton & Menk and Scott Koefod, Cargill

2 Ice melt capacity guidance provided by Scott Koefod, Cargill.

The challenge is that much of our granular salt does not stay on the road. Although it has high melting power, in theory our practical experience shows that only a portion of the salt applied remains on the road to melt ice. See Figure 13 that compares the difference in the amount of material that stays on the road due to reductions of bounce and scatter when a slurry is applied compared to dry salt. Table 9 provides estimates of application rates of dry salt that is likely to stay on the road when accounting for bounce and scatter.

**Figure 13:** Salt Scatter results MNDOT 2021



# 5. Storage

Proper storage and good housekeeping will help protect the future of your local water and keep you in compliance with salt and snow storage requirements. Salt that leaves the storage area will end up in the water via infiltration through soils or conveyances such as storm drains and ditches. It may move to water via runoff from storage into ponds, wetlands, lakes, and creeks. Holding ponds do not remove or break down salt; it moves from them. Storage strategies try to minimize the unnecessary movement of salt into the environment and keep products protected and working well.


**Your sand and salt storage may be governed by permits, laws, and/or ordinances. More detailed information can be found in Chapter 10: Laws & Ordinances. The exact statute language is available in Appendix A.**

## Salt and winter sand

- Salt, salt/sand, and winter sand piles should be covered and protected from wind, rain, snow, and meltwater.
- Indoor storage is recommended and may be required.
- Piles should be placed on a waterproof/impermeable pad.
- Sweep salt on the perimeter of the storage area back inside.
- Make sure salt storage area is in good repair.
- Pile snow downhill of salt storage area.
- Avoid over filling salt storage area.

## Ideas for storage building design

- Orient salt storage loading area away from the prevailing winter wind.
- Put doors on salt shed.
- Allow space to load and unload materials indoors.
- Slope the interior of the storage shed to prevent moisture from escaping.
- Slope exterior pavement/asphalt surrounding shed to prevent runoff into shed.
- Create a runoff catch, filter, and recycle system. Reuse the salty runoff in your brine making operations.
- Locate at a higher elevation than surrounding snow storage.
- Plan for increased brine production, liquid storage, and loading areas.
- Consider fill areas for others to load brine and brine blends from your facility.

# Storage area placement

- Storage areas should not be placed in areas of vulnerable groundwater.
  - Groundwater is most sensitive to salt pollution in areas where aquifers are near the land surface or not covered by thick confining layers of clay and/or other fine-grained materials.
  - The MnDNR produces a series of maps that highlight pollution sensitive areas where aquifers are most vulnerable to contamination. These maps are available on the MnDNR website by county. Aquifers rated with a high sensitivity to pollution are shown in orange and red.

**Install a catch system for salt storage runoff for reuse in brine making. The holding pond that catches your runoff does not remove the salt.**

**Invest in good salt storage to protect your future. Storage areas are hot spots for groundwater contamination.**

# Liquid deicers

## Best practices for storage:

- Label tanks with contents.
- Label tanks with a contact number in case of problems or put signs in highly visible areas of tank farm.
- Double wall tanks or secondary containment area in case of failed tank.
- If using secondary containment instead of double wall tank for outdoor storage, then the secondary containment must be a larger than the storage tank to account for rain/snow accumulation.
- If the tank is indoors, then you do not need to account for rain/snow in the sizing of the secondary containment.
  - When storing indoors, floor drains are not an acceptable secondary containment structure.
- Protect all tanks from vehicles.
- Protect outdoor tanks from vandalism (lock the taps, gated entrance, coded entry etc.).
- Know the freeze point of your liquid deicer and plan for inside or outside tanks appropriately.
- Determine if your liquids expand in hot weather. If they do, avoid going into summer with full tanks to prevent a spill.
- Inspect the integrity of your tanks at regular intervals.
- Agitate as needed depending on your liquid.

Review the MPCA Liquid Salt Storage Guidance and Regulations factsheet for more information.

# Snow

- Do not push, plow, or blow snow into lakes, rivers, and wetlands.
- Beware that pushing snow into holding ponds or rain gardens will shorten their life, increasing the cost of maintaining these structures.
- When storing snow near your salt storage area, keep the snow at a lower elevation than your salt or brine. This will reduce meltwater running through your storage area.
- Storing snow at lower elevations than your salted surfaces, reduces the meltwater footprint and potential refreeze on salted surfaces.

**Consider utilizing salt tolerant turf & plants surrounding snow pile areas to minimize vegetation damage.**

# 6. Tools for winter operations

### Bare pavement target

Tools trending towards more technology, data collection, analysis, and optimization of mechanical and chemical performance.

### Non-bare pavement target

Use tools focused on physical snow removal and basic use of materials to gain traction.

## Atmospheric weather

Existing and forecasted weather conditions are crucial for a successful snow and ice control operation. Air temperature can indicate what a storm is going to do. Consider micro-climates within your service area:

- Precipitation forecast
- Wind conditions (speed, gusts, directions)
- Temperature forecast
- Pay attention to micro-climates

Monitor the weather closely to prepare to act early in storm situations. Check the National Weather Service http://www.noaa.gov, local TV stations, or website weather.

In Minnesota, visit 511mn.org for information on weather, road conditions, and travel information.

## Road weather

### Bare pavement & Non-bare pavement target

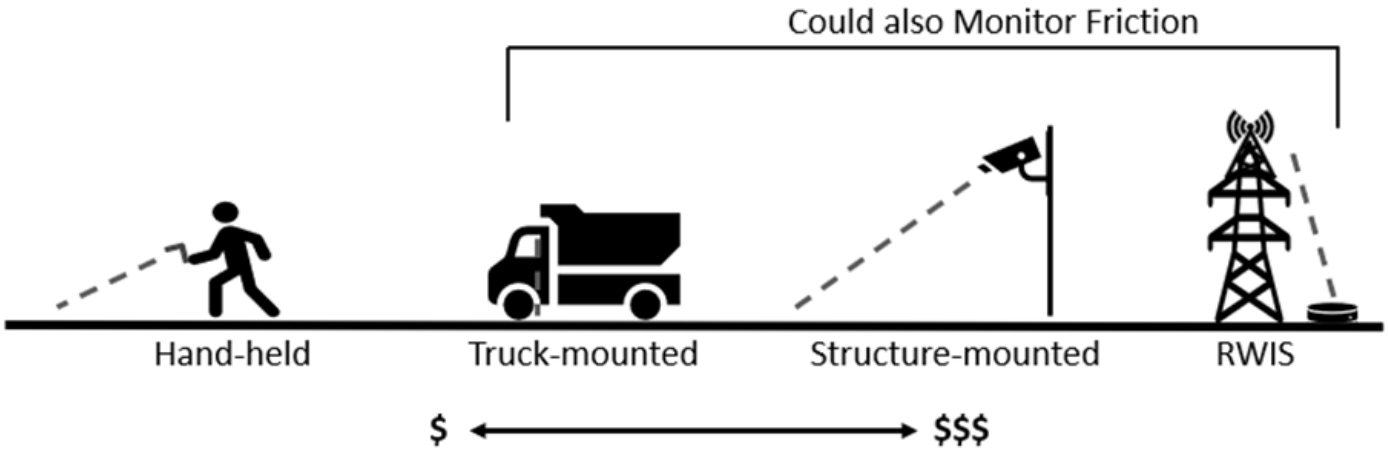
Pavement temperature, pavement temperature trend, and pavement forecasts will pave your way to success!

Pavement and air temperature are often different. Weather stations report air temperature which is measured at least six feet above roads and can differ from road temperature by as much as 20 degrees Fahrenheit. Air temperature influences pavement temperature and should be used as an indicator when deciding your application rates, but not the defining factor. Remember that road temperature cannot be computed by air temperature as too many factors are involved that influence pavement temperatures.

**Knowing the pavement temperature, and pavement forecast allows you to make better decisions.**

# Tools for real time pavement temperature sensing

**Figure 14:** Tools for monitoring pavement temperature




### *Hand-held temperature sensors*

Hand-held temperature sensors can be purchased at hardware stores and are inexpensive, easy to obtain and to use. Easy to misplace.

### *Truck-mounted infrared temperature sensors*

Truck-mounted sensors measure surface temperatures while your truck is moving. They are attached to your truck which means they are handsfree and not easily misplaced. They continually display both air and pavement temperature inside your truck. Some offer other data like relative humidity.

### *Structure-mounted temperature sensors*

Structure-mounted sensors can be attached to a pole or building and provide continuous site information. They do not give subsurface pavement temperatures but depending on the model may provide a variety of information such as chemical presence and grip or friction values. They are set up to be monitored remotely.

### *Road Weather Information System (RWIS)*

The RWIS provides real time pavement temperatures and other information from many locations in most states. It consists of a network of towers and temperature sensors embedded in state highways.

# Tools for pavement forecasting

- Road weather forecast services – Subscribing to a service that forecasts pavement temperatures allows you to plan for the future and make better decisions. MnDOT uses pavement forecasts as do some cities and counties.
- Polk County coordinates a group rate for interested counties. Contact Rich Sanders at rsanders@co.polk.mn.us to learn more.

# Friction monitoring

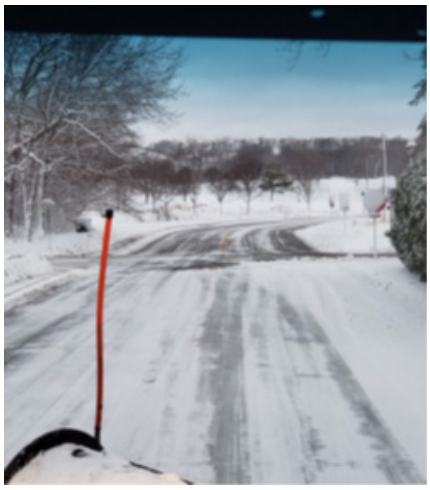
- Friction sensors come in optical and physical models. If mounted to the truck the driver has an excellent understanding of how the road surface is performing. Friction sensors have been shown to reduce salt use by giving operators confidence in how their road is performing.

- There is an ongoing study by Clear Roads on Grip Sensor Technology and Salt Applications that is looking at how friction data can be used to benefit winter maintenance operations.

# Blade technology

Physical removal of snow and ice reduces our dependence on deicers. The more aggressive and frequent our snow removal efforts, the better our results. However, not all cutting edges give equal performance. We are in an area of rapid advancement in blade technology. High performance blades cost more, perform better in many situations, typically wear longer, and reduce vibration. They can be multi-layer and multi-functional or customized to a certain type of terrain and condition. They can be mounted on front plows, wings, underbody, and tow plows. We encourage organizations to consider the return on Investment from upgrading their cutting edges to high performance cutting edges. Consider your management strategies for compacted icy/snowy roads and cycles times and match your cutting edge to your situation for optimal results. Figure 15 shows a demonstration of traditional blade foreground (before intersection) vs. live edge blade (after intersection).

**Figure 15:** Traditional plow blade vs. Joma blade



# Other technology

Rapid advancement in technology has allowed for Automatic Vehicle Locating (AVL), GPS, Maintenance Decision Support Systems (MDSS), ground speed controls, the use of drones, and data collection and interpretation across the board. This gives us the potential power to understand and optimize our performance. However, with new technology we experience fear and frustration trying to install, debug, sift through mounds of data, as well as understand and use the results. We encourage you to explore and expand your technology and network with others to learn tips and tricks to make it easier. Rely on your vendors to provide assistance. Do not be afraid to say, “I want a simple report with these 3 pieces of information” or “I do not want a spreadsheet with 400 columns of data”. Embrace the opportunities technology brings to us.

# Designing for winter

If we design our infrastructure for better winter performance, we increase safety and reduce maintenance effort and the use of salt. We expect the next generation of road design and road reconstruction to give more serious thought to improved winter performance with less dependence on deicers. Low Salt Design is an emerging science that offers great hope for improved winter performance. Low salt design strategies are helping improve winter performance and reduce our dependence on salt. A few examples of better winter design are:

- Snow fences
  - The use of snow fences has been shown to increase safety and decrease maintenance effort. MnDOT has done award-winning work in this area and presents you will a collection of insight and tools to help you in this area. Visit MnDOT’s Living Snow Fences webpage.
- Drift free road and ditch design
  - MnDOT has laid out the basic concepts of anti-drift road and ditch design.

- Optimize the sun
  - The ability to get more winter sun on our pavements allows a higher level of service with less salt. For example:
    - Planting deciduous trees (oak, maple, etc.) vs. coniferous trees (pine, spruce, etc.) along a roadway allows more sunlight in the winter and keeps the appeal of a vegetated border in the summer and provides summer shade.
    - Positioning buildings or trees on the north side of the road vs. the south side of the road takes advantage of southern sun exposure and allows more sunlight onto the winter pavements.

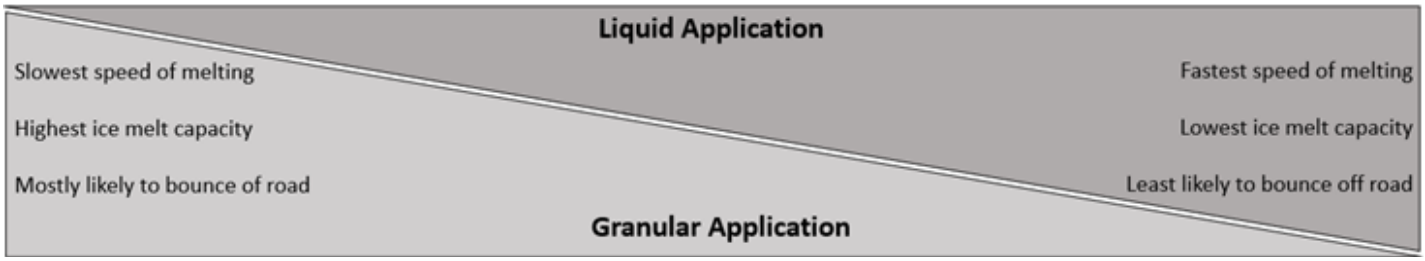
# 7. Liquid application

- Direct Liquid Application (DLA): Only liquid products used, no granular:
  - Anti-icing: applying liquids before the storm to prevent or weaken the bond between pavement and snow/ice (sometimes mistakenly referred to as pretreating)
  - Deicing: applying liquid only material during or after the storm to melt residual snow/ice or to weaken the bond under snow/ice
- Prewet Application: combining liquid deicer to granular deicer as they are being applied.

In general, as we increase our liquid to granular ratio, we speed up melting and reduce the amount of salt lost during delivery or blown off target. Since we reduce waste, we can use less salt and achieve the same or even better results.

## What are you looking for?

**Figure 16:** Liquid vs. granular application




# Overall bare pavement goal

The industry has moved from one rooted in the left side of the above diagram to one moving to the right side of the diagram. There is a place for granular salt in our operations of today, but there are more opportunities to increase liquid use than ever before. The industry leaders are those looking for ways to decrease overall salt use as we move towards a precision industry.

# Overall non-bare pavement goal

If you are managing roads that do not require bare pavements, the use of liquids will play a smaller role in your operations.  They have limited use to maintain friction on a snow-covered road, the barer pavement that you strive for, the more liquids will play a key role.

# Cycle time factors

With increased liquid use, we increase speed and accuracy but lower ice melt capacity. In many cases this is fine as we often have excess ice melt capacity. However, with long routes, significant snow and ice on the surface, and dropping temperatures, we dial up granular use.

# Before the storm

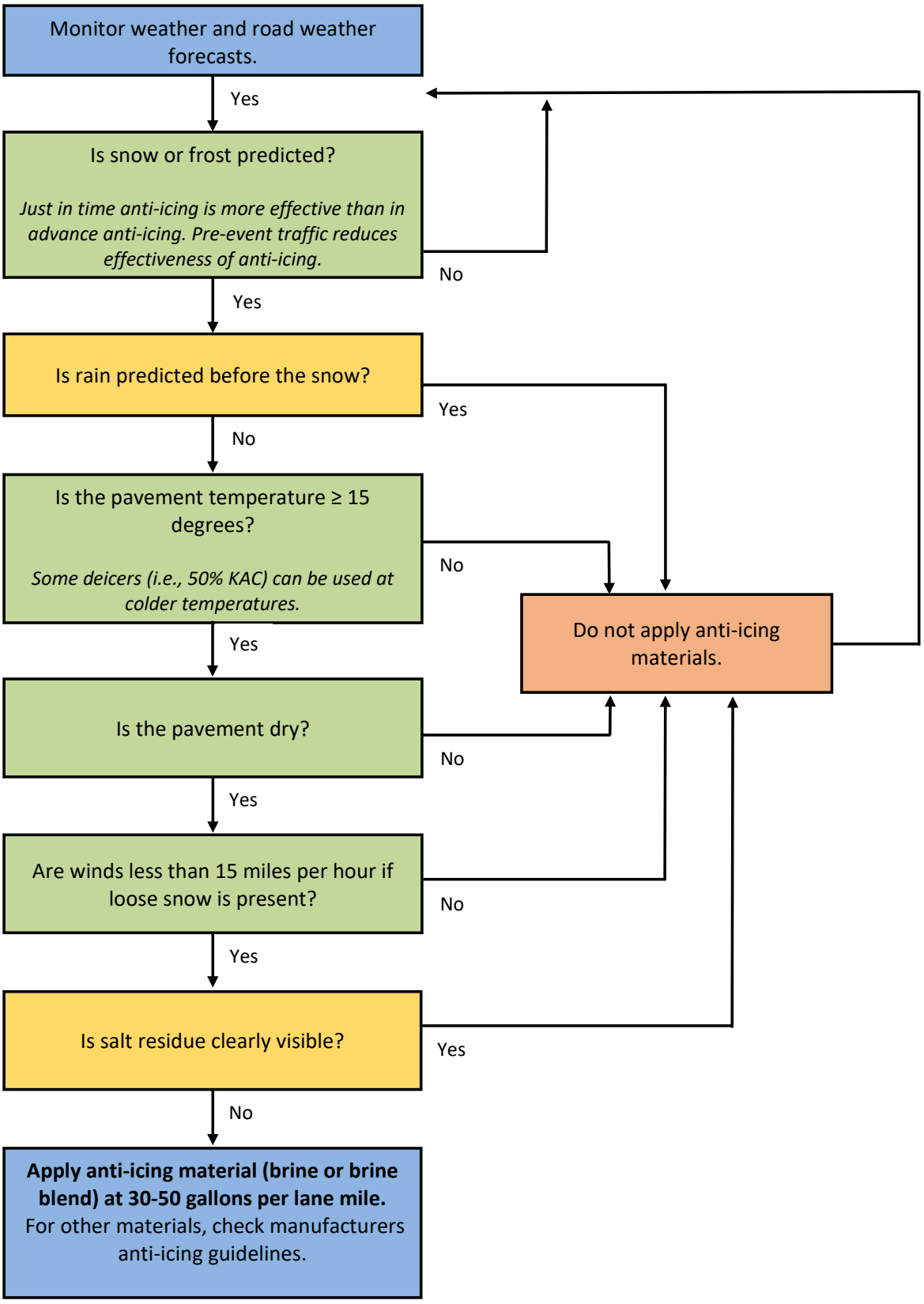
## Bare pavement goal

***Anti-icing – a proactive tactic***

- Anti-icing is the use of a liquid deicer before the storm. It is meant to create a micro layer of melting underneath the snow and ice. The goal is to weaken the bond of snow/ice to the roadway. A weaker bond results in more effective plowing operations.
- It can be a cost-effective strategy that reduces road recovery time with less effort and less chemicals.
- It can also be an ineffective strategy that increases chemical usage.

**It may not be convenient for you to anti-ice right before a snowfall. It may be more convenient to anti-ice a day or two in advance. But if that salt is no longer on the road when the storm hits, you have wasted your time and materials. Beware – science and convenience may not point to the same strategies..**

**Figure 17:** Anti-icing application decision flowchart




*Flow chart adapted from Clear Roads Manual of Best Management Practices for Road Salt in Winter Maintenance, with modifications from technical contributors.*

Do not anti-ice if:

- Bare pavement is not your goal.
- Your roads are already white with dry salt.
- You have to apply material so early that it tracks off before the storm.
- It rains before it snows. However, in low moisture leading edge events, such as light drizzles or freezing fog, anti-icing can be very effective.
- You do not have the right liquid for the pavement temperature and trend.
- You are experiencing blowing snow across the road or predicted blowing conditions.
- You do not have a liquid only delivery system.

**Anti-icing requires about ¼ of the material of deicers at ⅒ of the overall cost.**

### *Anti-icing spread patterns*

The traditional approach is to apply material with stream nozzles to maintain bare pavement between treated areas.

- Bare pavement before the storm = good traction.
- Why streamer spray vs. fan spray?
  - The bare areas between the anti-icing stripes are your traction safety net in case your liquid becomes greasy or icy.
  - Experts in liquid use sometime move from nozzles sprays to fan sprays, however this is not a recommended starting point

**Figure 18:** Stream nozzles for anti-icing

Photo credit: Jake Bennett, Iowa

**Figure 19:** Anti-icing steam nozzles spread pattern

Alternative spread patterns are being tested across the land in hopes of finding more effective methods of preventing the bond with less liquids and/or less effort.

- Anti-icing in wheel paths is a popular tactic with the Iowa DOT. They use the same application rates suggested in this manual and concentrate it into a narrower pattern.
- Reducing the material that is lost to the air can be accomplished by:
  - Putting short hoses on the nozzles to direct delivery closer to pavement.
  - Using a mud flap.

**Figure 20:** Wheel path anti-icing

Photo credit: Brad Becvar, Iowa DOT

# During the storm

Plowing is the number one tactic for both bare pavement and non-bare pavement levels of service targets. During the storm we have a lot of dilution so liquid benefits are less.

## Bare pavement goal

Most deicers applied at this time will melt, refreeze, and may be plowed off. If you apply deicer, you will have to watch it throughout the storm for dilution and refreeze. Bare pavement during the storm requires high effort, multiple passes, and a high chemical price tag.

## Non-bare pavement goal

Both deicers and abrasives have a short life during the storm, the best tactic is aggressive plowing. If you need to have a clear or high friction spot, you will have to continue to apply materials frequently. During a storm with a bare pavement goal, it creates a high material price tag.

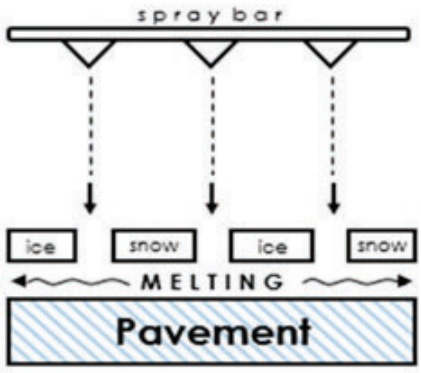
# After the storm

## Bare pavement goal

***Direct liquid application (DLA):***

- Short cycle times 2-3 hours.
- Need to penetrate the snow and ice to spread out under snow and ice.
- Liquids always work from the bottom up. To get the liquid under the snow/ice, you may need to adjust speed of travel, bar pressure, application rate, and type of liquid.

**Figure 21:** Direct liquid application




More difficult DLA situations:

- Cold pavements
- Steep drop in pavement temperatures
- Significant snow/ice on pavements
- Long cycle times
- Inadequate bar pressure, application rate, and/or high speed of travel during application

Easier DLA situations:

- Warm or warming pavement temperatures
- Micro layer of snow/ice on pavement
- Short cycle times

**Don't be fooled: Liquids look like water but put down a significant salt load. See Appendix B for how to calculate your chloride loading.**

DLA has the potential to reduce overall application rate of salt as liquids are faster acting, more accurate in placement, and are less likely to be blown or delivered off target. However, if we put blinders on and deliver high liquid rates on an intense delivery cycle, we can put down more salt compared to when using traditional granular or prewet application rates. Do the math and understand your chloride loading.

**Warning – DLA that does not get under the snow and ice is like a Zamboni. If you melt on the surface and it refreezes, you will have created fast ice.**

The winter maintenance industry is in a phase of rapid learning and improving DLA practices. See the Resource section under Materials and Deicers for DLA resources. Look for updates on DLA guidance on the Clear Roads website as recommendations continue to change and improve. DLA rate guidelines are also found in Chapter 11: Application Rate Guidelines.

### *Post storm DLA spread patterns*

Most DLA users apply material with stream nozzles with enough bar pressure and high enough application rate to burn through existing snow and ice and spread out underneath the snow and ice.

The most common spread pattern is the same as the one used in anti-icing with the wet/dry pattern across the drive lane. Alternative spread patterns are being tested in hopes of finding the more effective methods of preventing the bond with less liquids and/or less effort. A few different application patterns include:

- DLA in wheel paths is a popular tactic with the Iowa DOT. They use the same application rates suggested in this manual and concentrate it into a narrower pattern.
- Jefferson County in Wisconsin sprays the crown of the road with streamer nozzles, with the goal to open the inner wheel paths on both lanes with one pass. The image to the right illustrates a short spray bar for the crown of the road during DLA. The bar is 3 feet long with 5 nozzles.

Challenge yourself to get the results you need with the least amount of salt. Below are examples of spread patterns on a single pass, post storm application:

**Figure 22:** Streamer nozzles for DLA

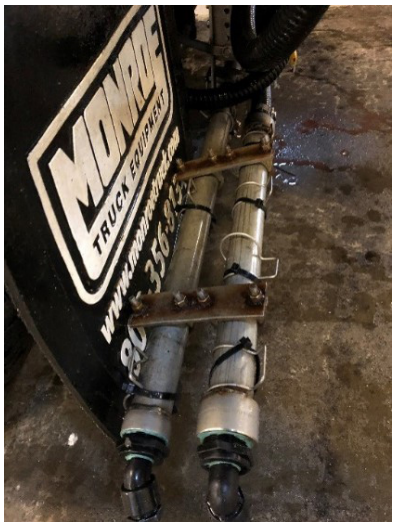
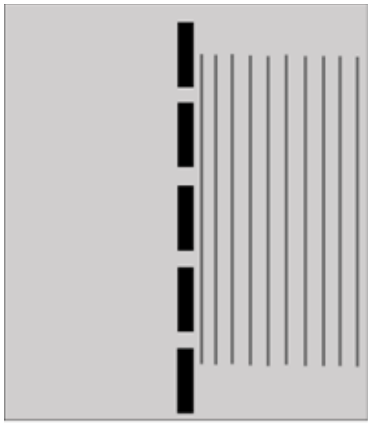



Photo credit: Bill Kern, Jefferson Co. WI

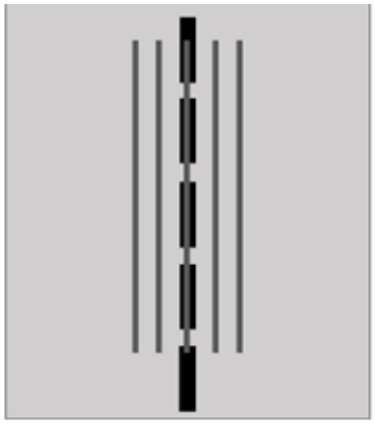
**Figure 23:** DLA application strategies

Most common DLA strategy



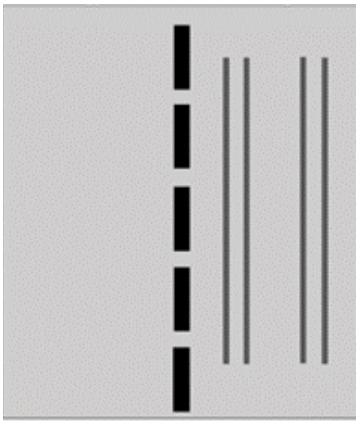
**Stream nozzles with ~8ft bar**

Jefferson Co, WI strategy



**Stream nozzles with ~3ft bar at crown of road**

Iowa DOT strategy



**DLA in wheel paths**

### *Prewetting (liquid granular mix)*

Salt easily bounces off the road. By adding a liquid to the salt, it can reduce bounce and speed up melting. Use the traditional spread pattern of any granular material. Table 8: Deicing Application Rate Guidelines recommends a narrow-spread pattern on the crown of the road. However, some may have three lanes, superelevation, or center rumble strips that do not allow for this.

- As you invest in bigger tanks, both externally and internally mounted on your truck, you will see faster performance and reduction of product bounced off the road.
- Liquid and granular product can come together at the spinner, auger, or conveyer – all which have shown to be effective.
  - Consider more than one nozzle at the spinner to help with increased liquid rates
  - Auger mixing has shown less freeze up if mixed in a portion of the auger closer to the discharge point.

**Figure 24:** External prewet tank

**Figure 25:** Internal prewet tank

## Non-bare pavement goal

A European process of heated water on sand has shown to hold sand in place 10 to 20 times longer than dry sand, as found in the Clear Roads' study on the Benefit-Cost of Various Winter Maintenance Strategies. To review the research on water heated sand, read about the Winter Friction Project in Norway. The use of liquid deicer glues an abrasive to an icy surface has shown promising results. However, the use of too much deicer may sink the abrasive into the ice or snow negating its traction benefits.

# 8. Granular application

## Using abrasives

### Bare pavement target

Abrasives only used in extreme cold situations, ice storms and unusual situations.

### Non-bare pavement target

Abrasives are a primary or secondary tool for winter operations.

A salt/sand mix has performance challenges. Salt reduces the effectiveness of sand by melting it below the surface, and sand does not improve the effectiveness of salt. Opportunities exist where a little salt, perhaps liquid salt, will melt the sand in place offering less displacement of the sand from traffic. Salt/sand mix is frequently used in rural areas, areas with mixed level of service expectations across a route, limited equipment, or limited storage.

### Non-bare pavement

When looking to provide traction instead of melting the use of abrasives is key. The amount of abrasives used is not as important as the spread pattern and the amount of deicer mixed in.

- Deicer amount in the blend should be as low as possible.
- Deicer mixed into abrasives decreases the amount of time the abrasive remains on the surface of the snow/ice.
- If salt/sand ratios are high.
  - The salt in that mix is often comparable to the straight salt rates in Table 8: Deicing application rate guidelines
  - Table 5: Pounds of salt in salt/sand mixes per lane mile shows the amount of salt in various mixes and application rates. It also highlights opportunities to lower application rates, change ratio of salt/sand, or move to straight salt to reduce overall volume of materials and more accurately get the results (melting or temporary traction).

**Table 5:** Pounds of salt in salt/sand mixes per lane mile

| Application Rates (pounds per lane-mile) | Salt % in Winter Sand | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5% | 10% | 15% | 20% | 25% | 30% | 35% | 40% | 45% | 50% |
| 200 | 10 | 20 | 20 | 30 | 40 | 40 | 50 | 50 | 60 | 70 |
| 400 | 20 | 30 | 40 | 50 | 70 | 80 | 90 | 100 | 110 | 130 |
| 600 | 20 | 40 | 60 | 80 | 100 | 110 | 130 | 150 | 170 | 190 |
| 800 | 30 | 50 | 80 | 100 | 130 | 150 | 170 | 200 | 220 | 250 |
| 1000 | 40 | 70 | 100 | 130 | 160 | 190 | 220 | 250 | 280 | 310 |

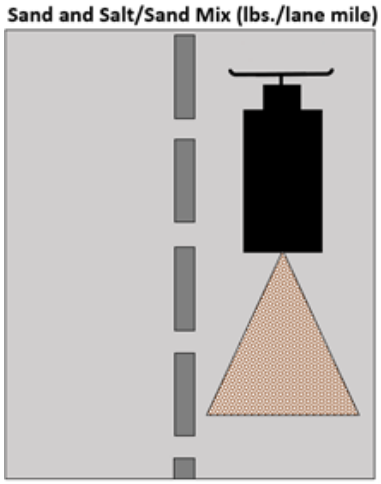
If your salt/sand use is in the highlighted area of Table 5, consider reducing the salt in your sand mix, lowering your application rate, or using straight salt.

- Caution when switching from salt/sand mix to straight salt. Make sure you have a smaller auger or a bigger auger with a large center shaft and small flights. You will never be able to deliver the small amount of straight salt needed with standard large augers.

## Salt/sand spread patterns

- Spread across wheel paths.
- Most effective when used in low-speed or low traffic areas.
- Use caution when switching spread patterns from in the lane to crown of road as recommended for straight salt applications, application rates move from lbs./lane mile to lbs./2-lane mile.
- Spot treatment of hills, curves, bridges, intersections, and other trouble areas is a more common practice than full route sanding.
- To increase road friction and protect our conveyance systems and receiving waters, sweep up sand when it is on bare pavement. Sweeping during winter is encouraged.

**Figure 26:** Sand spread pattern




# Using granular deicers

## Bare pavement target

In most cases, granular deicers perform better when in combination with liquid deicers.

## Non-bare pavement target

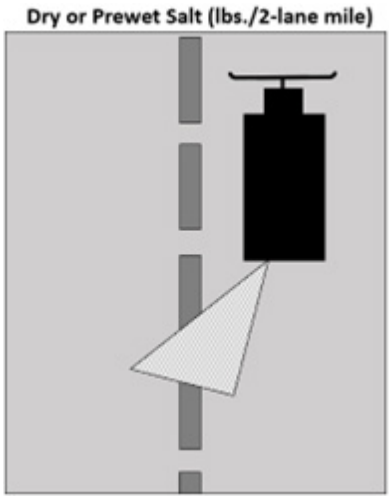
Used as a supplement to keep sand flowing and as a straight salt for spot treatment of higher priority areas.

## Dry or prewet salt spread patterns

The first objective when applying granular salt is to not bounce it off the drive lane. The second objective is to find a way for traffic to not blow it off the drive lane. Granular products are easily moved off target and rendered useless. The use of liquid deicers in combination with granular deicers reduces this loss as does the shape of the spread pattern, placement of salt, the speed of the plow truck, and application rate.

- Apply at crown of road or super elevation if you can clear both lanes before application. This allows for salt to melt and move slowly downward towards the shoulder.
- If you apply behind the truck in a single lane, take every caution to reduce scatter into unplowed lane or shoulder. Increasing your liquid ratio may be key.

**Figure 27:** Dry or prewet salt spread pattern



- Utilize a narrow-spread pattern.
  - Chutes, holes in spinners, and zero-velocity spreaders are all helpful in achieving a narrow-spread pattern.
  - Slower speed travel during application helps achieve a narrow-spread pattern.
  - Lower point of discharge helps achieve a narrow-spread pattern and reduce bounce.
  - This spread pattern correlates to Table 8: Deicing application rate guidelines
- Getting salt wet will reduce scatter.

# 9. After the storm

## Standard practices

Good housekeeping practices around salt storage, brine maker, trucks, and all equipment, will keep salt contained and managed to reduce off target migration. Evaluate what was done during the storm, how well it worked, and what could be changed to improve operations. A few suggestions include:

- Remove snow from bridge walls to prevent ramping, and clear snow from pedestrian ramps to allow safe pedestrian access.
- Bench back snow to provide storage for next event.

**Figure 28:** Benching snow


- Host a post-storm meeting or make available post storm results to all involved in the operations.
- Look for opportunities to try new and improve practices.
- Clean and check all equipment.
- Report any hazards observed during operations, such as low hanging branches and raised utilities.

## Documenting and charting

Good documentation helps:

- Understand how your operations, equipment, materials, cycle time, and application rates are working between events and between seasons.
- Provides evidence of where more or less material is needed.
- Allows you to improve operations based on experience.
- Offers proof of your operations which may be useful legal protection.

As operations are streamlined to reduce waste and boost efficiency, we often get environmental cost savings as well.

# 10. Laws & ordinances

State laws and local ordinances or rules may influence your winter maintenance activities. As chloride reduction efforts ramp up, it is likely that more rules and ordinances will be established. Be aware of changing requirements in your area.

# Minnesota rules and statutes

It is important to review the relevant Minnesota rules to your winter maintenance operations. Below is an overview of statutes that apply to material storage, and other miscellaneous considerations for snow removal and street sweeping. A detailed description of these statutes is found in Appendix A. For questions or clarification contact: smartsalting.pca@state.mn.us

## Material storage

### Liquid deicing materials

These are considered **Other Regulated Substances** in the Other Regulated Substance Requirements for Above Ground Storage Tank (AST) guidance and therefore are not subject to the same regulations as hazardous materials because they have limited risk. The MPCA does not require the registration of other regulated substance ASTs. The basic requirements for most liquid deicer storage includes labeling all tanks, having a posted sign on site, and secondary containment. However, the size and location of ASTs containing deicers will influence the specific regulations that are required. Here is a summary of requirements that may apply to deicer storage tanks:

- **Labeling ASTs containing deicer:** All tanks must be clearly labeled indicating the type of substance stored and the tank's capacity. If there is more than one tank, each tank must be labeled with a unique tank number.
- **Sign posting:** If a person is not on site 24 hours a day, a sign must be posted with the name, address, and telephone number of the facility owner or operator, or a local emergency response contact. The sign must be posted so that it can be seen outside any containment area.
- **Secondary containment:** Other regulated substance ASTs need 100% containment area volume of the largest tank in the containment area. An additional 10% capacity is required for ASTs exposed to precipitation. Double-walled tanks satisfy the secondary containment requirement.

### Salt and winter sand

These are required for anyone with an MS4 permit and are recommended for all. If a government entity has an MS4 permit, these storage requirements also apply to anyone storing salt in that geographic area (i.e., private companies):


a) Designated salt storage areas must be covered or indoors;

b) Designated salt storage areas must be located on an impervious surface; and

c) Implementation of practices to reduce material exposure to precipitation runoff when transferring material in designated salt storage areas (e.g., sweeping, diversions, and/or containment). [Minn. R. 7090]

## Other considerations

- Street sweeping: sweepings from streets, sidewalks, or parking lots that are not screened for trash and debris are considered industrial solid waste. These sweepings must be disposed of or stored in accordance with the law. MPCA managing street sweepings fact sheet.
- Discharges to Waters of the State: Do not plow, blow, or dump snow directly in waters of the state including rivers, wetlands, creeks, lakes, and natural ponds. [Minn. R. 7053]
- Illicit discharge: It is illegal to use salt to open storm drains or storage areas. [Minn. R. 7090]
- Most cities and counties prohibit pushing snow onto a public street or sidewalk.
- Check local visual screen ordinances before you build.

# Chloride specific language in MS4 permit

In 2020, new chloride specific requirements were added to the MPCA Municipal Separate Storm Sewer (MS4) permit. These requirements apply to all organizations that have an MS4 permit. A detailed description of these additions is found in Appendix A. Below is an overview of requirements from the permit:

- Distribution of educational materials focused on chloride impacts on water resources and practices to reduce salt use.
- Annual training of all staff performing winter maintenance operations. The MPCA Smart Salting Certification training courses meet this requirement.
- A written Snow and Ice Management Policy.
- Salt stored properly.
- Use regulatory mechanisms to require proper storage at commercial, institutional, and other non-permitted facilities.
- Maintain a written or mapped inventory of salt and snow storage locations.Those who have a chloride WLA must document the amount of deicer applied each winter maintenance season and must conduct an assessment of the permittee's winter maintenance operations to reduce the amount of deicing salt applied.

Many of these requirements can be addressed through resources offered by the MPCA such as Smart Salting trainings, the Smart Salting tool, and model policies, contracts, and ordinances.

# 11. Application rate guidelines

Application rate charts attempt to document the largest influencers of the road condition and tie it back to material performance. Most common variables considered are pavement temperature, pavement temperature trend, material selection, and rain/snow. They are key considerations, but they do not tell the full story. One variable that is rarely covered in charts is how much snow/ice is on the pavement, or how much deicer is lost to bounce and scatter during application and how much is lost by traffic pushing it off the target.

Interesting discussions have surfaced on the moisture of the snow and the effectiveness of granular vs. liquid products. Liquid deicers have been effective in the low moisture snow giving us a tremendous jump start - they dilute out faster in the wet slushy snow. Most application rate charts do not account for the snow moisture content, so it falls back on the decision makers to account for that as well as many other variables such as route cycle time and hours of coverage per day.

Application rate charts help standardize thinking and allow us to make adjustments at a higher level. Want to improve these charts? Add more variable or a secondary chart that considers other factors such as:

- Amount of snow/ice on the road
- Additional columns for different materials that you use (brine blends, KAC, salt/sand mix, etc.)
- Cycle times

Winter maintenance is becoming a precision industry and these charts are a steppingstone in the right direction.

Maintenance Decision Support Systems (MDSS) is a good example of innovation in our industry that involves more complex calculations to come up with application rates in real time. Other similar systems are being developed and used in cold climate regions.

# Maintenance Decision Support Systems

MDSS is the best example of innovation in our industry that involves more complex calculations to come up with application rates in real time. If you get the chance to use a tool like this, take full advantage of the opportunity. It helps agencies make better decisions about their winter maintenance activities by providing reliable weather and road conditions, as well as treatment recommendations. Since MDSS considers many more variables than application rate charts, it can produce better application rate recommendations.

# Anti-icing application rate guidelines

These guidelines are a starting point. Reduce or increase incrementally based on your experience.

**Table 6:** Anti-icing application rates

| Gallons/Lane mile | | | |
|---|---|---|---|
| **$MgCl_2$ or $CaCl_2$** | **Salt brine** | **Salt brine blends** | **Other products** |
| 15-25 Apply as storm hits, not before | 20-50 | Typically, same as salt brine. Check with supplier of additives | Follow manufacturers' instructions |

# Pounds of ice melted per pound of salt

**Table 7:** Pounds of ice melted per pound of salt

| Pavement temp. °F | One pound of salt (NaCl) melts | Melt times |
|---|---|---|
| 30 | 46.3 lbs. of ice | 5 min. |
| 25 | 14.4 lbs. of ice | 10 min. |
| 20 | 8.6 lbs. of ice | 20 min. |
| 15 | 6.3 lbs. of ice | 1 hour |
| 10 | 4.9 lbs. of ice | Dry salt is ineffective and will blow away before it melts anything |
| 5 | 4.1 lbs. of ice | |
| 0 | 3.7 lbs. of ice | |
| -6 | 3.2 lbs. of ice | |

# Deicing application rate guidelines

**24' of pavement (typical two-lane road)**
**These rates are not fixed values, but rather the low end of a range to be selected and adjusted by an agency according to its local conditions and experience**

**Table 8:** Deicing application rate guidelines
(LRRB Minnesota Snow and Ice Control Handbook 2022)

| | | | Lbs./two-lane mile | | | |
|---|---|---|---|---|---|---|
| **Pavement Temp. (°F) and Trend (↑↓)** | **Weather Condition** | **Maintenance Actions** | **Salt Prewetted/ Pretreated with Salt Brine** | **Salt Prewetted/ Pretreated with Other Blends** | **Dry Salt*** | **Winter Sand (abrasives)** |
| >30°↑ | Snow | Plow, treat intersections only | 80 (40/lane mile) | 70 | 100* | Not recommended |
| | Frz. rain | Apply chemical | 80-160 | 70-140 | 100-200* | Not recommended |
| 30°↓ | Snow | Plow & apply chemical | 80-160 | 70-140 | 100-200* | Not recommended |
| | Frz. rain | Apply chemical | 150-200 | 130-180 | 180-240* | Not recommended |
| 25-30°↑ | Snow | Plow & apply chemical | 120-160 | 100-140 | 150-200* | Not recommended |
| | Frz. rain | Apply chemical | 150-200 | 130-180 | 180-240* | Not recommended |
| 25-30°↓ | Snow | Plow & apply chemical | 120-160 | 100-140 | 150-200* | Not recommended |
| | Frz. rain | Apply chemical | 160-240 | 140-210 | 200-300* | 400 |
| 20-25°↑ | Snow or frz. rain | Plow & apply chemical | 160-240 | 140-210 | 200-300* | 400 |
| 20-25°↓ | Snow | Plow & apply chemical | 200-280 | 175-250 | 250-350* | Not recommended |
| | Frz. rain | Apply chemical | 240-320 | 210-280 | 300-400* | 400 |
| 15-20°↑ | Snow | Plow & apply chemical | 200-280 | 175-250 | 250-350* | Not recommended |
| | Frz. rain | Apply chemical | 240-320 | 210-280 | 300-400* | 400 |
| 15-20°↓ | Snow or frz. rain | Plow & apply chemical | 240-320 | 210-280 | 300-400* | 500 for frz. rain |
| 0 to 15° ↑↓ | Snow | Plow, treat with blends, sand hazardous areas | Not recommended | 300-400 | Not recommended | 500-750 spot treat as needed |
| <0° | Snow | Plow, treat with blends, sand hazardous areas | Not recommended | 400-600** | Not recommended | 500-750 spot treat as needed |

***Dry salt is not recommended. It is likely to blow off the road before it melts ice.**

# Chloride power deicing application rates

Understanding how adding liquid deicers reduces your need for granular products is important. It can give you a chloride boost while increasing the speed of melting and decreasing bounce and scatter.

As found in the Michigan Department of Transportation study on bounce and scatter, when dry salt is applied to roads, approximately 30% of the application is lost to bounce and scatter when travelling at 35mph. The chloride-equivalent application rate shows how much prewet salt could be applied to have the same chloride power as the salt that remained on the road after subtracting the loss from bounce and scatter.

**Table 9:** Salt-equivalent deicing application rates

| Application Rates (pounds per two-lane mile) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weather Condition | | | | | Dry Salt | | Equivalent Application Rate Assuming all Salt Stays on the Road | | | | |
| Pavement Temp | | | | | | | Brine Prewet Rate (gallons/ton) | | | | |
| Low (°F) | High (°F) | Trend | Precip Type | Maintenance Actions | Salt Applied Low - High | Salt that Likely Stayed on the Road | 5 | 10 | 30 | 60 | |
| >30 | | up | Snow | Plow, treat intersections only | 100 - 100 | 70 | 63 | 56 | 28 | NR | |
| | | | Frz Rain | Apply Chemical | 100 - 200 | 70 - 140 | 63 - 133 | 56 - 126 | 28 - 98 | NR - 57 | |
| >30 | | down | Snow | Plow & apply chemical | 100 - 200 | 70 - 140 | 63 - 133 | 56 - 126 | 28 - 98 | NR - 57 | |
| | | | Frz Rain | Apply Chemical | 180 - 240 | 126 - 168 | 119 - 161 | 112 - 154 | 84 - 126 | 43 - 85 | |
| 25 | 30 | up | Snow | Plow & apply chemical | 150 - 200 | 105 - 140 | 98 - 133 | 91 - 126 | 63 - 98 | 22 - 57 | |
| | | | Frz Rain | Apply Chemical | 180 - 240 | 126 - 168 | 119 - 161 | 112 - 154 | 84 - 126 | 43 - 85 | |
| 25 | 30 | down | Snow | Plow & apply chemical | 150 - 200 | 105 - 140 | 98 - 133 | 91 - 126 | 63 - 98 | 22 - 57 | |
| | | | Frz Rain | Apply Chemical | 200 - 300 | 140 - 210 | 133 - 203 | 126 - 196 | 98 - 168 | 57 - 127 | |
| 20 | 25 | up | Either | Plow & apply chemical | 200 - 300 | 140 - 210 | 133 - 203 | 126 - 196 | 98 - 168 | 57 - 127 | |
| 20 | 25 | down | Snow | Plow & apply chemical | 250 - 350 | 175 - 245 | 168 - 238 | 161 - 231 | 133 - 203 | 92 - 162 | |
| | | | Frz Rain | Apply Chemical | 300 - 400 | 210 - 280 | 203 - 273 | 196 - 266 | 168 - 238 | 127 - 197 | |
| 15 | 20 | up | Snow | Plow & apply chemical | 250 - 300 | 175 - 210 | 168 - 203 | 161 - 196 | 133 - 168 | 92 - 127 | |
| | | | Frz Rain | Apply Chemical | 300 - 400 | 210 - 280 | 203 - 273 | 196 - 266 | 168 - 238 | 127 - 197 | |
| 15 | 20 | down | Either | Plow & apply chemical | 300 - 400 | 210 - 280 | 203 - 273 | 196 - 266 | 168 - 238 | 127 - 197 | |
| 0 | 15 | Either | Either | Plow, treat with blends, sand hazardous areas | NR | | NR | | | | |
| <0 | | Either | Either | Plow, treat with blends, sand hazardous areas | NR | | NR | | | | |

Table 9 shows how much was applied (1st column), how much likely stayed on the road (2nd column) at 35 mph delivery speed, and how you might set your application rate using brine at variousf ratios to get essentially the same amount of chloride on the road. It assumes all the prewet salt and brine stay on the road from delivery.

# Deicing application rate tables: for dry salt, prewet salt and liquid only applications

**(Clear Roads research: Material Application Methodologies Guidebook, 2019)**

DLA Application rate charts are rapidly evolving. Keep an eye out for updates. These Clear Roads charts serve as a good example of DLA rates.

- Use lower end of range for lower service goals or shorter cycle times
- User higher end of range for higher service goals, long cycle times, or greater dilution potential
- Plow to remove as much snow or ice as possible before material application
- Abbreviations: lb./LM = pounds per lane mile, G/LM = gallons per lane mile, *NR* = Not Recommended

## Application rate guidelines for light snow (<1 in/hr., <4" in 24 hrs.)

**Table 10:** Clear Roads deicing application rates for light snow

| | | Material application | | | | | |
|---|---|---|---|---|---|---|---|
| | | Liquid (G/LM) | | | Solid (lb./LM) | | |
| **Pavement Temp. Range, Trend** | **Road Surface Condition** | **NaCl** | **$MgCl_2$** | **$CaCl_2$** | **Dry NaCl** | **Pre-wet NaCl** | **Abrasives (less than 20% salt added)** |
| 32°F steady or rising | Dry | *NR* | | | *NR* | | |
| | Icy patches | 20-40 | 15-35 | 15-35 | 120-160 | 110-150 | *NR* |
| 32°F or below is imminent | Dry (snow forecast) | 20-40 | 15-35 | 15-35 | *NR* | 75-125 | *NR* |
| | Slush or light snow | 30-40 | 15-35 | 15-30 | 140-180 | 100-150 | *NR* |
| 25 to 32°F, remaining in range | Dry (snow forecast) | 30-50 | 20-40 | 20-40 | *NR* | 100-125 | *NR* |
| | Light snow cover | 40-60 | 20-40 | 20-40 | 160-200 | 125-175 | *NR* |
| 20-25°F, remaining in range | Dry (snow forecast) | 40-60 | 30-50 | 30-50 | *NR* | 125-175 | *NR* |
| | Light snow cover | 50-80 | 20-40 | 20-40 | 200-250 | 175-225 | *NR* |
| 15-20°F, remaining in range | Dry (snow forecast) | *NR* | 40-60 | 45-65 | *NR* | 175-225 | *NR* |
| | Light snow cover | *NR* | 45-65 | 45-65 | 250-300 | 200-250 | 500-750 |
| 0-15°F, steady or falling | Dry (snow forecast) | *NR* | | | *NR* | 200-250 | *NR* |
| | Light snow cover | *NR* | | | *NR* | 200-250 | 600-750 |
| Below 0°F, steady or falling | Light snow cover | *NR* | | | *NR* | *NR* | 600-750 |

# Application rate guidelines for moderate snow (1-2 in/hr., about 4-8" in 24 hrs.)

**Table 11:** Clear Roads deicing application rates for moderate snow

| | | Material application | | | | | |
|---|---|---|---|---|---|---|---|
| | | Liquid (G/LM) | | | Solid (lb./LM) | | |
| **Pavement Temp. Range, Trend** | **Road Surface Condition** | **NaCl** | **$MgCl_2$** | **$CaCl_2$** | **Dry NaCl** | **Pre-wet NaCl** | **Abrasives (less than 20% salt added)** |
| 32°F steady or rising | Dry | *NR* | | | *NR* | | |
| | Icy patches | 30-50 | 15-35 | 15-35 | 140-160 | 120-160 | *NR* |
| 32°F or below is imminent | Dry (snow forecast) | 20-40 | 15-35 | 15-35 | *NR* | 75-125 | *NR* |
| | Slush or light snow | *NR* | *NR* | *NR* | 140-180 | 100-150 | *NR* |
| 25 to 32°F, remaining in range | Dry (snow forecast) | 30-50 | 20-40 | 20-40 | *NR* | 100-150 | *NR* |
| | Light snow cover | 50-80 | 20-40 | 20-40 | 180-220 | 160-190 | *NR* |
| 20-25°F, remaining in range | Dry (snow forecast) | 40-60 | 30-50 | 30-50 | *NR* | 150-200 | *NR* |
| | Light snow cover | *NR* | *NR* | *NR* | 250-300 | 220-260 | *NR* |
| 15-20°F, remaining in range | Dry (snow forecast) | *NR* | 40-70 | 30-70 | *NR* | 200-250 | *NR* |
| | Light snow cover | *NR* | 40-75 | 30-70 | 325-375 | 275-325 | 500-750 |
| 0-15°F, steady or falling | Dry (snow forecast) | *NR* | | | *NR* | 300-350 | *NR* |
| | Light snow cover | *NR* | | | *NR* | 300-350 | 600-900 |
| Below 0°F, steady or falling | Light snow cover | *NR* | | | *NR* | *NR* | 600-900 |

# Application rate guidelines for heavy snow (>2 in/hr. >8" in 24 hrs.)

**Table 12:** Clear Roads deicing application rates for heavy snow

| | | Material application | | | | | |
|---|---|---|---|---|---|---|---|
| | | Liquid (G/LM) | | | Solid (lb./LM) | | |
| **Pavement Temp. Range, Trend** | **Road Surface Condition** | **NaCl** | **$MgCl_2$** | **$CaCl_2$** | **Dry NaCl** | **Pre-wet NaCl** | **Abrasives (less than 20% salt added)** |
| 32°F steady or rising | Dry | *NR* | | | *NR* | | |
| | Icy patches | 30-60 | 15-35 | 15-35 | 150-180 | 130-170 | *NR* |
| 32°F or below is imminent | Dry (snow forecast) | 20-40 | 15-35 | 15-35 | *NR* | 100-150 | *NR* |
| | Slush or light snow | *NR* | *NR* | *NR* | 150-200 | 125-175 | *NR* |
| 25 to 32°F, remaining in range | Dry (snow forecast) | 40-60 | 20-40 | 20-40 | *NR* | 125-175 | *NR* |
| | Light snow cover | 60-90 | *NR* | *NR* | 225-275 | 175-250 | *NR* |
| 20-25°F, remaining in range | Dry (snow forecast) | *NR* | 30-50 | *NR* | *NR* | 200-250 | *NR* |
| | Light snow cover | *NR* | *NR* | *NR* | 275-325 | 225-300 | 500 |
| 15-20°F, remaining in range | Dry (snow forecast) | *NR* | 40-70 | *NR* | *NR* | 200-250 | *NR* |
| | Light snow cover | *NR* | *NR* | *NR* | 300-350 | 275-325 | 500-750 |
| 0-15°F, steady or falling | Dry (snow forecast) | *NR* | | | *NR* | 300-350 | 600-900 |
| | Light snow cover | *NR* | | | *NR* | 400-500 | 600-900 |
| Below 0°F, steady or falling | Light snow cover | *NR* | | | *NR* | *NR* | 600-900 |

# Application rate guidelines for freezing rain

**Table 13:** Clear Roads deicing application rates for freezing rain

| | | Material application | | | | | |
|---|---|---|---|---|---|---|---|
| | | Liquid (G/LM) | | | Solid (lb./LM) | | |
| **Pavement Temp. Range, Trend** | **Road Surface Condition** | **NaCl** | **$MgCl_2$** | **$CaCl_2$** | **Dry NaCl** | **Pre-wet NaCl** | **Abrasives (less than 20% salt added)** |
| 32°F steady or rising | Icy patches | *NR* | | | *NR* | 125-175 | *NR* |
| 32°F or below is imminent | Slush or ice | *NR* | | | 180-240 | 140-180 | *NR* |
| 25 to 32°F, remaining in range | Slush or ice | *NR* | | | 200-275 | 180-225 | *NR* |
| 20-25°F, remaining in range | Slush or ice | *NR* | | | 250-350 | 225-300 | 500 |
| 15-20°F, remaining in range | Slush or ice | *NR* | | | 350-450 | 300-400 | 500-750 |
| 0-15°F, steady or falling | Slush or ice | *NR* | | | *NR* | *NR* | 600-750 |
| Below 0°F, steady or falling | Slush or ice | *NR* | | | *NR* | *NR* | 750-900 |

# Definition of terms

**°C** – degrees Celsius

**°F** – degrees Fahrenheit

**Above Ground Storage Tank (AST)** – Tanks that are above-ground that contain liquid substances. Product types in the tanks include liquid deicers.

**Abrasive** – Product used to provide traction on top of snow or ice e.g., sand.

**Anti-icing** – Application of liquid deicer before a storm

**Application rate** – Amount of material that is put down on an area. For this manual, typical units are measured in gallons/ton, lbs./two-lane miles, and gallons/mile.

**AVL** – Automatic Vehicle Locating

**Bare pavement** – level of service goal to remove of all snow or ice from a surface.

**Best practices** – Methods that have been established in an industry as the most effective and efficient.

**Brine** – Liquid deicer made from water and rock salt (NaCl)

**CaCl2** – Calcium Chloride

**Chloride** – Common chemical component in deicer.

**Deicer** – Product used to melt snow or ice e.g., rock salt.

**Deicing** – Application of deicer during or after a weather event.

**DLA** – Direct Liquid Application (liquid only application)

**GPS** – Global Positioning System

**Ice melt capacity** – Fixed amount of snow or ice that a given amount of deicer will melt.

**Ice melt speed** – How fast snow or ice melts

**Lbs.** – Pounds

**Level of service goal (LOS)** – Established target for how clear a surface needs to be in a given time frame.

**MDSS** – Maintenance Decision Support System

**Mechanical removal** – Using equipment to physically remove snow and ice from a surface (i.e., plowing)

**MgCl2** – Magnesium Chloride

**MnDOT** – Minnesota Department of Transportation

**MPCA** – Minnesota Pollution Control Agency

**Municipal Separate Storm Sewer System (MS4)** – Conveyance of system of conveyances that is owned or operated by a public entity, designed, or used for collecting stormwater, not a combined sewer, and not part of a publicly owned treatment works.

**Municipal Separate Storm Sewer System (MS4) General Permit** – Designed to reduce the number of pollutants entering state waters from stormwater systems. Entities that are located in an urbanized areas with a population of at least 1,000 or owned by a municipality with a population of at least 10,000 or have a population of at least 5,000 and the system discharges to specially classified bodies of water must satisfy the permit requirements. These entities must develop a stormwater pollution prevention program and adopt best practices.

**NaCl** – Sodium Chloride

**Non-bare pavement** – Level of service goal that allows for some snow or ice to remain on a surface.

**Other Regulated Substances** – Tanks storing products that have the potential to pollute the waters of the state but are not hazardous materials or petroleum. Chloride containing liquid deicers falls into this category.

**Pavement temperature** – The temperature of the surface. For our purposes this refers to the temperature of the road.

**Pretreating** – Adding liquid to rock salt stockpile.

**Prewetting** – Liquid and granular materials mixed at point of discharge.

**RPM** – Revolution Per Minute

**RWIS** – Road Weather Information System

**Salt** – Chloride-based product used for deicing.

**Smart Salting** — Statewide certification program administered by the MPCA with the goal of reducing salt use.

**Snow and ice policy** — A document outlining your strategy for winter maintenance operations.

**Spread pattern** – Where the deicers or abrasives come to rest after application.

**Water quality standard** – In Minnesota, the aquatic life chloride water quality standards are 230mg/L (chronic) and 860mg/L (acute). The drinking water standard for taste is 250 mg/L.

# Resources

## MPCA Smart Salting program

- Training program overview: https://www.pca.state.mn.us/business-with-us/smart-salting-training
- Training calendar: https://www.pca.state.mn.us/smart-salting-trainings
- Smart Salting Tool: https://smartsaltingtool.com/
- Smart Salting Contact: smartsalting.pca@state.mn.us

## Manuals

- *Smart Salting for Parking Lots and Sidewalks.* Minnesota Pollution Control Agency. https://www.pca.state.mn.us/sites/default/files/p-tr1-10.pdf
- *Smart Salting for Property Management.* Minnesota Pollution Control Agency. https://www.pca.state.mn.us/sites/default/files/p-tr1-11.pdf
- *Minnesota's Stormwater Manual.* Minnesota Pollution Control Agency. https://www.pca.state.mn.us/business-with-us/minnesota-stormwater-manual
- *Minnesota Snow and Ice Control Handbook for Snowplow Operators.* Minnesota Local Road Research Board. Minnesota Department of Transportation. https://www.mnltap.umn.edu/publications/handbooks/documents/snowice_2022.pdf

## Winter maintenance

- *Talkin Winter Ops.* AASHTO https://sicop.transportation.org/stwo/
- *Grip Sensor Technology and Salt Applications.* Clear Roads. https://clearroads.org/project/21-01/
- *Planning: Plow Route Optimization.* Clear Roads. https://clearroads.org/plow-route-optimization/
- *Calibration Guide for Ground-Speed-Controlled and Manually Controlled Material Spreaders.* Clear Roads. http://clearroads.org/wp-content/uploads/dlm_uploads/05-02_WisDOT-0092-06-21_Calibration-Final-Calibration-Guide.pdf
- *Benefit-Cost of Various Winter Maintenance Strategies.* Clear Roads. http://clearroads.org/wp-content/uploads/dlm_uploads/FR_CR.13-03_Final.pdf
- *Winter Friction Project in Norway.* Transportation Research Record: Journal of the Transportation Research Board. https://journals.sagepub.com/doi/10.3141/1741-06

### Deicers and materials

- *Materials: Liquid Materials.* Clear Roads. https://clearroads.org/materials-liquid-materials/
- *Material Application Methodologies Guidebook.* Clear Roads. https://clearroads.org/wp-content/uploads/dlm_uploads/Guidebook_CR15.01_FINAL_7-28-19.pdf
- *Application Rate Guidance for Salt Brine Blends for Direct Liquid Application and Anti-icing.* Clear Roads. https://

clearroads.org/wp-content/uploads/dlm_uploads/Application-Rate-Guidance_CR.19-01.pdf

- *Assessing the Effectiveness of Potassium Acetate to Control Snow and Ice on Minnesota Highways.* Minnesota Department of Transportation. http://www.dot.state.mn.us/research/reports/2020/202020.pdf
- *Efficacy, Cost, and Impacts of Non-Chloride Deicers.* Clear Roads. https://clearroads.org/project/21-03/
- *Determining the Toxicity of Deicing Materials.* Clear Roads. https://clearroads.org/project/11-02/
- *Chloride Free Snow and Ice Control Material.* Local Road Research Board. https://lrrb.org/media/reports/TRS1411.pdf
- *Salt Bounce and Scatter Study.* Michigan Department of Transportation. https://www.drscw.org/wp-content/uploads/2019/01/MDOT-Bounce-and-Scatter-Final_ReportNov2012_404228_7.pdf

### Weather

- National Weather Service. https://www.noaa.gov/
- Minnesota 511. https://511mn.org

# Policy/Rules/Guidance

- *Model Snow and Ice Management Policy Form.* Minnesota Pollution Control Agency. https://www.pca.state.mn.us/sites/default/files/p-tr1-51a.pdf
- *Model Chloride Reduction Ordinance Language.* Minnesota Pollution Control Agency. https://www.pca.state.mn.us/sites/default/files/p-tr1-54.pdf
- *Model Snow and Ice Management Contract Form.* Minnesota Pollution Control Agency. https://www.pca.state.mn.us/sites/default/files/p-tr1-52a.pdf
- Winter Maintenance Management Plan Templates
  - Basic: https://www.bassettcreekwmo.org/download_file/view/4952/545
  - Intermediate: https://www.bassettcreekwmo.org/download_file/view/4953/545
  - Detailed: https://www.bassettcreekwmo.org/download_file/view/4954/545
- *Amending Section 10.28(1) of the Madison General Ordinances to Limit the Use of Salt and Melting Agents on Sidewalks.* City of Madison. https://madison.legistar.com/ViewReport.ashx?M=R&N=Master&GID=205&ID=5837868&GUID=C7AC0B61-E138-4B58-A78D-5D865F4659FF&Extra=WithText&Title=Legislation+Details+(With+Text)
- *Liquid salt storage guidance and regulations.* Minnesota Pollution Control Agency. https://www.pca.state.mn.us/sites/default/files/p-tr1-12.pdf

# MS4 Permit

- MS4 Permit Information: https://www.revisor.mn.gov/rules/7090/
- *Guidance for Meeting Chloride TMDL MS4 Permit Requirements.* Minnesota Stormwater Manual. https://stormwater.pca.state.mn.us/index.php?title=Guidance_for_meeting_chloride_TMDL_MS4_permit_requirements
- *Stormwater Mapping Tool – MS4 Program.* Minnesota Pollution Control Agency. https://www.arcgis.com/apps/webappviewer/index.html?id=8d310e604baa43699b25395834d0c69a

# Funding

- MPCA Small Business Environmental Assistance Loan Program: https://www.pca.state.mn.us/grants-and-loans/small-business-environmental-improvement-loans
- MPCA Clean Water Partnership Loans: https://www.pca.state.mn.us/grants-and-loans/clean-water-partnership-loans
- MPCA Chloride Reduction Grants: https://www.pca.state.mn.us/business-with-us/grants-loans-and-contracts

# Assistance

- Minnesota GreenCorps: https://www.pca.state.mn.us/business-with-us/minnesota-greencorps
- GreenStep Cities: https://greenstep.pca.state.mn.us/

# Vegetation

- *Plant Selector Program.* Minnesota Department of Transportation. https://plantp.dot.state.mn.us/plant/
- *Interactive Plant Selection Tool.* Minnesota Department of Transportation. http://www.dot.state.mn.us/roadsides/plantselector/index.html
- *Plants for Stormwater Design – Minnesota Stormwater Manual.* Minnesota Pollution Control Agency. https://stormwater.pca.state.mn.us/index.php/Minnesota_plant_lists
- *Best Management Practices for Establishment of Salt Tolerant Grasses on Roadsides.* Minnesota Department of Transportation. http://dot.state.mn.us/research/reports/2017/201731.pdf
- *Living Snow Fences.* Minnesota Department of Transportation. https://www.dot.state.mn.us/environment/livingsnowfence/cost-benefit.html

# Chloride resources

- *Minnesota Statewide Chloride Management Plan.* Minnesota Pollution Control Agency. https://www.pca.state.mn.us/sites/default/files/wq-s1-94.pdf
- MPCA Chloride page: www.pca.state.mn.us/pollutants-and-contaminants/chloride
- City of Minneapolis Commercial Stormwater Credits: https://www.minneapolismn.gov/resident-services/utility-services/stormwater/commercial-stormwater-credits

# Water softening resources

- MPCA Water Softening Resources: https://www.pca.state.mn.us/business-with-us/statewide-chloride-resources (Go to Water softening.)
- University of Minnesota Water Resources Center: https://www.wrc.umn.edu/watersoftening
- Minnesota Water Quality Association: http://www.mwqa.com

# Low Salt Infrastructure Design resources

- *Episode 72: Designing in salt reduction.* AASHTO. https://sicop.transportation.org/episode-72-designing-in-salt-reduction/

# General

- MPCA Turfgrass Maintenance training program overview: https://www.pca.state.mn.us/business-with-us/turf-grass-maintenance-training
- *County Geologic Atlas (CGA).* Minnesota Department of Natural Resources. https://www.dnr.state.mn.us/waters/groundwater_section/mapping/county-geo-atlas.html
- *Managing Street Sweepings.* Minnesota Pollution Control Agency. https://www.pca.state.mn.us/sites/default/files/w-sw4-54.pdf

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Stefan H., Novotny E., Sander A., Mohseni O. (2008) *Study of Environmental Effects of Deicing Salt on Water Quality in the Twin Cities Metropolitan Area, Minnesota.* Minnesota Department of Transportation. https://www.lrrb.org/media/reports/200842.pdf

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# Appendix A: Minnesota Statutes applicable to winter maintenance

## Discharges to Waters of the State.

### Minnesota Rules 7053.0205 (2017)

Subp. 2. Nuisance conditions prohibited. No sewage, industrial waste, or other wastes may be discharged from either point or nonpoint sources into any waters of the state so as to cause any nuisance conditions, such as the presence of significant amounts of floating solids, scum, visible oil film, excessive suspended solids, material discoloration, obnoxious odors, gas ebullition, deleterious sludge deposits, undesirable slimes or fungus growths, aquatic habitat degradation, excessive growths of aquatic plants, or other offensive or harmful effects.

## Liquid deicer storage regulation.

### Minnesota Rules, Chapter 7151

The general requirements for ASTs with less than one-million-gallon capacity include: registration with the MPCA, properly labeled tanks, secondary containment, a sign at the facility, and tank construction using appropriate industry standards. However, liquid de-icing materials are considered Other Regulated Substances and are not subject therefore to the same regulations as hazardous materials because they have limited risk. The MPCA does not require the registration of other regulated substance ASTs. The basic requirements for most liquid deicer storage include labeling all tanks, having a posted sign on site, and secondary containment. However, the size and location of ASTs containing deicers will influence the specific regulations that are required. Here is a summary of requirements that may apply to deicer storage tanks:

- **Labeling ASTs containing deicer:** All tanks must be clearly labeled indicating the type of substance stored and the tank's capacity. If there is more than one tank, each tank must be labeled with a unique tank number.
- **Sign posting:** If a person is not on site 24 hours a day, a sign must be posted with the name, address, and telephone number of the facility owner or operator, or a local emergency response contact. The sign must be posted so that it can be seen outside any containment area.
- **Secondary containment:** Other regulated substance ASTs need 100% containment area volume of the largest tank in the containment area. An additional 10% capacity is required for ASTs exposed to precipitation. Double-walled tanks satisfy the secondary containment requirement.

For guidance on liquid storage, not specific to deicers visit:

- MPCA General Requirements for Aboveground Storage
- MPCA Indoor Storage Tank Factsheet

# Snow Removal; Salt and Chemicals Restricted.

## Minnesota Rules 160.215

*(1) Minimize harmful or corrosive effects of salt or other chemicals upon vehicles, roadways, and vegetation;*
*(2) Reduce the pollution of waters; and*
*(3) Reduce the driving hazards resulting from chemicals on windshields; road authorities, including road authorities of cities, responsible for the maintenance of highways or streets during periods when snow and ice are prevalent, shall utilize such salt or other chemicals only at such places as upon hills, at intersections, or upon high-speed or arterial roadways where vehicle traction is particularly critical, and only if, in the opinion of the road authorities, removal of snow and ice or reduction of hazardous conditions by blading, plowing, sanding, including chemicals needed for free flow of sand, or natural elements cannot be accomplished within a reasonable time.*

# Street sweepings.

## Minnesota Rules 7035.2855.

Street sweepings that are not screened for trash and debris are considered industrial solid waste and must be disposed of at a permitted solid waste facility that can accept the waste. Unscreened street sweepings must also be stored in accordance with solid waste storage standards.

# MS4 general permit.

## Minnesota Rules chapter 7090

An MS4 is a system of conveyance that is owned by a state, city, town, or other public entity that discharges to waters of the United States. It is designed to collect or convey stormwater that is not part of a sewage treatment plant. Certain operators are required to obtain NPDES permits and develop stormwater management programs (SWMPs) to prevent pollutants from being washed or dumped into MS4s. The SWMP describes the stormwater control practices that will be implemented consistently with permit requirements to reduce pollutant discharge from the sewer system.

### Chloride specific language in the 2020 MS4 permit:

*MCM 1: Public Education and Outreach.*

16.5 At least once each calendar year, the permittee must distribute educational materials or equivalent outreach focused on the following:

a. Impacts of deicing salt use on receiving waters; and
b. Methods to reduce deicing salt use.

16.6 For businesses, commercial facilities, and institutions, the permittee must implement an education and outreach program focused on communicating appropriate deicing salt use (e.g., direct mailing, phone calls, and/or meetings). The permittee must maintain a written or mapped inventory of businesses, commercial facilities, and institutions that the permittee will target for education and outreach over the permit term. At a frequency defined

by the permittee's education and outreach plan in item 16.8, the permittee must distribute educational materials or equivalent outreach to these audiences, which must include information on the following:

a. Environmental impacts of deicing salt use;
b. BMPs that reduce the use of deicing salt;
c. Proper storage of salt or other deicing materials; and
d. Training opportunities to improve winter maintenance activities.

*MCM 3: Illicit Discharge Detection and Elimination (IDDE).*

18.6 The permittee's regulatory mechanism(s) must require proper salt storage at commercial, institutional, and non-NPDES permitted industrial facilities. At a minimum, the regulatory mechanism(s) must require the following:

a. Designated salt storage areas must be covered or indoors;
b. Designated salt storage areas must be located on an impervious surface; and
c. Implementation of practices to reduce exposure when transferring material in designated salt storage areas (e.g., sweeping, diversions, and/or containment).

*MCM 6: Pollution Prevention/Good Housekeeping For Municipal Operations.*

21.5 The permittee must implement the following BMPs at permittee owned/operated salt storage areas:

a. Cover or store the salt indoors;
b. Store salt on an impervious surface; and
c. Implement practices to reduce exposure when transferring material from salt storage areas (e.g., sweeping, diversions, and/or containment). [Minn. R. 7090]

21.6 The permittee must implement a written snow and ice management policy for staff that perform winter maintenance activities. The policy must establish practices and procedures for snow and ice control operations (e.g., plowing or other snow removal practices, sand use, and application of deicing compounds).

21.7 Each calendar year, the permittee must train all staff that perform winter maintenance activities. The permittee may use training materials from the Agency's Smart Salting Training or other organizations to meet this requirement. The employee training program must include:

a. The importance of protecting water quality;

b. BMPs to minimize the use of deicers (e.g., proper calibration of equipment and benefits of pretreatment, pre-wetting, and anti-icing); and

c. Tools and resources to assist in winter maintenance (e.g., deicing application rate guidelines, calibration charts, Smart Salting Assessment Tool).

*Discharges to Impaired Waters with a USEPA-Approved TMDL that Includes an Applicable Waste Load Allocation (WLA).*

22.5 If the permittee has an applicable WLA for chloride, the permittee must document the amount of deicer applied each winter maintenance season to all permittee owned/operated surfaces.

22.6 If the permittee has an applicable WLA for chloride, each calendar year the permittee must conduct an assessment of the permittee's winter maintenance operations to reduce the amount of deicing salt applied to permittee owned/operated surfaces and determine current and future opportunities to improve BMPs. The permittee may use the Agency's Smart Salting Assessment Tool or other available resources and methods to complete this assessment. The permittee must document the assessment. The assessment may include, but is not

limited to: a. operational changes such as pre-wetting, pre-treating the salt stockpile, increasing plowing prior to deicing, monitoring of road surface temperature, etc.; b. implementation of new or modified equipment providing pre-wetting, or other capability for minimizing salt use; c. regular calibration of equipment; d. optimizing mechanical removal to reduce use of deicers; or e. designation of no salt and/or low salt zones.

# Industrial stormwater general permit. Minnesota Rules 7090.3000

**17.1 Salt storage, use, and management at the facility (if present at the facility).**

17.2 The Permittees should implement the following BMPs if salt piles are present at the facility:

a. Cover salt piles or store the salt piles indoors;

b. Minimize the use of salt or other de-icing/anti-icing materials by using the proper equipment, material, and application rates.

c. Implement practices to reduce exposure resulting from adding or removing material from the salt piles (e.g., sweeping, diversions, containment); and

d. Document within the SWPPP the location of any storage piles containing salt

# Appendix B: Chloride loading calculation templates & examples

Reference Table 2 and Table 3 when completing calculations.

## Absolute quantity of chloride

**Table 2:** Chloride content in granular deicers

| Deicer chemical | Absolute quantity of chloride | Chloride in 1 Lb. of deicer |
|---|---|---|
| NaCl | 60.66% | 0.6066 lbs. |
| $MgCl_2$ | 74.47% | 0.7447 lbs. |
| $CaCl_2$ | 63.89% | 0.6389 lbs. |

**Table 3:** Chloride content in liquid deicers

| Deicer chemical | Absolute quantity of chloride | Standard brine concentration | Calculation | Chloride |
|---|---|---|---|---|
| NaCl 9.84 lbs./gal | 60.66% | 23.3% | (0.233)x(9.84)x(0.6066) | 1.39 lbs. Cl per gallon |
| $MgCl_2$ 10.7 lbs./gal | 74.47% | 30% | (0.30)x(10.7)x(0.7447) | 2.39 lbs. Cl per gallon |
| $CaCl_2$ 10.8 lbs./gal | 63.89% | 30% | (0.30)x(10.8)x(0.6389) | 2.07 lbs. Cl per gallon |

You can adjust these calculations based on the percent of chloride product you are applying. (i.e. if you use 28% $MgCl_2$ adjust the equation)[1]

1 These values are representative of completely anhydrous (0% water content) compounds. Hydrate forms of these chemicals are more common than their anhydrous forms in typical solid calcium chloride and magnesium chloride ice melt products. As a result, the mass of chloride listed for the chemicals above will be greater than actual chloride content of packaged deicers. However, this is still a useful way to express relative chloride content.

Calculations provided and reviewed by Doug Klimbal, Bolton & Menk and Scott Koefod, Cargill

# **Template 1:** Worksheet for PREWET chloride load calculation

## Setup

| | |
|---|---|
| Area of Operations:<br>Area applied | ,<br>% |
| Application Rate | , |
| Material | , , |
| Number of Applications | |

## Calculations

1. Chloride from Granular Material

*Application Rate × CI Quantity × Salted Area*

× × _.__ = ___._ *pounds*

2. Chloride from Liquid Material

*Material × Application Rate*

× = __._ *gallon*

3. Chloride per Application

*Granular Material + (Liquid Material × CI per Gallon)*

___._ + (__ × )= ___._ *pounds*

4. Total Chloride Load

*Chloride per Application × Number of Applications*

___._ × =____ *pounds $Cl^-$ per year for Area of Operations*

# **Example 1:** PREWET chloride loading calculation

## Setup

| | |
|---|---|
| Area of Operations:<br>Area applied | 1-mile paved road, 2 lanes (24') wide,<br>100%salted surface |
| Application Rate | 200 lbs. per two-lane mile |
| Material | Rock salt (60.66% chloride<br>Prewet with 10 gallons/ton brine (1.39 pounds chloride per gallon) |
| Number of Applications | 17 |

## Calculations

1. Chloride from Granular Material

*Application Rate × Cl Quantity × Salted Area*

200 × 0.6066 × 1.00 = *121.3 pounds*

Rock Salt is approximately 60.66% chloride by mass as shown in Table 2, so 200 pounds of rock salt contains 121.3 pounds of chloride. The third term (1.00) expresses 100% of the area is salted

2. Chloride from Liquid Material

*Material × Application Rate*

$$\frac{10}{2{,}000} \times 200 = 1.0 \text{ gallon}$$

Prewet rate is 10 gallons of brine per ton of salt (2,000 pounds). Using 200 pounds of rock salt, we'll need to add 1 gallon of brine.

3. Chloride per Application

*Granular Material + (Liquid Material × Cl per Gallon)*

121.3 + (1.0 × 1.39 )= *122.7 pounds*

Add the granular and liquid materials together. Using Table 3, we see 1.0 gallons of brine prewet contains 1.39 pounds of chloride.

4. Total Chloride Load

*Chloride per Application × Number of Applications*

122.7 × 17 = ***2,085 pounds $Cl^-$ per year***

Multiply the total chloride per application by the total number of applications for your area of operations outlined in the setup.

# **Template 2:** Worksheet for DRY SALT ONLY chloride load calculation

## Setup

| | |
|---|---|
| Area of Operations:<br>Area applied | ,<br>% |
| Application Rate: | |
| Material: | |
| Number of Applications: | |

## Calculations

1. Chloride from Granular Material

*Application Rate × Cl Quantity × Salted Area*

× × = ___._ *pounds*

2. Total Chloride Load

*Chloride per Application × Number of Applications*

___._ × =____ *pounds $Cl^-$ per year for Area of Operations*

# **Example 2:** DRY SALT ONLY chloride loading calculation

## Setup

| | |
|---|---|
| Area of Operations:<br>Area applied | 1-mile paved road, 2 lanes (24') wide,<br>25% salted surface (spot treated) |
| Salt Application Rate | 200 lbs. per two-lane mile |
| Material | Dry Rock Salt<br>(60.66% chloride) |
| Number of Applications | 17 |

## Calculations

1. Chloride from Granular Material

*Application Rate × Cl Quantity × Salted Area*

200 × 0.6066 × 0.25 = *30.4 pounds*

Rock Salt is approximately 60.66% chloride by mass as shown in Table 2, so 200 pounds of rock salt contains 121.3 pounds of chloride. The third term (0.25) expresses 25% of the area is salted. If you salt everything use "1" as the multiplier not 0.25.

2. Total Chloride Load

*Chloride per Application × Number of Applications*

30.4 × 17 = ***517 pounds $Cl^-$ per double -- lane mile year***

Since there is no liquid additive, the total chloride load is the product of chloride from granular materials and number of applications.

# **Template 3:** Worksheet for DRY SALT/SAND ONLY chloride load calculation

## Setup

| | |
|---|---|
| Area of Operations:<br>Area applied | ,<br>% |
| Application Rate:<br>*For salt sand mixes subtract out the sand | |
| Material: | |
| Number of Applications: | |

## Calculations

1. Chloride from Granular Material

*Application Rate × Cl Quantity × Treated Area*

× × _.__ = ___._ *pounds*

2. Total Chloride Load

*Chloride per Application × Number of Applications*

___._ × =____ *pounds $Cl^-$ per year for Area of Operations*

# **Example 3:** DRY SALT/SAND ONLY chloride loading calculation

## Setup

| | |
|---|---|
| Area of Operations:<br>Area applied | 1-mile paved road, 2 lanes (24') wide,<br>25% salted surface (spot treated) |
| Salt Application Rate<br>*For salt sand mixes subtract out the sand | 500 lbs./salt/sand mix at 10-90 =<br>50 lbs. salt per lane mile |
| Material | Winter Sand<br>(Dry Rock Salt is 60.66% chloride) |
| Number of Applications | 17 |

## Calculations

1. Chloride from Granular Material

*Application Rate × Cl Quantity × Treated Area*

50 × 0.6066 × 0.25 = *7.6 pounds*

Rock Salt is approximately 60.66% chloride by mass as shown in Table 2, so 200 pounds of rock salt contains 121.3 pounds of chloride. The third term (0.25) expresses 25% of the area is salted

2. Total Chloride Load

*Chloride per Application × Number of Applications*

7.6 × 17 = ***129 pounds $Cl^-$ per single -- lane mile per year***

Since there is no liquid additive, the total chloride load is the product of chloride from granular materials and number of applications.

# **Template 4:** Worksheet for LIQUID ONLY APPLICATION chloride load calculation from ANTI-ICING/DLA

## Setup

| | |
|---|---|
| Area of Operations:<br>Area applied | ,<br>% |
| Application Rate: | |
| Material: | |
| Number of Applications: | |

## Calculations

1. Chloride per Application

*Application Rate × CI Quantity × Treated Area*

× × = ____ *pounds*

2. Total Chloride Load

*Chloride per Application × Number of Applications*

___.__ × = ____ *pounds $Cl^-$ per year for Area of Operations*

# **Example 4:** LIQUID ONLY APPLICATION chloride loading calculation from ANTI-ICING/DLA

### Setup

| | |
|---|---|
| Area of Operations:<br>Spread area: | 1-mile paved road, 1 lane (12') wide,<br>100% treated |
| Application Rate | 35 gallons per single lane mile |
| Material | Brine for Anti-icing<br>(1.39 pounds chloride per gallon) |
| Number of Applications | 17 |

### Calculations

1. Chloride per Application

*Application Rate × Cl Quantity × Treated Area*

35 × 1.39 × 1.00 = *48.6 pounds*

The brine application rate, amount of chloride per gallon of brine, and % of operations area which is treated using this method are multiplied to determine total chloride per application.

2. Total Chloride Load

*Chloride per Application × Number of Applications*

48.6 × 17 = ***827 pounds per single -- lane mile per year***

Total chloride per application is scaled based on the number of applications per year.

Notice that this example uses a single-lane mile instead of double in order to match the method of material application.

# **Template 5:** Worksheet for LIQUID ONLY APPLICATION chloride loading calculation from DUST SUPPRESSANT

## Setup

| | |
|---|---|
| Area of Operations:<br>Area applied | ,<br>___% treated |
| Application Rate: | |
| Material: | |
| Number of Applications: | |

## Calculations

1. Convert Area Measurements

*1 mile = 5,280 feet*

*Double – lane miles to square yards*

___ × ___ = ___ *square feet*

*1 square yard = 9 square feet*

___ ÷ *9* = ____ *square yards*

2. Gallons of Liquid Material

*Application Rate × Treated Area*

___ ×___ = ___ *gallons*

3. Total Chloride Load

*Gallons per Application × $Cl^-$ Quantity × Applications per year*

___× ___ × ___ = ___ *pounds per double – lane mile per year*

# **Example 5:** LIQUID ONLY APPLICATION chloride loading calculation from DUST SUPPRESSANTS

## Setup

| | |
|---|---|
| Area of Operations:<br>Spread area | 1-mile gravel road, 2 lanes (18') wide,<br>100% treated |
| Application Rate: | 0.25 gallons per square yard |
| Material: | Magnesium Chloride for Dust Control<br>(2.39 pounds chloride per gallon) |
| Number of Applications per year: | 1 |

## Calculations

1. Convert Area Measurements

*1 mile = 5,280 feet*

*Double – lane miles to square yards*

*5,280* × 18 = *95,040 square feet*

*1 square yard = 9 square feet*

*95,040 ÷ 9 = 10,560 square yards*

It's important to ensure we match our units for area of operations to the units used for our application rate. In this example, dust suppressants are applied based on a per square yard basis. These steps convert a mile-long stretch of roadway with 18' width to a square yard area.

2. Gallons of Liquid Material

*Application Rate × Treated Area*

0.25 × *10,560 = 2,640 gallons*

Using the per square yard application rate, calculate the total number of gallons for dust suppressant.

3. Total Chloride Load

*Gallons per Application × $Cl^-$ Quantity × Applications per year*

*2,640* × 2.39 × 1 = *6,309 pounds per double – lane mile per year*

Using Table 1, we see that each gallon of $MgCl_2$ contains 2.39 pounds of chloride. Multiplying the pounds of chloride per gallon by the total number of gallons yields the total chloride load.