Enhanced Winter Maintenance Training Manual

A guide to Smart Salting practices that protect our waterways, infrastructure, and health

Prepared by the
Interstate Commission on the Potomac River Basin
for the Maryland Department of the Environment

Disclaimers

The information contained in this manual was compiled and adapted from publicly available existing salt training programs that are cited within each module. The full citations can be found at the end of the document. Within the manual, the citation number applies to the sentence if it is found before the period. The citation number applies to the entire paragraph if it is located after the period at the end of a paragraph.

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Module 1. Basics: Why Should I Reduce Winter Salt Use?

Learning Objectives:

1. Learn about the history of salt.
2. Summarize the impacts these materials have on our health, infrastructure, and the environment.

Background

Winter salt

During the winter, deicers are used to melt ice and snow on our roadways, parking lots, and sidewalks to maintain public safety [12]. Salt, or sodium chloride, is the most common and cheapest deicing agent [8,14]. While winter salt helps make roads safer to travel, overapplication of salt leads to drinking water contamination, stream pollution, and corrosion of infrastructure such as cars and bridges [12]. This manual provides information about winter maintenance practices, known as Smart Salting, that save money and reduce the impacts of winter salt use.

Salt can be applied in a solid form like rock salt or in a liquid form by being mixed into a brine solution. **It can be used to prevent the accumulation of snow and ice on hard surfaces by being applied prior to winter storm events (anti-icing) and/or can be used during and after the storm event to melt ice and snow (deicing)** [14].

Salt needs moisture to begin melting snow and ice. When salt is first applied, it draws moisture from the surrounding snow or ice so it can become a salt and water solution. The salt dissolves into the water and becomes salt water, also known as brine. It is this brine that does the work to melt snow and ice to create safer driving and walking conditions. **While granular salts can be applied to the pavement, they don't start to melt snow and ice efficiently until it is part of a brine solution.** Pre-wetting rock salt can jumpstart the melting process by providing that initial bit of moisture needed to bring rock salt into a brine solution. [9]

Figure 1. Example of winter salt application. Image by JerzyGorecki from Pixabay.

History of winter salt use

Salt application on roads and paved surfaces for public safety has increased in the United States since the 1930s [14]. The fastest increase in winter salt application in the United States has occurred from the 1960s to present [14] and has doubled since 1975 [7]. This increase in salt use mirrors an increase in human population [8], the number of vehicles on the road [8], and the number of roads and paved surfaces that need maintenance during winter storms [7].

Apply salt wisely! Once in our waterways, it can't be taken back.

What is salt?

Winter Maintenance Options

Any contractor will tell you that having the right tool for the job is a key to success. While sodium chloride is the cheapest deicing agent [12], having access to a variety of deicing *tools* allows the response to be tailored to the situation [3]. Some situations will respond better using a traction agent while other times using a deicing agent will be most effective. Sometimes, only a broom is needed to get the job done right!

Deicers, which include chlorides and acetates and can be granular or liquid, are used to melt snow and ice [3]. They work by lowering the freezing point of water to a temperature below 32°F [10]. They can be harmful when washed into our waterways.

Figure 2. Example of liquid deicer (salt brine) and solid/granular deicer (rock salt). Image from McHenry County [11].

Abrasives, like sand, are used to increase traction on top of snow and ice but do not melt the snow or ice [3]. Also, like sand, it can add sediment to runoff, which impacts water clarity and wildlife habitat. This is especially important to consider in areas where there is already excess sediment in local waterways. In addition, abrasives can get in the air and create air quality issues and may lead to the release of heavy metals into the environment [10].

***Organic compounds*,** such as beet juice, molasses, or acetates, lower the freezing point of deicers and alter the formation of ice crystals. These are often agricultural byproducts and can be sticky [3]. The organic nature of these additives means that they carry nutrients that end up in streams and rivers — leading to changes in the aquatic plant and animal communities and increased frequency of algal blooms [10].

Figure 3. Example of an abrasive (sand) used to increase traction. Image from Fortin Consulting Inc. (2019) [3].

Acetates have the downside of being man-made, which means that adding them to the environment adds chemicals that do not naturally occur [1]. Additionally, they are corrosive with certain types of metals and can react with concrete [14]. In water, acetates compete with vegetation and aquatic wildlife for available oxygen and may contribute additional nutrients that can lead to algal blooms [10].

Deicer chemistry basics

Different deicers melt different amounts of snow and ice. To optimize the use of a deicer, it is important to consider these two factors [5]:

Ice melt capacity — how much snow and ice a given amount can melt.

Ice melt speed — how fast the deicing agent works to melt the snow and ice [5]. This depends on several elements:

- the temperature of the pavement and whether it is getting warmer or colder;
- which deicing agent is used;
- the precipitation type; and
- whether the deicing agent is in the liquid or granular form.

* List derived from [5].

Figure 4. Example of Organic Treated Salt. Salt can be Treated with Organic Materials such as Beet Juice. Image from Fortin Consulting Inc. (2019) [3].

Adding *more* salt won't make the ice and snow melt faster.

If the appropriate amount of salt is already applied, adding more will not melt snow and ice any faster nor increase safety. When temperatures are too cold, chemical deicers no longer work and adding more will not change that. [3]

Despite the higher ice melt capacity of granular deicers, they melt snow and ice more slowly and sit on the surface after application. When granular deicers sit on the surface they are frequently removed from their intended location by wind or foot traffic prior to ever melting snow or ice. [5]

Liquid deicers melt snow and ice faster than granular deicers, reduce the amount of salt entering the environment, and tend to stay where they are placed [5]. They also save money because less product is used overall.

Smart Salting winter maintenance professionals adapt to specific winter storm conditions and use the most appropriate material for the situation — liquid, granular, or both. Taking an adaptive approach to winter maintenance improves the efficiency and effectiveness of winter maintenance operations. [5]

Anti-icing before the winter storm is the most cost-effective and environmentally-friendly way to maintain safe winter conditions!

Deicing chemicals

By decreasing the freezing point of water, deicers make it possible for snow and ice to transition to a liquid state even when the temperature outside is lower than 32°F. The chemical composition of each deicer is responsible for determining the ice melt capacity and the speed at which the deicer works. [5]

Not all deicers work in every situation, thus it is important to pay attention to what you are purchasing. This can be difficult because there are no deicer labeling laws. [5]

In addition, the melting temperatures listed on deicer packaging can be confusing. Frequently, packaging lists the ***eutectic temperature***, which is the lowest possible temperature at which the deicer can melt ice. Using this temperature for guidance is impractical because it would take an extremely long time for the given deicer to melt ice at this temperature. Instead, the lowest ***practical melting temperature*** should be used. [1]

Figure 5. Example educational material showing the ideal order of winter maintenance. Note that snow removal is first. Image obtained from Maryland Department of the Environment.

The table below shows the following information for common deicers: eutectic temperature, lowest practical melting temperature, and the ***optimal concentration***. While there is no standard in determining the lowest practical melting temperature, it can be obtained by asking the supplier for the practical melting temperature of the given deicer and the time the deicer takes to melt ice at said temperature or by using the table below. [1]

Chemical	Lowest Practical Melting Temp.	Eutectic Temp.	Optimal Concentration
NaCl (Sodium Chloride)	15°F	-6°F	23%
MgCl2 (Magnesium Chloride)	-10°F	-28°F	27 to 30%
CaCl2 (Calcium Chloride)	-20°F	-60°F	30%
KAc (Potassium Acetate)	-15°F	-76°F	50%
Blends	Variable depending on chemicals in blend		x
Winter Sand/Abrasives	Never melts – provides traction only		x

Table 1. Table of Lowest Practical Melting Temperature, Eutectic Temperature, and Optimal Concentration for Common Deicers. Adapted from McHenry County (2010) [10].

The practical melting temperatures refer to real world conditions while the eutectic temperatures indicate the lowest possible temperature at which a deicer will work [1]. The table below shows how long it will take one pound of rock salt (NaCl) to melt differing amounts of ice. Make sure to note that different pavement temperatures influence the time needed for deicers to work.

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

Table 2. Table of Melt Times and Amounts for Rock Salt (NaCl). Reprinted from McHenry County (2010) [10].

Dry salts don't work below 15°F. Applications below this temperature wastes time and money!

Impacts

While winter salt is great at deicing and increasing public safety during winter storm events, the following section presents concerns associated with its over-application and incorrect use [8]. **There is a limited amount of usable, accessible freshwater on earth** [3].

When snow and ice melts, it flows to local waterways. In urban areas, water flows over roads, parking lots, and other impervious surfaces into storm drains and eventually into streams and rivers [3].

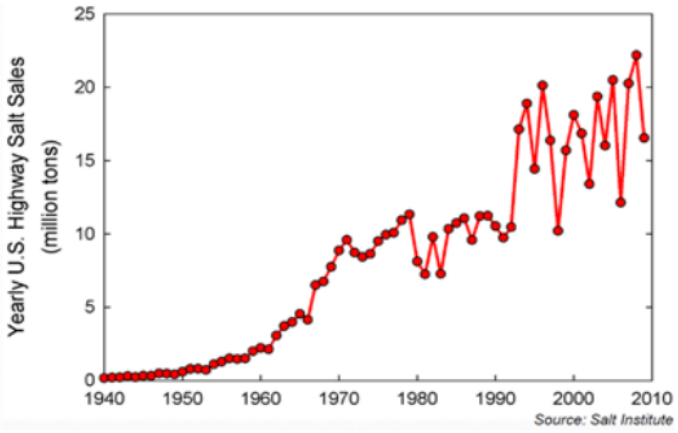


Figure 6. Trend in salt sales in the United States (1940-2010). Reprinted from [14].

Protecting public drinking water sources from accumulating excess salt is a big job. The Maryland public obtains drinking water from multiple sources — groundwater wells, local streams and rivers, and reservoirs. For example, the Potomac River provides drinking water for over five million people. In 2015, the Potomac River had sodium levels that were three times greater than just 25 years earlier. [8]

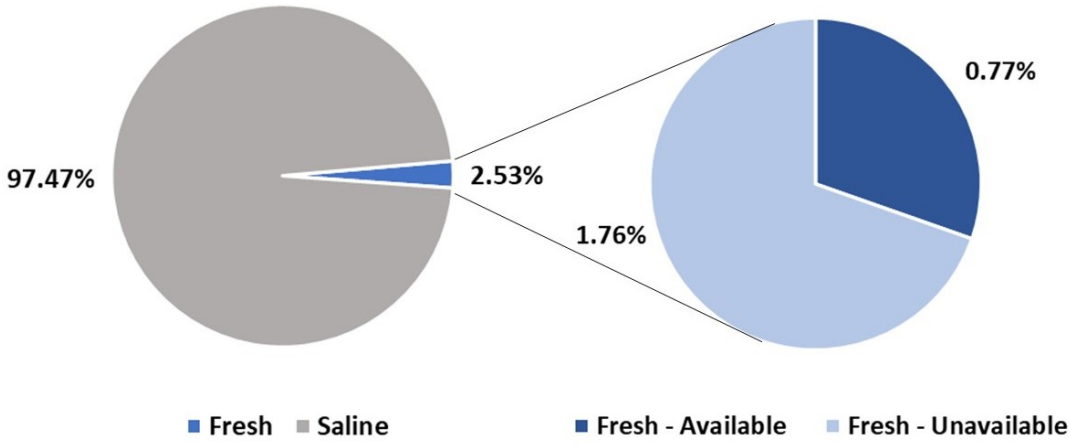


Figure 7. Pie charts depicting the amount of freshwater available on Earth. Only a fraction of the 2.5% of freshwater on Earth is available for human use. Image from ICPRB developed with data from USGS article, "Where is Earth's Water?"

Deicers should be used to break the bond between the pavement or road and ice, not to melt snow and ice off a surface.

By flowing into our waterways, the excess salt can impact human health, infrastructure, and the environment. [8]

It's not just rivers and streams impacted by winter salt use. Groundwater wells can be contaminated with salt due to natural recharge processes during the winter. About half of people in the United States rely on groundwater for their drinking water [3].

Salt is called a "forever pollutant" because it is not easily removed once it enters the environment.

The degree to which our local surface and ground-water are impacted depends on the type of winter salt, where and how they enter the environment, and how fast the salt travels to local waterways [14].

Figure 8. Example of excess salt pile near a curb on a Maryland sidewalk. Image from ICPRB.

Financial Costs

Winter salt use comes at a cost to our infrastructure, automobiles, vegetation, and the environment. Estimated damages can range from approximately $800 to $3300 per ton of salt applied. The total cost includes infrastructure damage, cost of materials, and labor and equipment of application. [6]

The table below shows how damage is the greatest portion of the true cost of winter salt use [6].

Table 3. Total Costs Associated with Using Winter Deicing Salts. Adapted from Fortin & Mulhern (2013) [6].

Item	Cost
Materials (salt)	$55/ton
Labor and Equipment to Apply Salt	$100/ton
Damages from Use of Salt	$800/ton - $3300/ton
Total Costs	**$955/ton - $3455/ton**

Winter salt applied to Maryland roads in response to winter storm events are important for public safety but can damage infrastructure in both the public and private sectors — including bridges, cars, stormwater treatment facilities, roads, and tunnels [8,14]. Overapplication and incorrect use can potentially lead to a faster rate of damage to infrastructure, corroding metals used in bridges, culverts, and pipes, and deteriorating concrete [8]. It can increase the number and size of cracks in concrete due to more frequent freeze/thaw cycles [14].

Figure 9. Example of corroded public-use infrastructure. Image by Brett Sayles from Pexels.

In bridges, the corrosion and rust that occurs in response to winter salt leads to an increase in the volume of the metal components. This leads to excess pressure on the non-metal components, or concrete, which can eventually result in concrete cracking. [8]

Chlorides can lead to deterioration of roads and sidewalks, making them uneven and full of potholes [8]. Water then makes its way into the cracks and freezes, creating excessive pressure on the concrete, making the problem worse. This occurs in a cyclical process throughout the winter season, leading to what is called the *freeze and thaw cycle* [8]. Eventually, the concrete will need to be replaced [3].

Estimating the true cost of winter salt to metal reinforced concrete is difficult, however, the best way to ensure cost savings is to prevent the issues from the beginning. [13]

Chlorides corrode the metal in culverts and pipes used for drinking water and may lead to toxins making their way into the water. Sodium (associated with sodium chloride used as winter deicing salts) can also corrode drinking water pipes, leading to higher sodium levels in our drinking water. [8]

Figure 10. Example of car (top) and metal reinforced concrete (bottom) corrosion. Top image by ICPRB. Bottom image from McHenry County courtesy of Scott Kuykendall.

Salts are especially damaging to vehicles that drive on treated roadways [8]. Other personal property that is subject to corrosion from chlorides include household appliances that use water such as washing machines, water heaters, shower heads, and even coffee makers. [8]

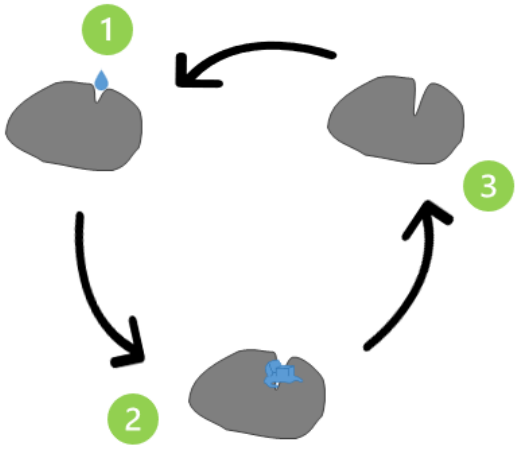


Figure 11. Example of the freeze/thaw cycle. (1) Water enters small cracks in rocks, concrete, and other impervious surfaces. (2) Water freezes, increasing pressure on the surrounding area leading to (3) The extra pressure causes the cracks to enlarge. Image from ICPRB.

Storm drains don't go to a treatment plant — they go to local Maryland waterways.

Health

Overapplication and incorrect use of winter salt can be associated with increased sodium levels in our sources of drinking water [8]. People can taste chlorides in drinking water at levels of 250 mg/L or above [3]. Additionally, high sodium levels in public drinking water contribute to an increase in the rate of cardiovascular, kidney, and liver diseases in the population and are associated with high blood pressure [8]. As of 2018, over 30% of Maryland adults have been diagnosed with high blood pressure [8]. Exacerbating high blood pressure can lead to a higher risk of stroke and heart disease [8].

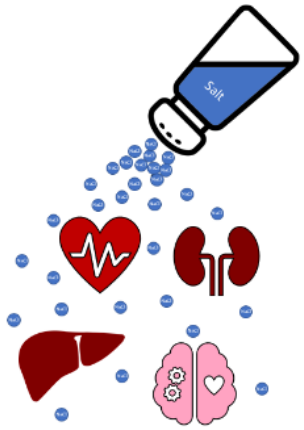


Figure 12. Salt impacts cardiac health, kidney and liver function, and can lead to stroke. Image from ICPRB.

A study that looked at the sodium concentrations of different wells in New York found drinking water sources that were around 30 mg/L, but some were as high as 860 mg/L. This is a significant amount to ingest for people on sodium restricted diets. [7]

In addition, children and pets who ingest water high in sodium are at risk of becoming ill [8].

Figure 13. Paws can become dry and cracked after exposure to winter salt on sidewalks. Image by Helgy from Canva.

Winter salt poses a risk to pets. There are no standards in place to guide the labeling of winter salt, which means that "pet friendly" can mean different things on different packages [6]. Not only are pets at risk if they ingest sodium-rich water, but they may ingest the salt itself that is applied to the ground by eating salty snow or licking their feet to relive the irritation from walking on winter salt [8]. In fact, some pets — namely certain bird species — can die when they ingest winter deicing salts [6].

Environment

Winter salt applied to Maryland roads, sidewalks, and parking lots can impact the local environment on multiple levels. When salts, especially excess salts tied to incorrect use and overapplication, make their way into local lakes and streams, it is a permanent pollutant and cannot be removed [10]. It impacts waterbodies by impairing the natural turnover processes in ponds and lakes, aquatic life health, and harming aquatic vegetation [3].

Currently there are 28 rivers and streams in Maryland that are impaired by chlorides [8].

It only takes 1 teaspoon of road salt to pollute 5 gallons of water!

While winter salt that mixes into water is permanently tied to the water, local water has a residence time, this is how long the water remains local before moving on in the global water cycle. As more salts are applied and enter the local watershed, the time between application and when the subsequent salty water is flushed from the watershed increases. **It is estimated that salt levels may take decades to stabilize in our freshwater as long as salt application does not increase.** Even after the rate of salt application is reduced, salt levels in our streams and rivers may still rise because of existing winter deicing salts that have not made it to waterways yet, such as those mixed in soils. [7]

Figure 14. Example of corroded manhole cover and stormwater infrastructure frequently exposed to salt-rich stormwater. Image from [3].

Aquatic Life

It's not just humans — freshwater fish don't like salty water, either.

In a typical water cycle, local lakes are subject to seasonal turnover (i.e., vertical mixing of water) which cycles nutrients and oxygen through the various depths of the lake. Water high in salts and chlorides is heavier than freshwater, and sinks to the bottom of lakes, disrupting the natural turnover cycles. This change in turnover prevents the bottom salty layers from mixing in and traps nutrients while also limiting the amount of oxygen available for aquatic life. [3]

The United State Environmental Protection Agency has established a chronic chloride concentration limit of 230 mg/Liter. **Water concentrations higher than 230 mg/L can negatively affect the survival, growth, and reproduction of fish, amphibians, aquatic macroinvertebrates, and even insects.** [3]

Every species has a range of salinity that they can tolerate. While it is uncommon for waterbodies to reach lethal levels of salinity for long durations, lethal levels may occur in some waterbodies in urban areas or temporarily during the period right after winter storm salt application. [7]

Figure 15. Image depicting the difference in seasonal turnover in a non-salty lake (left) and a salty lake (right). Reprinted from Fortin Consulting, Inc. (2019) [3].

It is easier to apply less salt or sand than to recover the material after it is applied.

High salt concentrations in local waterways can impact important internal functions of aquatic life. For example, freshwater fish exposed to water with high salinity can have trouble with osmoregulation (the regulation of water and salt concentrations within the fish's body), difficulty breathing, and even reduced eating habits. Fish use more energy for survival and less for digestion and growth. Migratory fish may be forced to find alternative spawning grounds that are easier for fish and egg survival.

Even low salt concentrations can impact eggs and small aquatic life. They may be low on the food chain, but they are vital to a healthy ecosystem, including the fish and birds that prey on them. [3]

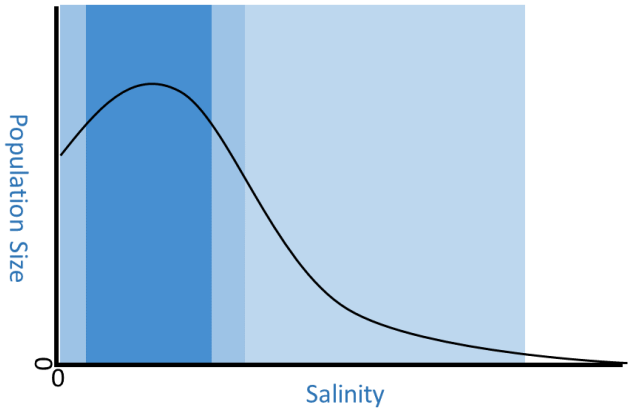


Figure 16. Example of a given species' tolerance range. The species can survive, grow, and reproduce in the darkest blue range. It doesn't reproduce as well in the middle blue range and has limited survival in the lightest blue range. Outside of the blue ranges the given species cannot survive. Image from ICPRB.

Saltier habitats may lead to reductions in local Maryland fish populations and the diversity of the fish community. [8]

Diversity and population size of fish species in urban areas are already recorded to be less than that of non-urbanized areas [11]. The impact of winter deicing salts may exacerbate that difference.

Certain species that live on the bottom of streams, like benthic macroinvertebrates, are also sensitive to increased salt concentrations [8]. Benthic populations may not have the ability to escape when there is a change in seasonal turnover as they cannot leave the lower zones where the salty, less oxygenated water is trapped.

Salt spray can damage branches and buds of trees.

Vegetation

Have you ever wondered why there are often patches of dead grass along the sidewalk? Salt can impact vegetation — both aquatic and terrestrial. Lawns and landscaping are especially susceptible to drying out and salt burns. **Excess deicers sprayed during application or runoff with melting snow can damage or kill plants**. With enough salt accumulation the plant will eventually die. [3]

Aquatic vegetation may be subject to a similar fate as terrestrial vegetation. They are exposed to salty water that can accumulate in plant leaves, stems, and roots and eventually lead to plant death [3].

Native plant species that are not tolerant to high salt concentrations may completely die out, which could allow non-native salt-tolerant species to take hold [3].

Soil

The addition of sodium can change soil structure, leading to compaction and poor drainage. Soil chemistry can change with the addition of sodium, causing a rise in pH. This reduces the amount of nutrients readily available for plant growth. [3]

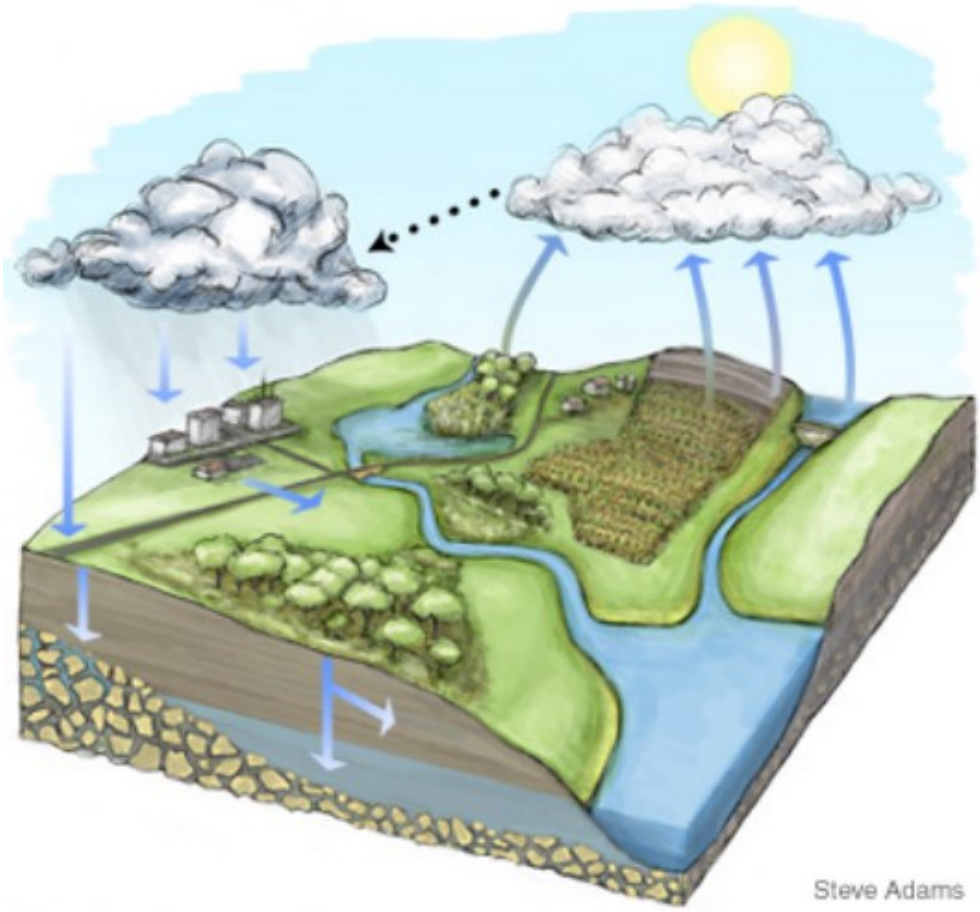


Figure 17. Example of the water cycle depicting multiple paths water can move. Note that in this watershed, water can enter through precipitation, groundwater, or surface water. Water can also exit the watershed in the same way. Image by Steve Adams and obtained from MCPA.

Module 2. Smart Salting

Learning Objectives:

1. Recognize the many ways that Smart Salting can improve winter operations while saving money, time, and effort.
2. List the main practices that are involved in Smart Salting.
3. Learn more about site drainage and facilities maintenance strategies.

What is Smart Salting?

Smart Salting is an integration of both science and best practices in winter maintenance decisions. It is an opportunity for winter maintenance professionals, those who hire them, and the public to reduce salt use, save time and money, and help the environment.

More salt does not mean more safety. **Smart Salting maintains public safety on roads, sidewalks, and parking lots, while reducing the amount of overall salt-use to protect aquatic life, infrastructure, and our drinking water.**

The Maryland Smart Salting training materials provides proactive, cost-effective, and environmentally conscious choices and techniques for winter maintenance of non-highway roads, parking lots, and sidewalks.

As with most situations, one size does not fit all. There are a range of circumstances, winter storms, and experiences. Winter maintenance professionals will find a variety of options for Smart Salting in this material and are encouraged to experiment, adapt, and refine their own practices.

Figure 18. Manual snow removal. Image by Karolina Grabowska from Pexels.

Focus on Manual Removal vs. Material Use

Removing snow early and often can reduce compaction and reduce the amount of salt needed to maintain safety.

Applying the right amount of salt or brine prior to a storm can aid mechanical removal by preventing the snow from bonding to the pavement. This practice is known as anti-icing.

Mechanical removal on sidewalks

Depending on the amount of snowfall, a winter maintenance professional may utilize the *One-Pass* or *Two-Pass* mechanical removal method. [4]

Figure 19. Mechanical snow removal. Image by Lauren Hedges from Pexels.

Lighter snow: one-pass

A once-over with a broom or shovel may be all that is needed to fully remove the snow during a lighter snowstorm.

Heavy snow: two-pass

The two-pass method is effective during heavier snowstorms. This involves using two different tools for better snow removal. The initial pass removes the bulk of the snow (using a plow, for example), then the second pass removes the snow closer to the sidewalk. Tools used for the second pass could be a broom or shovel.

Use the One-Pass or Two-Pass Removal Method *before* adding a deicer.

Best practices for sidewalks [7]:

- Always remove snow mechanically first. This reduces the chances of refreezing and slush build-up. This also allows you to better identify and selectively address problem areas.
- Use drop spreaders, not rotary spreaders. If you must use a rotary spreader, adjust the opening to limit dispersion or install shields to restrict the spread pattern.
- Using heated or textured mats on sidewalks or steps can reduce the need for deicers in small problem areas. Be sure to test them. Avoid using deicers on heated sidewalks.
- Look for opportunities to close extra entrances during the winter. Many slip and fall incidents happen within ten feet of the curb. Anti-icing and aggressive mechanical snow removal can create a safer walking surface.
- Keep in mind that salt and sand on sidewalks get tracked into buildings. This leads to slippery areas inside the building.
- Consider using alternative, plant-based deicers. These may be effective for you, depending on your situation, and they have reduced environmental impacts when compared to salt. As with any new material or strategy, be sure to test any alternative deicers first and follow manufacturers' application guidelines.

Although property managers may need to adjust staff time during a snowstorm to apply these best management practices, they will see a benefit from less product used, less infrastructure damage, and a healthier environment.

Use Existing and New Equipment

The right tool for the job can mean the difference between wasted time and materials, and a job well done. Properly working equipment is equally crucial for winter maintenance success, especially when it comes to reducing the amount of wasted salt during a winter storm.

Some types of equipment can be retrofitted or calibrated for a more consistent rate of application, which reduces salt usage, spillage, and cleanup. (See the calibration section for more information on correct calibration of specific equipment types.)

Case Study: Villages of Shorewood Hills learned that the same equipment-type could have drastically different salt output. The organization saw significant salt use reduction after correctly calibrating each piece of equipment separately.

In some cases, it is economical to purchase new equipment. **An investment in new, innovative equipment can be recouped through increased efficiency.** This is particularly true for equipment that is used for the application of liquid deicers (i.e., brine).

The following list provides suggestions for new equipment or retrofitting of existing equipment that will help winter maintenance professionals reduce their material use while providing a safe and economical service (reprinted from [3]):

- Purchase a pavement sensor.
- Buy equipment that can deliver very low rates of granular products.
- Outfit larger trucks with ground speed controls so that the application rate changes automatically as the speed changes.
- Modify existing equipment so that it can discharge the application rates described in the *Calibration Rates* section of this manual. Older equipment often applies more salt than is recommended.
- Invest in equipment that can deliver liquid deicers.
- Outfit sidewalk spreaders with shields to better direct the spread pattern.
- Obtain a tank for liquid storage or find a near-by source of liquids to fill up trucks.

Figure 20. Mechanical snow removal. Image by Tim GG from Pexels.

Equipment upgrades are not the only path to Smart Salting. Instituting these practices will help reduce the amount of salt used while protecting the environment and your bottom line (reprinted from [3]).

- Anti-ice before the storm.
- Remove snow from surfaces as quickly as possible to reduce compaction.
- Plow before applying deicers to avoid dilution of the salt.
- Minimize deicer use during the storm.
- Never plow or blow snow into bodies of water, wetlands, traffic or into streets.
- Minimize back-up maneuvers to reduce the chance of accidents.
- Limit use of salt and sand during the storm; use only to reduce bonding.
- Do not use salt to burn off snow.
- Use application rate chart to determine how much salt to use.
- Don't apply dry salt (sodium chloride) below 15º F pavement temperature. It will not melt fast enough to help.
- Below 15° F, use wetted salt.
- For extreme cold, skip melting and use sand.
- Clean up spills.
- Accurately record the material used at each site.
- Pay attention to its effectiveness and record observations. (Find templates in the *Documentation of Application* section of this manual.)
- Use only what is needed based on proper application rates for the conditions.
- Put extra back in salt pile or return extra bags.

Figure 21. Salt on a parking lot surface. Image from ICPRB.

Figure 22. Rusted grocery cart corral. Image from ICPRB.

Why Salt Smart?

Smart Salting combines best management practices and science to lead winter maintenance professionals to the best decisions. There are many different views and opinions that winter maintenance professionals must navigate when it comes to doing their job. Some of those views include the idea that feeling the *crunch of salt* underfoot means that sidewalks are safe for foot traffic. Others support less salt application for clean parking lots and sidewalks and less environmental impacts. [5]

As we saw in the previous section, the rise in winter salt applications has been the subject of many research studies in recognition of the environmental and infrastructural impacts [9], many focused on developing the best methods for ensuring safe roads during winter storms [9]. The increased research efforts have led to enhanced media attention and public outreach [5]. Public opinion is shifting from the idea that more salt is safer to believing that excess salt is not environmentally friendly and looks unprofessional [5]. **Frequently, companies are looking to hire winter maintenance professionals that have local Smart Salting training and certification** [5].

Figure 23. Example of dead vegetation due to winter deicing salts applied to parking lots (top) and roads (bottom). Top image from McHenry County Courtesy of Michael Adams and Lake County Health Department. Bottom image by Famartin from Wikimedia Commons.

Plant-based deicers contain phosphorus. The addition of just 1 pound of phosphorus to water can lead to a 500-pound increase in algae growth.

County of McHenry

SNOW AND ICE CERTIFICATION

This certifies that

Successfully completed the Winter Snow & Ice Control Training and Calibration Clinic and has passed the certification examination in November, 2017. Further, the above named individual has volunteered to apply snow and ice control best management practices for parking lots, sidewalks, driveways, and roadways in Northern Illinois.

Sponsored by: McHenry County Divisions of Transportation and Water Resources, the Village of Algonquin, the City of Crystal Lake, and the Village of Spring Grove

Certification expires November 2020

Smart Salting for Property Management

This is to certify that

[Name]

completed requirements of the MPCA Smart Salting Training for Property Management on behalf of

Minnesota Pollution Control Agency

and for committing to reduce their salt use

Your actions will help protect Minnesota lakes, streams and groundwater.

MINNESOTA POLLUTION CONTROL AGENCY

SAFER FOR LAKES & STREAMS CERTIFIED SMART SALTER

Brooke Asleson
Resource Management and Assistance Division

Issued: 07-01-2020

Certification valid for 3 years

Figure 24. Example of Smart Salting Snow and Ice Certifications from McHenry County (Top) and Minnesota Pollution Control Agency (Bottom).

By educating customers and tenants on sustainable winter maintenance practices, you can help expedite the shift in public perception and increase public support for better practices [5].

There are several best management practices available to reduce winter salt use:

- Anti-icing with brine prior to the winter storm.
- Pre-wetting salt before application to the roads.
- Calibrating equipment to prevent inefficient application.
- Using variable application rates in automated spreaders to change the speed of application with the speed that the vehicle is traveling.
- Storing salt properly minimizes product loss and pollution.
- Allotting time to clean up unintended spills.
- Staying up to date on road conditions.
- Understanding and using the ideal plow type.
- Using the pavement temperature and pavement temperature sensors to guide decisions.
- Adjusting the level of service of winter maintenance to current conditions.
- Identifying areas that should have no- or low- salt application based on the surrounding environment.

Know the pavement temperatures to know the right rate of application.

Save money, time, and effort

Adding too much salt is just a waste of time, money, and salt. By using alternative deicers and best management practices, we can reduce the costs to the environment and infrastructure, therefore saving money, while still maintaining safety.

In addition to the costs associated with direct damage due to corrosion and higher drinking water treatment costs, there are indirect costs associated with the application of winter salt. These include public health costs and costs to the drinking water suppliers (outside of the need for extra chemicals or damages to infrastructure) [8].

Overall, the damage to local infrastructure — including roads, bridges, stormwater infrastructure, culverts, pipes, and appliances — can cost up to five times as much as the initial cost of purchasing the winter salt [4].

Contracts based on fee-per-pound of deicing materials used can lead to excess material application and threaten Maryland waters.

More effective and safe for clients

Communicating with clients prior to the winter season can help to ensure a smooth transition to new products and practices and ensure that client and applicator expectations are in sync [7]. Be sure to express the time and money saved by adopting best management practices — less indoor and outdoor cleaning costs for the customer and reduced maintenance and product costs for the applicator [3].

In areas where the client is associated with tenants, such as apartment buildings and neighborhoods, getting residents involved in Smart Salting principles can ease any tenant concerns associated with the reduced use of salt. Providing tenants with a list of best practices that they can use that promote efficient and effective salt application and explaining the benefits of each best management practice (both economic and environmental) can lead to reduced resident concerns and lead to an increase in public support for Smart Salting practices.

Examples of best practices for the public [10]:

- Shovel early and often to prevent the need for salt.
- Plan to stay home until the sun naturally melts the snow.
- Use a blend of native bird seed for traction.

Business owners, property managers, and winter maintenance professionals can help move the "salt" needle further by helping to educate and inform the public on the reasons behind Smart Salting techniques.

Protect your clients' property and your equipment

By adopting Smart Salting principles, equipment damage and client property damage can be reduced. [10]

Some methods for protecting equipment include:

- using application rate charts;
- calibrating equipment;
- using anti-icing prior to a winter storm; and
- staying informed about *practical melting temperatures* associated with each deicer [11].

Some methods that help protect client property include:

- plowing before deicer application;
- using pre-wetted deicing materials;
- cleaning up excess deicer after winter storm events;
- ensuring proper disposal of excess materials [11]; and
- closing additional entrances/exits during the winter season or even just during winter storm events [7].

Figure 25. Example of closed stairway to avoid adding excess salt when a main stairway is available. Image from MPCA [5].

In addition to the above practices, having a clear contract and communication plan between client and applicator can help ensure that best management practices are used correctly and therefore protect property and equipment [5]. **Best management practices protect both the client's property and the applicator's equipment.**

Case study video: The Bruce Company *saw a reduction in materials cost without compromising customer service or safety.*

While using more advanced equipment and adjusting application procedures may have a higher upfront cost, the case studies make it obvious that the practices save money in the long run.

Tracking the return on investment will help make the case for those worried about the bottom line. Find templates for tracking in the *Documentation of Application* section of this manual.

Using the correct amount of the ideal material at the correct time will save time and money.

Tap into the eco-minded business market

Advertising the use of Smart Salting techniques can help applicators communicate with clients (and their tenants) and bring in new customers who wish to support eco-friendly businesses. Advertising efforts can range from large campaigns to offering and posting fliers with key information. For example, Wisconsin Saltwise has the "love the lines" slogan which informs businesses and the public that good anti-icing will appear as lines on roadways [4].

Sharing what to expect during a winter storm and when customers should use extra caution can also increase client and associated tenant confidence in winter maintenance operations.

To further build trust between winter maintenance operations and customers, including residents, it is important to understand the client's/resident's current expectations of salt use and safety. This can help tailor efforts to the client's/resident's current expectations and understand what level of advertising will be most effective. Some simple facts and phrases can be extremely effective. Using posters that advertise facts such as, "1 teaspoon of salt is all it takes to permanently pollute 5 gallons of water," can convey the need for Smart Salting practices. [5]

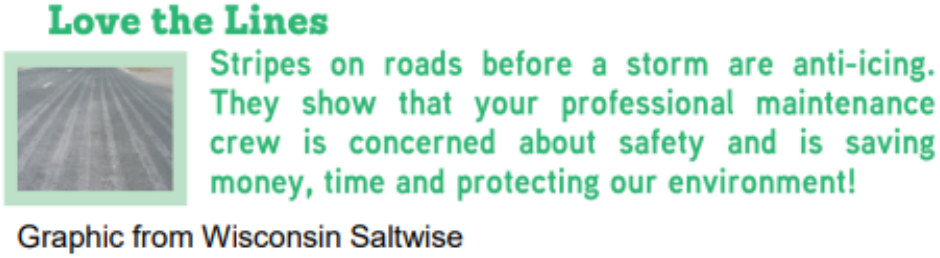


Figure 26. Love the Lines advertisement from Wisconsin Saltwise. Reprinted from [4].

The Virginia Salt Management Strategy (SaMS) Toolkit recommends focusing advertising efforts on the following five topics:

1. The importance of public safety.
2. The unintended environmental impacts of salt use.
3. Why minimizing salt application matters.
4. The pros and cons of winter salt use (keeping in mind the concerns of all stakeholders).
5. Information on ways the target audience can address the issue.

*List reprinted from [8]

Figure 27. Outdoor staircase. Image by Nguyen Lam from Pexels.

Good communication with customers, residents, and visitors will help establish trust and rapport between the two groups.

These core ideas should be conveyed to customers and the public using a positive tone and with action-oriented phrasing. Additionally, sticking with a key phrase throughout all outreach products and advertisements can help to maintain the same message and increase education on Smart Salting. For example, using the same slogan on all visual advertisements and as hashtags in social media platforms can increase the number of views and people that are exposed to Smart Salting concepts. [8]

Figures 28. Sticker from Minnesota Parks & Recreation Board (left) and smart salter graphic and winter cling (right). Images from Fortin & Jacobson (2020) [5].

How Smart Salting Improves your Bottom Line

Salt is cheap but salt damage can be expensive. According to Fortin Consulting Inc., 2014 [2], one ton of salt inflicts $800-$3,300 in infrastructure damage annually. Sidewalks, railings, steps, landscaping, vehicles, and roads can all be damaged by salt. When the salt is tracked inside a building it can do further damage to walls, carpets, and maintenance equipment, creating costly maintenance and repairs for property managers.

Reduction in Salt Use*	Operations (materials, labor and equipment) Potential Savings		Combined Operations-Plus-Damages Potential Cost Savings (millions) per Year†	
Percentage	Thousands of Tons/yr	Direct Cost (millions)/yr**	*Low* Damages Basis	*High* Damages Basis
10%	35	$8	$36	$124
20%	70	$16	$72	$249
30%	105	$23	$107	$373
40%	140	$31	$143	$497
50%	174	$39	$179	$622
60%	209	$47	$215	$746
70%	244	$54	$251	$870

* TCMA baseline salt use is approximately 349 thousand tons/yr (Sander 2007).
** Estimated based on $73/ton material cost (Schaefer 2012, MnDOT ca 2012, U.S. Salt 2012), and $150/ton labor and equipment cost (Stefan et. al 2008).
† TCMA estimated baseline combined cost is $358 million/yr on *low* overall damages basis and $1,243 million/yr on *high* overall damages basis (Table 3).

Figure 29. Potential Annual Cost Savings from Reduced Deicing Salt Use in the TCMA. Reprinted from Fortin Consulting, 2014 [2].

A contractor's perspective:

J. Swope of Chesapeake Bay Landscape Professional,

> Brine applications provide an opportunity for contractors to provide profitable, additional pro-active services for their client while also reducing the potential for excessive ice melter to be applied during and after a weather event. By combining brine pre-treatment pricing with per application pricing, the contractor can be profitable while also being smart about how much salt is applied. It creates a win-win situation for the contractor and property manager.

Saving Money

Cost-benefit analysis

When considering which Smart Salting practices to implement, some practices provide higher potential cost savings than others.

The following list contains planning practices with the highest return on investment [8]:

- develop a Winter Maintenance Plan;
- accountability for Smart Salting at all levels;
- Smart Salting training;
- proper storage of deicer piles;
- establish a calibration process;
- calibrate equipment;
- weather forecasting;
- know the surface temperature;
- use enhanced equipment and technology (e.g., spreaders that can deliver low rates, collect data, and/or are ground controlled/speed-synchronized);
- perform anti-icing;
- plow early and often;
- use the right tool for the job (i.e., choose the right plow, shovel, pusher, blower, blade, or broom for the property);
- vary application rates depending on conditions;
- use pre-wet deicers;
- direct liquid application; and
- measure and record deicer use.

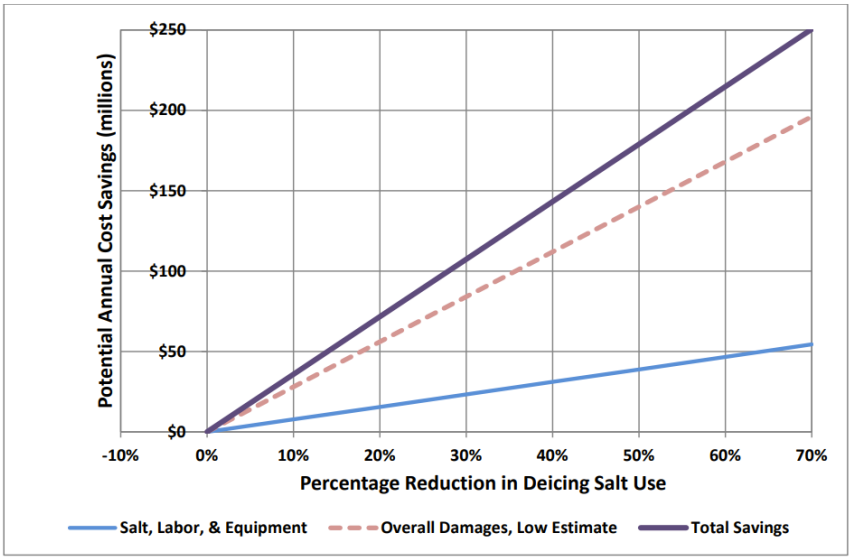


Figure 30. TCMA Potential Cost Savings from Reduced Deicing Salt Use. Reprinted from Fortin Consulting, 2014 [2].

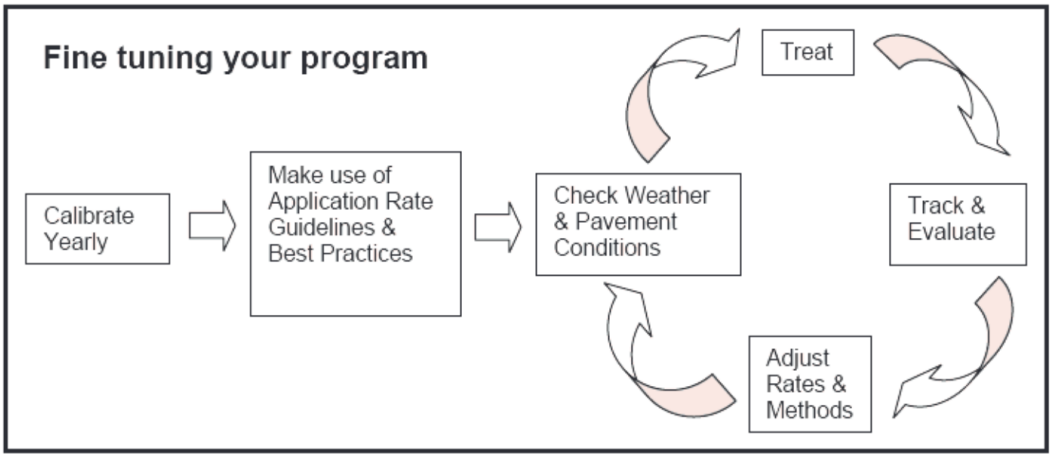


Figure 31. Reprinted from McHenry County, Snow & Ice Control Handbook for Sidewalks and Parking Lots, page 28 [7].

The sample anti-icing and de-icing tracking forms in this manual can be used to document the process. Make sure to discuss the results with the property managers and other maintenance workers.

For many businesses, there's more to the cost-benefit analysis than just the bottom line. **When snow contractors and property managers work closely together to develop and implement a winter maintenance plan based on Smart Salting concepts, they develop a collaborative relationship based on mutual trust and respect which benefits both parties in the long run.**

How much can be saved a year and or season when applying savvy salt operations? **Smart Salting operations can lead to significant annual savings for the winter maintenance operators, property managers, and even individuals who visit the site of interest.** While there may be upfront costs, savings can be seen in as little as one year. For example, the University of Minnesota, Twin Cities saved $55,000 in the first year of adopting best management practices. While the new equipment purchased to enable the application of the best management practices cost $10,000, the overall savings was $45,000. [4]

Reducing salt application by just one ton per year can save anywhere from 2 to 4 figures per ton of salt not applied (reduced). For instance, Fortin Consulting Inc. (2014) [2] showed savings between $600-1,460 in infrastructure damages and $75-227 in environmental damages.

Estimates	Infrastructure Damage		Environmental Damage	
	Road Maintenance	Infrastructure Damage	Tree Damage	Ecosystem Damage
Low Estimate	$600	x	$75	$172
High Estimate	$615	$1460	$110	$227

Table 4. Estimated Savings in Damages in $USD per 1 Ton Reduction in Salt Applied for Winter Maintenance Estimated by Fortin Consulting Inc., (2014). Adapted from Virginia SaMS [8].

Savings associated with reduced salt application can also benefit individuals. Michigan estimated the costs of vehicular corrosion associated with various deicing products for the year 1993 and found estimated costs to car owners ranging from $4 per ton of deicer applied to $715 per ton of deicer applied. The table below shows estimated costs due to vehicular corrosion in Michigan in 1993 for various deicing products (adapted from DEQ, 2021 — Public Sector Consultants 1993) [8].

Case Study: C&W Services worked collaboratively with the site manager at CUNA Mutual to reduce their bulk salt usage by 14% and their bag salt usage by 35% while still providing the service and safety their client had come to expect.

Deicing Product	**Low Estimate ($USD/ton)**	**High Estimate ($USD/ton)**
Sodium Chloride	$321	$715
2:1 Salt-Sand Mixture	$214	$476
Calcium Magnesium Acetate (CMA)	$19-$32	$17-71
Calcium Chloride	$241	$457

Table 5. Table of Estimated Vehicle Corrosion in Michigan Per Ton of Applied Product in 1993 Dollars. Adapted from Table 6 in Virginia SaMS, DEQ, 2021 [8].

MS4 language/Maryland policies

Many states, including Maryland, are starting to require specific winter salt maintenance Best Management Practices in the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permits for some jurisdictions (e.g., section 4.d. of Permit 20-DP-3320 of Montgomery County, Maryland). Maryland, which has 28 waterbodies with chloride impairments [9], has a vested interest in reducing winter salt application without compromising public safety.

Smart Salting saves taxpayers' money by reducing material costs and reducing infrastructure damage, all while protecting our natural resources and drinking water. The State of Maryland sees the benefits in reducing the amount of salt we use, and they want to help you see it, too.

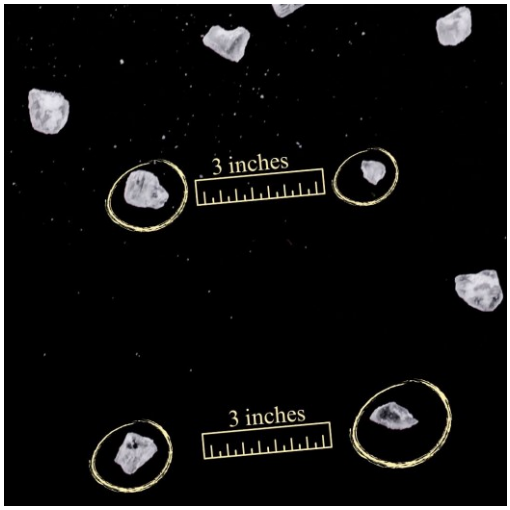


Figure 32. Smart Salting techniques reduce the amount of product used. Image from ICPRB.

Success Stories

The entities listed in the table below were able to save significant amounts of money after implementing practices they learned in a Smart Salt training such as the one offered by the Minnesota Pollution Control Agency. **Similar money-saving tips and tricks can be found in this Maryland Smart Salting training material.** Additional information on each case study can be found on the Minnesota Stormwater Manual Success Stories: Salt Reduction and Cost Savings Examples website.

Entity	Time Period	Main Actions Implemented	Salt Reduction	Cost Savings
University of Minnesota, Twin Cities	Start 2006	Began making salt brine and anti-icing and adopted several other salt reduction BMPs.	48%	New equipment cost $10,000; $55,000 cost savings first year
City of Waconia	Start 2010	Switch from 1:1 sand:salt to straight salt & liquid anti-icing; calibration; equipment changes; use of air and pavement temperatures.	42%	$8,600 yearly cost savings ($1.80 per lane-mile)
City of Prior Lake	2003-2010	Upgrade to precision controllers & sanders; anti-icing & pre-wetting; use of ground temperatures, best available weather data; on-site pre-mix liquid & bulk-ingredient storage, mixing & transfer equipment; staff education.	42%	$2,000 per event estimated cost savings; 20-40 mg/L decrease in receiving-water chloride (liquid app-only watershed).
Rice Creek Watershed District Cities	2012-2013	Staff training; purchased shared anti-icing equipment.	32%	$26,400 in one winter
City of Cottage Grover	2011-2012	Staff Training	Not available	$40,000 in one winter
City of Shoreview	Start 2006	Stopped using a salt/sand mixture and moved on with straight salt; set up all its large plow trucks with state of the art salt spreading controls, pre-wetting tanks and controls and pavement sensors; use of calcium chloride in the pre-wetting tanks reduced the amount of rock salt as well; all applicators and supervisors annually attend training; crews attend an annual snowplow meeting to review procedures and talk about salt use and conservation methods; trucks set up for anti-icing main roads with calcium chloride.	44% since 2006	$24,468 in 2014
Joe's Lawn & Snow, Minneapolis	Start 2013-2014	Owner & staff training; purchase of new spreader, temperature sensors; equipment calibration; use of temperature data; on-going experimentation.	50%	$770 estimated cost savings in 2014 - Expected to use 20 tons, only use 9 tons
Edina Public School	Start 2014	Purchasing less salt at the start of the season; invested in mechanical removal equipment; training for staff and crew starting in 2016; incorporated salt brine and created their own brine-making equipment.	60%	Went from using 45 pallets of salt to 16 pallets.

Table 6. Success stories (adapted from MPCA, 2016 [1], with additions from Fortin & Jacobson, 2020 [5] and Fortin, 2015 [4]).

Modules 3 and 4: Pre-Season Preparations, Site Planning, and Contracts

Learning Objectives:

1. Prepare staff and equipment for winter operations (e.g., calibration, repairs, trainings).
2. Calculate area treated for your property and the amount of material using Smart Salting BMPs.
3. Describe proper site drainage and storage of onsite material, and why they are important.
4. Develop site-specific service agreements and maintenance operation policies.
5. Identify the different types of materials used during winter maintenance and how they work.
6. Understand the steps for pretreatment and when/ where to use which kind (pretreatment).
7. Understand the steps for pretreatment and during the storm application.
8. Understand pavement vs air temperature and speed of melting.
9. Determine the correct usage of salt for sidewalks, building entrances and parking lots (e.g., how much is just right/ too much).

Preparation is an important Smart Salting practice. Getting ready for winter operations includes general pre-season activities like creating a winter maintenance operations policy, trainings, calibration, and repairs as well as site-specific planning activities and developing winter maintenance contracts that promote cost-effective and environmentally friendly salting strategies.

Preseason Preparations

Operations Policy

The first step in preseason preparations is to create a winter maintenance operations policy. **The policy should identify the roles and responsibilities of all staff.** This includes schedules, equipment assignments and maintenance, and routes where applicable. The policy should also outline the strategies and resources that will be used during snow fighting, including [3,9]:

- chemical and/or abrasive materials that will be used;
- location of short- and long-term storage for particulate and liquid products;
- how spillage and overapplication will be handled;
- the *when* and *how* of treatment: apply brine before a winter event, treat chemically only at 1" of snowfall and under, plow and treat above 1" of snowfall; etc. [4];
- snow and ice disposal locations should be carefully selected (see subsection *Snow pile locations*); and
- snow removal procedures for loading and hauling when sufficient on-site storage is lacking.

Maintain Safety During Winter Events

Property managers and winter maintenance professionals should begin discussions about safety and expectations well before the first snowflake falls. Public safety is the primary goal for all parties during a snowstorm. However, it is a misconception that more salt means more safety. Together, they can develop a plan to reduce salt use while still ensuring safety and service.

Figure 33. Hand-held Temperature Sensor. Image from [3].

Avoiding lawsuits is typically the number one reason for overapplication. Addressing this issue during your pre-planning process can put everyone at ease. A Winter Maintenance Plan will help guide winter operations and decisions. A template, like MPCA's Model Contract for Snow and Ice Management Services safety clause, can be used to address many areas of concern.

The following steps can be used by property managers to ensure all parties are well-prepared for winter maintenance (reprinted from [5]):

Figure 34. Mechanical snow removal. Image by Lauren Hedges from Pexels.

- Review the maintenance policy/plan with staff and inform customers of your high-level plan.
- Establish a clear level of service expectations and education for staff and building users.
- Incorporate certification training into contracts and/or require it of their staff.
- Follow the plan.
- Fully document maintenance activities to prove you followed the plan.
- Review and update the maintenance policy and plan each year.
- Understand your regulatory obligations and the effects of over-salting on the environment.

Figure 35. The sidewalk on the left with excess salt is no safer than the stairs on the right cleared of snow and ice without excess salt. Images from [5].

Staff training

Having a knowledgeable staff will help ensure the job is done professionally and correctly. Site managers, equipment operators, and contract or seasonal crew members should receive the appropriate training. **A basic course in winter maintenance is suggested for all staff and a more advanced level for managers.** Topics of classroom and hands-on training include material properties, material selection appropriate for a given weather condition, timing of applications, application rates, proper materials storage, record keeping and analysis, environmental impacts, snow and ice removal procedures, as well as equipment choices, maintenance, and calibration.

Providing training prior to the winter season ensures staff are knowledgeable about Smart Salting concepts and operators are well versed in how to operate and maintain their assigned equipment [12]. The *Minnesota Pollution Control Agency (*MPCA) provides a short two-part video series that introduces the concept of Winter Maintenance Training For Small Sites (Part 1 and Part 2), and was produced by the Mississippi Watershed Management Organization, University of Minnesota, and Fortin Consulting.

Materials

Get to know your material

A variety of chemicals are available to fight ice and snow. The type, form, and application rate of the materials depends on the prevailing weather conditions (i.e., snow, ice, sleet), as well as on pavement and air temperatures. Materials fall into four categories — abrasives, deicers, anti-icers, and organics. They come in either granular or liquid form. Abrasives do not melt snow nor ice, rather they provide traction. Anti-icers prevent adhesion and ice formation. Deicers melt existing snow and ice. [4]

Although some deicers (e.g., acetates) cost more than others, they still may be more economical during certain weather conditions because less material may be required to do the job.

Test your materials

Especially when using an unfamiliar product, small amounts should be tested to verify that it is performing as claimed by the manufacturer or vendor. Tests should be done under various conditions, and the results should be recorded. If the product performs differently than expected, the manufacturer or vendor should be contacted for advice.

Store your materials properly

Proper storage of all winter maintenance materials is imperative. It will reduce impacts to natural resources and infrastructure and save money because loss of material due to rain, leaching, or wind will be minimized (see *On-site storage of deicers* and *Drainage* below for more details).

When choosing a chemical, the potential adverse impacts to the environment and infrastructure should be considered.

Which materials to buy and why

Materials that can be used in winter maintenance programs include physical abrasives, deicers, anti-icers, and organics/carbohydrates. Physical abrasives (e.g., sand, gravel, slag, cinders) do not melt snow and ice, but rather provide traction. Sand, the most used abrasive, may improve safety on icy sidewalks, on hills, in curves, or on packed snow that is too deep for chemicals to melt. However, it works only when it is on top of snow or ice and is ineffective on slush. Mixing sand with salt or other winter chemicals may not provide added benefit as these materials can work against each other. **Sand and other abrasives are best reserved for cold temperatures at which deicers are ineffective.** [2]

In large quantities, sand can adversely impact water quality and aquatic species and their habitat. When sand is not swept up after the winter event or season, it can be washed into streams, stormwater ponds, lakes, etc. where it causes sedimentation and clouding of the water column. In addition, sand can become contaminated with motor oil and other substances and may have to be disposed of as a hazardous waste when it is swept up at the end of the season. [2]

Deicers and anti-icing products come in granular and liquid forms and fall into two broad categories: chloride-based (e.g., sodium chloride, calcium chloride, magnesium chloride, and salt-brine) and non-chloride based (e.g., acetates, formates, glycols, succinates, urea). Deicers work by lowering the freezing point of water. The proper choice depends on the pavement temperature and pavement temperature trend (i.e., is the pavement getting warmer or colder?). For example, the commonly used deicer — rock salt — works to a pavement temperature of -6 ^{o}F, although its melting capacity is greatly reduced below 15 ^{o}F. The speed of melting is also influenced by the size (gradation) of the material. In general, liquid deicers, either alone or mixed with granular materials, speed up melting. [2]

Anti-icers help prevent ice and frost formation on pavement and keep things from getting slippery. They also absorb moisture before it can freeze but may fail to perform satisfactory after absorbing a certain amount of moisture.

Sodium chloride, a.k.a. rock salt, is the most widely used winter maintenance material because of its low cost as compared to other deicers. **Chloride-based materials, however, can impact water quality, be toxic to aquatic species, damage vegetation, and corrode vehicles and infrastructure.**

Non-chloride-based deicers are generally only used in very cold temperatures due to their higher cost and potential lack of availability. However, they may be a good option in areas where protecting bridges or buildings from corrosion or reducing impact to aquatic resources are the goal.

Chemical deicer packaging can often be a mystery that is made even more difficult when comparing products. **There are no labeling laws that apply to deicers** [6]. Therefore, it is on the customer to decipher what the ingredients mean for them [4].

When looking at bagged deicer blends, a good rule of thumb is that less expensive blends tend to have more sodium chloride (NaCl). **One benefit of bagged blends is that the granules are generally smaller in size and can move through a spreader more consistently.** [4]

The best way for winter maintenance operations staff to ensure they have all the relevant information to make the best decision possible is to contact the vendors [6]. By contacting vendors, winter

maintenance professionals can obtain a full ingredient list and relative quantities, best storage and handling practices, and even the practical melting temperature for the deicing product [6]. Remember, it is important to use the lowest practical melting temperature when deciding products, not the eutectic temperature [15]. This is because the lowest practical melting temperature tells you the lowest real-world temperature that the product can realistically work [3]. More information on eutectic temperatures and lowest practical melting temperatures can be found in *Module 1: Basics: Why Should I Reduce my Salt Use?* and *Module 5: Storm Operations*.

Although carbohydrates, which include agricultural products such as beet juice, molasses, and corn syrup, do not melt snow or ice on their own, they can be added to deicers to improve their performance. Positive attributes include increased "stickiness" of deicers, reduced freezing point of brine, and interference with ice crystal formation. Their addition may also reduce the amount of deicer required and lower corrosion potential. However, due to their high organic matter content, these additives may adversely impact aquatic resources by increasing oxygen demand and causing nutrient enrichment (phosphorus and nitrogen), which may trigger algal blooms and fish kills.

A summary of winter maintenance materials is provided in the table below. For additional information refer to *Understanding the Effectiveness of Non Chloride Liquid Agricultural Byproducts and Solid Complex Chloride/Mineral Products* available at the ClearRoads website.

Figure 36. Brine truck. Image from Jason Swope.

The *practical melting temperature* is the lowest temperature at which the product will still work.

Material	Sodium Chloride		Magnesium Chloride	Calcium Chloride	Acetates			Abrasives
	Rock Salt	**Salt Brine**			**Calcium Magnesium**	**Sodium**	**Potassium**	
Typical Form	Solid granular	Liquid	Solid or liquid	Solid or liquid	Solid or liquid	Solid or liquid	Liquid	Granular* (mixed with salt)
Equipment	Spreader	Sprayer	Spreader	Sprayer	Sprayer		Sprayer	Spreader
Lowest Practical Melting Temperature	15° F	15° F	-10° F	-20° F	20° F	0° F	-15° F	N/A
Usage	Deicing anti-icing	Prewetting anti-icing	Deicing prewetting anti-icing	Deicing	Anti-icing	Anti-icing	Anti-icing	Temporary traction
Positive Attributes	Cheaper than other products; Excellent melting capacity	Cheaper than other products; No granular scatter; Prevents bonding of ice and snow to pavement	Compared to rock salt: Less product needed; Better melting capacity; Persist on pavement; Longer prevention of black ice	Compared to rock salt: Less product needed; Better melting capacity	Less corrosive than chlorides		Less corrosive than chlorides	Good for spot treatments; Effective at very low temperatures; Useful in no salt zones
Negative Attributes	Corrosion to infrastructure and vehicles; Pavement deterioration	Corrosion to infrastructure and vehicles	Higher cost than rock salt; More corrosive than sodium chloride; Pavement deterioration; Leaching/runoff from stockpiles	Higher cost than rock salt; More corrosive than sodium chloride; Pavement deterioration	Compared to chlorides: Expensive; More product need; Performs worse below 5° F, for heavy snow fall and freezing rain	Compared to chlorides: Expensive; More product need; Performs worse below 5° F, for heavy snow fall and freezing rain	Compared to chlorides: Expensive; More product need; Performs worse below 5° F, for heavy snow fall and freezing rain	Requires more plow passes and applications than chemicals; No deicing; Must be cleaned up after season; Corrosive when mixed with salt; Can clog drains
Impacts to water quality/ aquatic species	Excessive chloride loading, metals contamination, ferrocyanide additives	Excessive chloride loading, metals contamination	Increased oxygen demand	Increased oxygen demand	Increased oxygen demand	Impacts water quality/aquatic species by sedimentation; When mixed with salt behaves like salt		

Impacts to soil and vegetation	Sodium accumulation breaks down soil structure; decreases permeability and soil stability; may mobilize metals. Causes osmotic stress in root system and chloride toxicosis. Spray damages foliage.	May improve soil structure; increase permeability; may mobilize metals. Causes osmotic stress in root system and chloride toxicosis. Spray damages foliage.	May improve soil structure; increase permeability; may mobilize metals. Little impacts to vegetation except osmotic stress at high levels	High aquatic toxicity				

Table 7. The table below provides a summary of the properties of the more commonly used anti-icing and deicing products (adapted from City of River Falls Winter Maintenance Operations Policy and the Minnesota Stormwater Manual).

Removing the snow first will mean you can use less deicer.

How much material to buy

How much winter products will be needed for a season depends on:

- the size of the area to be treated;
- weather conditions (e.g., temperature, ice versus snow); and
- number of winter events anticipated.

Additionally, the lower the temperature, the more materials are needed to melt snow and/or ice.

These items are treated in more detail in *Modules 1, 2, and 5*.

The following is a handy table that summarizes deicing application rate guidelines for various winter maintenance materials and pavement temperatures. The table is reprinted from the Wisconsin Salt Wise website: Application Guidelines & Calculator, which also supplies an interactive online version.

Deicing Application Rate Guidelines for Parking Lots, Sidewalks and Trails

For best results remove as much snow and ice as possible before applying deicers

Pavement Temp. (ºF)	Application Rate in lbs/per 1000 square foot area Wet at 6 to 12 gallons per ton — Apply with calibrated equipment					
	Rock Salt *	Bagged Blend Mostly Sodium Chloride	Bagged $MgCl_2$ or $CaCl_2$	Rock Salt wet with Salt Brine	Rock Salt wet with other liquids	Winter Sand **
28 º to 32 º	2.3	2.3		1.6		
23 º to 28 º	2.3-4.5	2.3-4.5		1.6-3.2		
15 º to 23 º	2.3-6.8	2.3-6.8		1.6-4.8	1.6-4.8	
0 º to 15 º			2.3-6.8	3.2-4.8	3.2-4.8	Spot treat as needed
-5º to 0º			6.8		4.8	
< -5º	Plow Only					
SPEED of melting	AVERAGE The colder it is the slower it works	Faster than rock salt if the gradation is finer	ABOVE AVERAGE	FAST	FAST	NONE

If the temperature is increasing, apply at the lower end of the range. If the temperature is decreasing, apply at the higher end of the range.

Figure 37. Deicing Application Rate Guidelines for Parking Lots, Sidewalks, and Trails. Reprinted from [18].

Example of how to calculate the amount of salt needed:

> You can calculate the material needed for a 2,500 square foot parking lot at 30 °F weather with light-to-moderate snow fall by using the chart above. It recommends 2.3 lbs. of salt per 1,000 sq ft under these conditions. This means 5.75 lbs. of salt per snow event. If there are ten snow events in a year, a total of 57.5 lbs. of salt would be needed to treat the parking lot for the entire season. If the same parking lot were treated with "rock salt wet with salt brine", a total of 40 lbs. would be needed for the season.

Please refer to *Calculating size of area treated* in the Section *Site Planning* for instructions on how to calculate area size.

Below are a few tips that should be considered when estimating how much materials to buy:

- When applicable, pretreat the surface with a brine solution because this will reduce the amount of salt used and be more cost effective (see *Module 5: Storm Operations*). Of course, this quantity must be added to the amount of materials to buy.
- Plow, shovel, or otherwise remove snow mechanically before applying deicers. This reduces the amount of chemicals needed. More information about this can be found in *Manual/Mechanical Removal Equipment* and in *Module 5: Storm Operations*.
- Prewetting salt will also lower the quantity needed to do the job right.
- When temperatures are lower than expected, more salt or other chemicals are needed to maintain safe surface conditions.
- Because winter weather is often unpredictable and varies from year to year and by location (e.g., in mountainous versus coastal areas), it is advisable to purchase more materials than anticipated, provided that any excess can be safely stored for the next season. It may be more expensive to order them later in the season when stock is depleted.

Equipment checklist

Smart Salting goals mean using the least amount of material necessary to provide a high level of public safety — all while minimizing environmental impacts and saving money. The following are a few tips that may aid in reaching this goal:

- Invest in road pavement sensors or infra-red thermometers to obtain accurate, real-time surface temperature information.
- Ensure tools for mechanical removal are available and in good condition.
- When purchasing new equipment, prioritize spreaders that can deliver very low amounts of product.
- Modify existing equipment to discharge less product.
- Outfit sidewalk spreaders with shields to improve their spread pattern [10].
- Decide on the right equipment to do the job based on the type and amount of winter precipitation and the size of the site to be treated.

Sidewalk equipment includes brooms, power brooms, snow shovels/pushers, and snow blowers as well as hand-held, backpack, and walk-behind sprayers and spreaders. Smaller blades and tanks can also be mounted on ATVs, SUVs, tractors, etc.

Larger equipment typically employed in the private sector to clear parking lots includes three-quarter ton plow trucks equipped with blades or wings, front end loaders with blades or pushers, skid-steer loaders, snow blowers, and liquid anti-icing tanks mounted on trucks [7].

Search online for informational and how-to videos on winter maintenance equipment.

Manual/mechanical removal equipment

Broom and power broom

A push broom is the simplest tool to remove light, fluffy snow from smaller areas. It is also appropriate for snow removal from surfaces that may be damaged by shovels or other hard-edged tools.

Walk-behind and vehicle-mounted power brooms are available to treat larger areas. Because the brooms clear snow down to the surface, deicers or abrasives may not be needed to further treat the area. Depending on the model, power brooms are suited to clear sidewalks, parking lots, or roads. One advantage of power brooms is that they do not damage surfaces because they adjust to surface imperfections. Walk-behind types are also less strenuous to use than snow shovels and pushers especially for larger areas. As an additional benefit, they can be used for other purposes throughout the seasons such as sweeping grass clippings, leaves, and dirt.

Above is a small hand-held anti-icing sprayer

Snow shovel, pusher, and thrower

Other simple, mechanical tools useful for removing snow from staircases, sidewalks, and other small areas include snow shovels, snow pushers, and snowplows, as well as power assisted snow throwers and power shovels.

Above an ATV is applying deicer in a wet/dry spread pattern

Figure 38. Spreaders and sprayers. Images from [4].

Snow blowers and snowplows

Other mechanical options include snow blowers and snow pushers, which are less strenuous to use than snow shovels and pushers, especially for larger areas.

Spreaders and sprayers

Both spreaders and sprayers come in various shapes and sizes to accommodate different application needs. Hand-held, back-pack, and walk-behind equipment is more suitable for smaller areas and where maneuverability is an issue like stairways and sidewalks. Vehicle-mounted equipment is best deployed on parking lots and service roads.

Spreaders are used to dispense granulated materials such as salt and sand. These materials are put into a hopper, which tapers downward. As the material is released, a spinning disk spreads an even layer over the area being treated. Spreaders can be outfitted with deflection shields for more precise application. Common pedestrian spreaders include push broadcast and walk-along types. V-box and tailgate spreaders are examples of vehicle-mounted equipment.

Figure 39. Combination sidewalk plow and salt spreader outfitted with deflection shields. Image from Jason Swope.

Sprayers can be as simple as hand-held pump sprayers. Vehicle-mounted spraying equipment includes booms with holes or nozzles, hoses, and tanks that hold salt brine and other liquids. Sprayers should be designed such that they create a solid stream rather than a fan stream to achieve a wet/dry spread pattern and avoid slippery conditions. Stream nozzles may be constructed or purchased and should have the appropriate number of holes spaced eight inches apart, and the bar height should be 12 to 14 inches above the surface [9].

Using calibrated equipment ensures accurate application rates and no wasted materials.

Equipment

Inspect all equipment

During late summer or early fall, all equipment should be inspected and repaired if necessary. To ensure uninterrupted service, parts that are not readily available should be ordered and restocked as needed.

Calibration of equipment

Equipment ***calibration*** involves measuring the amount of chemicals or abrasives applied to a known area size at varying equipment settings and speeds over a specified time. Uncalibrated equipment can be messy and wasteful. Calibration of all winter maintenance equipment, including vehicle-mounted, manual spreaders, and sprayers, is an essential component of the Smart Salting concept. It should be done annually before the start of the winter season to ensure accurate application rates. **Proper calibration allows for better tracking of materials and prevents overapplication, which can reduce costs and minimize impacts to the environment while still maintaining public safety.**

Offer a variety of tools to staff so that they can use the right tool for the job.

Calibration tips: [5,9]

- Follow the manufacturer's guidelines and/or contact the manufacturer or vendor for training.
- Keep a copy of the calibrated application rate chart with the equipment or in the shop.
- Each piece of equipment should be calibrated separately because it may behave differently due to wear and tear.
- All equipment that is not dispensing material at the correct application rate should be readjusted.
- Equipment should be recalibrated after major services or adjustments.
- Different granular materials (e.g., salt, sand, granular blends) dispense at different rates, so equipment should be calibrated for each material that will be used during the winter season.
- Equipment should be recalibrated after receiving a new shipment of salt because its gradation may have changed.
- If applicable, the auger should be in place during calibration.
- Sprayers should be calibrated for each anti-icing and deicing product that will be used.

A contractor's perspective:

J. Swope of Chesapeake Bay Landscape Professional,

> Reviewing calibration directly with applicators would be a good 'hands-on' type of training. There may be an opportunity to partner with a local vendor or manufacturer representative to assist with this training. By partnering with a vendor/manufacturer, we may be able to include information on the latest technology with salt spreaders, such as remote tracking, metering, variable speed controls, etc.

During the calibration process, make sure to review application charts that provide information about application rates based on temperature, timing, materials, and other factors. These charts should be placed in each vehicle, attached to manual equipment, or be available in the shop.

Short instructional videos for calibration of salt trucks and drop spreaders are available at the Wisconsin Salt Wise website. Additionally, a video showing the calibration of a drop spreader can be found in the Winter Operations Training Series produced by the Iowa Department of Transportation. The Pass the Salt: Winter Maintenance Training video discusses calibration starting at 41 minutes. Examples of proper and improper material applications are provided in *Module 5: Storm Operations*.

Videos are available online that show proper calibration techniques for a variety of equipment.

To make the calibration process easier, the Minnesota Pollution Control Agency created a flowchart for augers and conveyor systems. Following the flowchart requires a calibration worksheet/form like the one below.

It should be noted that calculated calibration rates are starting points and should be adjusted based on experience and for current conditions. This includes the timing of the application, the type and rate of the winter precipitation, air and pavement temperatures and trends, sun angle, dew point, surface material, wind, material lost during plowing, etc. [3]. Application rates, conditions, and results should be recorded and analyzed to determine what went well and what could be improved. Records of the equipment maintenance and repair should also be kept.

Overall, good documentation will aid in identifying equipment problems needing corrective action and may improve snow and ice control, reduce waste of materials, minimize impacts to the environment and infrastructure, and lower costs [1,3].

Below are examples of a blank calibration form for auger or conveyor systems and anti-icing application rate guidelines that were adapted from [3]. Additional forms can be found in the last section of this document, *Hands-On Classes*.

Anti-icing Application Rate Guidelines

Condition for Application	**Gallons/1,000 sq. feet**		**Other Materials**
	Calcium Chloride	**Magnesium Chloride**	
Regularly scheduled	0.2 – 0.4	0.3 – 0.6	Follow manufactures' guidelines
Prior to forecasted frost or black ice event	0.2 – 0.4	0.3 – 0.6	
Prior to light or moderate snowfall	0.2 – 0.4	0.3 – 0.8	

Table 8. Anti-icing Application Rate Guidelines. Adapted from [3].

To use the chart

1. Determine the size of the area to be treated in square feet and divide it by 1,000 (see Section *Calculating size of area treated*).
2. Choose the row of the appropriate condition and the column of the material to be used.
3. Multiply the result of #1 by the application rate of #2.

Example calculation for a parking lot measuring 20,000 square feet to be treated prior to light to moderate snow with magnesium chloride brine:

1. Divide the parking lot size by 1,000 (20,000/1,000 = 20)
2. Choose the application rate (0.3 -0.8)
3. Calculate how much brine is needed (20 x 0.5 = 10 gallons)

Calibration Chart for Auger or Conveyor Systems

Date: **Spreader #:** **Material: Rock Salt**

Setting	Pounds per Minute	5 MPH (x12)	10 MPH (x6)	15 MPH (x4)	20 MPH (x3)
1		*	*	*	*
		**	**	**	**
2		*	*	*	*
		**	**	**	**
3		*	*	*	*
		**	**	**	**
Example	10	120	60	40	30
		1.9	1.0	0.6	0.5

Table 9. Calibration Chart for Auger or Conveyor Systems. Adapted from [3].

*Top half of each row = lbs./lane mile. To get this number multiply pounds/min by the factor shown for the speed.
**Bottom half of each row = lbs./1000 sq. feet. To find this, divide the number in the top half by 63.

What if calibration is not practiced?

The amount of material needed to treat an area can be determined even when equipment is not calibrated. You will still need to know the size of the area, pavement temperature, and the application rate (from an application rate chart that can be obtained from the vendor or manufacturer). Even distribution is important, regardless of calibration status of the equipment. The "chicken feed"-like application method may work well for stairways and sidewalks [3].

Example on how to calculate the right amount of material (adapted from [3]):

- The area to be treated is a 2,000 sq foot sidewalk.
- The pavement temperature is 20 ^{o}F and rising.
- The material is dry salt.
- The recommended application rate for this condition is 2.25 lbs./1,000 sq. ft.
- The amount of salt needed is 4.5 lbs.

Establish an equipment maintenance routine

To be ready for each winter event, it is essential to keep all equipment in good repair. Therefore, it is advisable to establish a regular maintenance routine to be followed throughout the winter season.

Keep records

It is essential to keep accurate records of how much materials were used for each winter event and then to analyze and adjust application rates as necessary for future events. This will ensure that the proper amount of deicing product will be applied and may reduce costs while maintaining a high level of safety.

To ensure that preparations for the winter season are completed in a timely manner, it may be helpful to fill out a check list like the "Snow and Ice Control Check Sheet" reprinted from The Snowfighter's Handbook [12].

SNOW AND ICE CONTROL CHECK SHEET

(Answer YES or NO except where more information is requested)

Organization: _____

Please complete, sign, and return this form to: _____ *by* _____(*Date*)

Miles on Clear Pavement Standard	Estimated Winter Salt Requirement (Tons)	Salt On Hand	Salt On Order	Abrasives On Hand	Abrasives On Order

STORAGE					
FACILITIES AVAILABLE			FACILITIES NEEDED		
TYPE	**NUMBER**	**CAPACITY (TONS)**	**TYPE**	**NUMBER**	**CAPACITY (TONS)**
BUILDINGS			BUILDINGS		
CRIBS			CRIBS		
PADS			PADS		
GRAVITY BINS			GRAVITY BINS		
TOTAL TONS			TOTAL TONS		

1. If cover material needed: Type _____

2. Condition of salt on hand: ❒ Dry ❒ Wet

3. All mechanical parts, storage facilities, such as hinges, slides, conveyors are operating properly and ready for winter use ..... ❒ Yes ❒ No

4. If no, explain needed repairs: _____

5. Area lights are in working condition ..... ❒ Yes ❒ No

6. Storage areas are clean and cleared of items that might cause accidents or impede operations ..... ❒ Yes ❒ No

7. Drainage is adequate at storage sites ..... ❒ Yes ❒ No

8. Have there been public complaints about any storage area? ..... ❒ Yes ❒ No

9. If so, please explain and give dates. _____

10. Traffic warning or control signs are posted at entrances and exits to storage areas ..... ❒ Yes ❒ No

11. Engine heaters and shed facilities are available ..... ❒ Yes ❒ No

EQUIPMENT

1. LOADERS:

A. Loaders of all types have been checked and needed repairs made ..... ❒ Yes ❒ No

B. Describe repairs not yet completed: _____

_____

2. SPREADERS

A. All spreaders have been calibrated and needed repairs made ..... ❒ Yes ❒ No

B. Spreading rates posted in cab; spinners checked for width of spread ..... ❒ Yes ❒ No

C. Following items have been inspected and tested on all spreaders:

1. Spinners and augers ..... ❒ Yes ❒ No
2. Sheet metal ..... ❒ Yes ❒ No
3. Gasoline Engines ..... ❒ Yes ❒ No
4. Cab and other operator controls ..... ❒ Yes ❒ No
5. Number of spreaders ready for operation: _____
6. Hydraulic systems ..... ❒ Yes ❒ No
   a. Filter element in systems (replace if necessary) ..... ❒ Yes ❒ No
   b. Oil-drain and flush hydraulic system, fill with oil of manufacturer's recommendation. ..... ❒ Yes ❒ No

3. SNOWPLOWS & UNDERBODY BLADES

A. All plows have been checked and needed repairs made ..... ❒ Yes ❒ No

B. Blade edges checked and replaced if necessary ..... ❒ Yes ❒ No

C. Plows have been placed on trucks to be sure all attachments and fittings are available ..... ❒ Yes ❒ No

D All hoses, cylinders and fittings have been inspected and tested ..... ❒ Yes ❒ No

E. Reversible plows work properly and freely ..... ❒ Yes ❒ No

F. Plow ends are marked with flags ..... ❒ Yes ❒ No

G. An adequate stock of all types of blades and bolts is on hand ..... ❒ Yes ❒ No

H. Number of plows ready for operation. _____

4. SAFETY DEVICES

A. All winter maintenance vehicles are equipped with lights according to official guidelines ..... ❒ Yes ❒ No

B. If not, describe preparations: _____

_____

C. Wiring and connections have been inspected ..... ❒ Yes ❒ No

D. Following items have been inspected on all equipment:

Headlights ..... ❒ Yes ❒ No

Taillights ..... ❒ Yes ❒ No

Stop lights ..... ❒ Yes ❒ No

Turn lights ..... ❒ Yes ❒ No

Rear & side view mirrors ..... ❒ Yes ❒ No

E. All trucks are equipped with:

Flares ..... ❒ Yes ❒ No

Safety Vests ..... ❒ Yes ❒ No

Tire chains ..... ❒ Yes ❒ No

F. Following items have been inspected and found in working order:

Windshield wipers ..... ❒ Yes ❒ No

Tires ..... ❒ Yes ❒ No

Defroster ..... ❒ Yes ❒ No

Exhaust system ..... ❒ Yes ❒ No

Rotary lights ..... ❒ Yes ❒ No

Flashing lights ..... ❒ Yes ❒ No

Instrument lights ..... ❒ Yes ❒ No

Dome lights ..... ❒ Yes ❒ No

Flashlight ..... ❒ Yes ❒ No

First aid kit ..... ❒ Yes ❒ No

Tow chain ..... ❒ Yes ❒ No

Wiper blades ..... ❒ Yes ❒No

Heater ..... ❒ Yes ❒ No

Fuel gauge ..... ❒ Yes ❒ No

Front end alignment ..... ❒ Yes ❒ No

Site Planning

Proactive site planning is a key element for operational success. **Tailoring snow management to the needs of a property manager or applicator's specific sites promotes public safety and reduces negative environmental impacts.** Specifically, site planning reduces product usage, reduces material and labor costs, minimizes impacts to the environment, and lessens damage to infrastructure all while maintaining reliable service, safety, and mobility. Fortunately, tools are readily available to make this a standardized, yet site-specific and flexible, process that is readily adoptable at any location. Practices should be documented, and effectiveness should be evaluated each season to improve over time.

Site planning involves multiple steps, including itemizing your property and calculating the treatment area; developing a plan for any onsite snow and salt storage; evaluating ingress and egress issues and considering closure of unused areas onsite; and identifying drainage problems and solutions. Developing a site-specific map of each component is also an essential step in the process. Each of these are discussed in more detail below, followed by a site planning form.

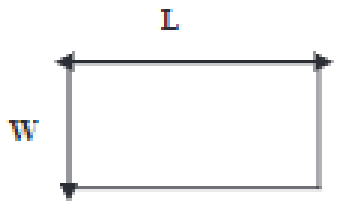
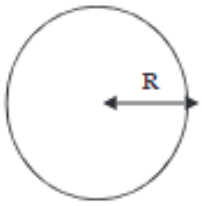
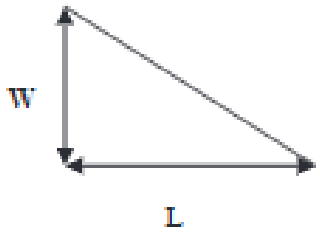
Good site planning means you will be prepared with the correct materials, equipment, and knowledge.

Calculating size of area treated

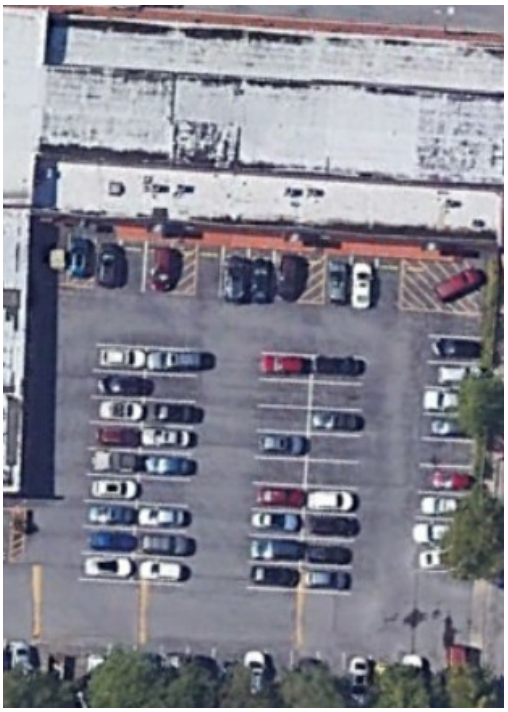
The quantity of deicing materials needed at any given site is a function of many factors including the desired level of service, surface temperature, and the size of the area being treated. **This section provides instructions on calculating the size of the area being treated to inform decision-making and site planning.**

Input measurements for calculating area can be obtained using a map or plan, an internet mapping tool (e.g., Google Earth or similar), or by measuring in the field using a handheld Global Positioning System (GPS) or other measuring tool.

Formulas for calculating the area are as follows [9]:

The area of a rectangle is length*width.	The area of a circle is 3.14*radius*radius. The radius is the distance from the center of the circle to the edge of the circle.	The area of a triangle is length*width divided by 2.
		

Irregular shaped areas that cannot be adequately estimated using the basic formulas above can be broken into regularly-shaped sections whose areas are summed to obtain a total.



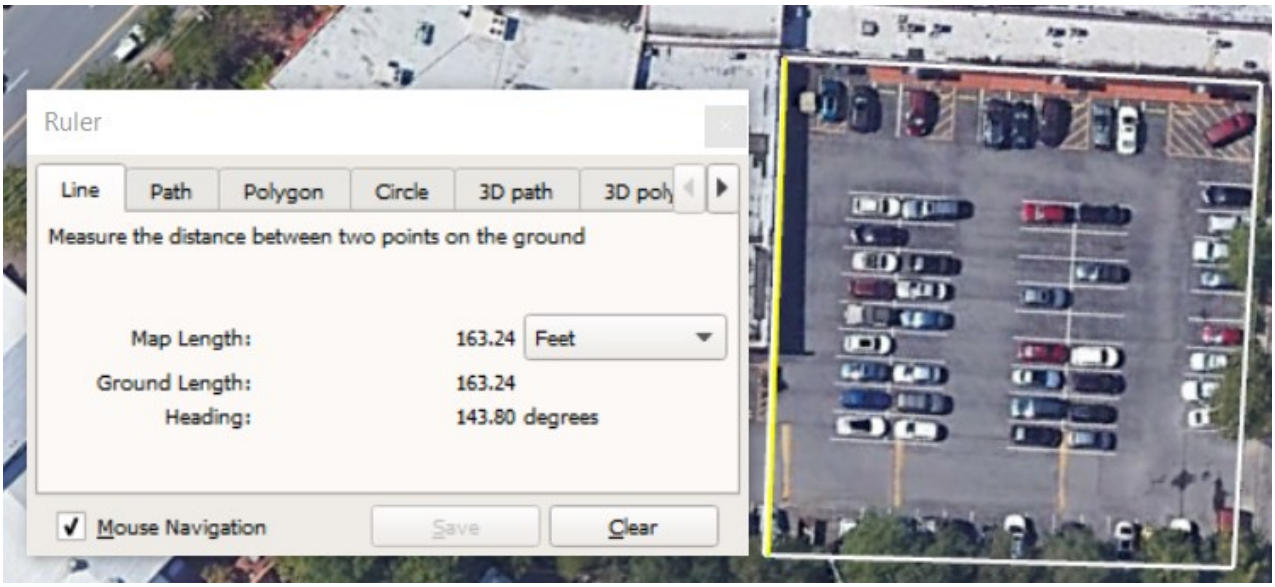
Examples of how to calculate regularly and irregularly-shaped areas can be found below.

Calculate the parking lot area for a rectangular shaped lot

We are going to calculate a regularly-shaped parking lot area by using this Google Earth[1] image of a parking lot in Frederick County, Maryland.

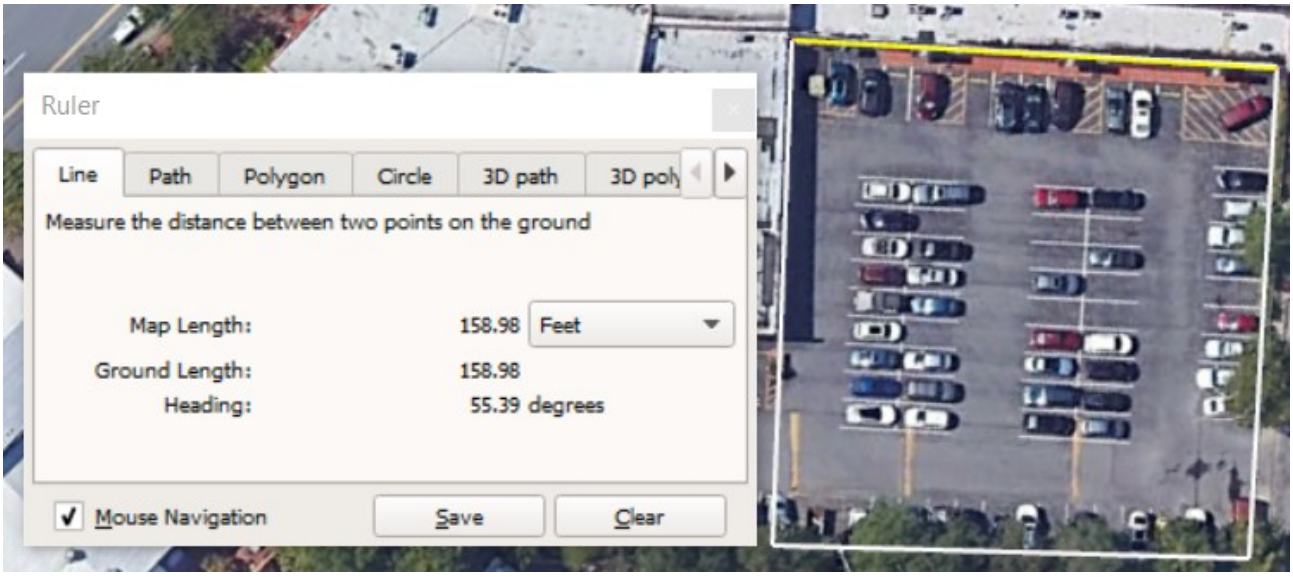
First, calculate the area by measuring length and width in Google Earth using the Line tab of the Ruler tool. Then, apply the equations presented above to calculate the area. Note that the Polygon tab can also be used to calculate the area automatically. Use of the Polygon tab is demonstrated in the next example.

Length = 163 feet (rounded to nearest foot)



[1] Google Earth is used in this example; however, it is only one of multiple options for this type of analysis. Use for this purpose does not imply endorsement.

Width = 159 feet (rounded to nearest foot)



Final Calculation:

*Area = length*width*

*Area = 163*159 = 25,917 square feet*

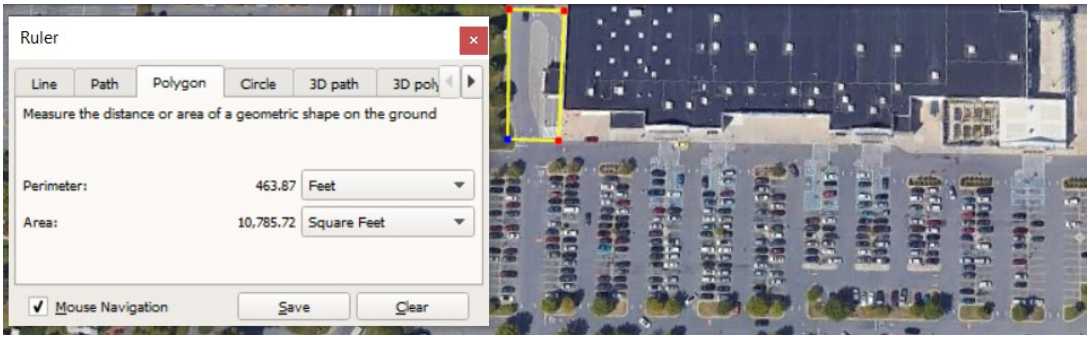
Calculate the parking lot area for an irregularly shaped lot

We are going to calculate an irregularly-shaped parking lot area by using this Google Earth image of a parking lot in Frederick County, Maryland.

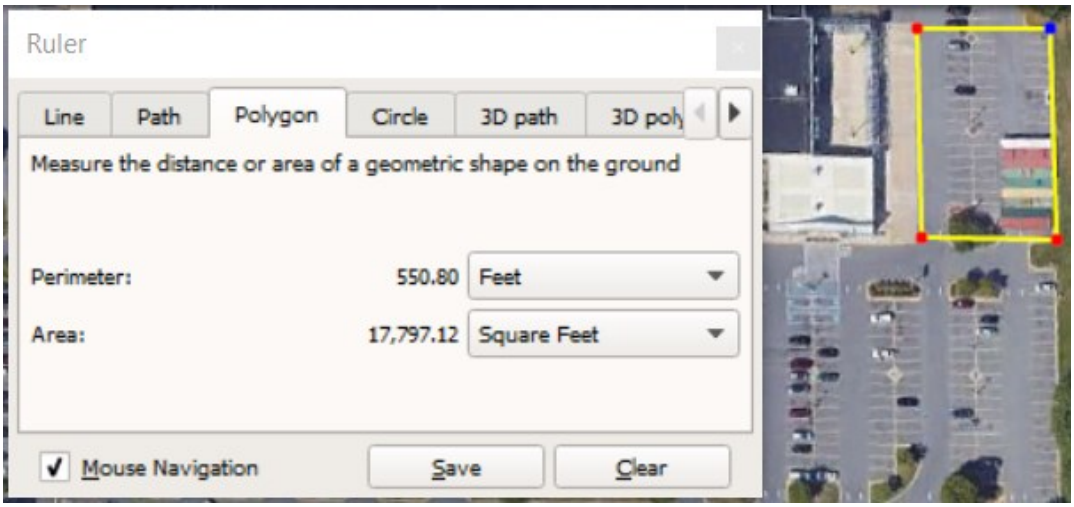
First, divide the parking lot area into regular shapes for calculations. Note that this example assumes that the entire parking lot area will be treated. See the section *Closure of unused areas onsite* for a discussion on identifying site areas for seasonal closure.

Then, use the Ruler tool in Google Earth to estimate area of each shape using the Polygon tab. Note that this automatically calculates the area of the polygon, rather than requiring the user to calculate the geometry from the dimensions as in the previous example.

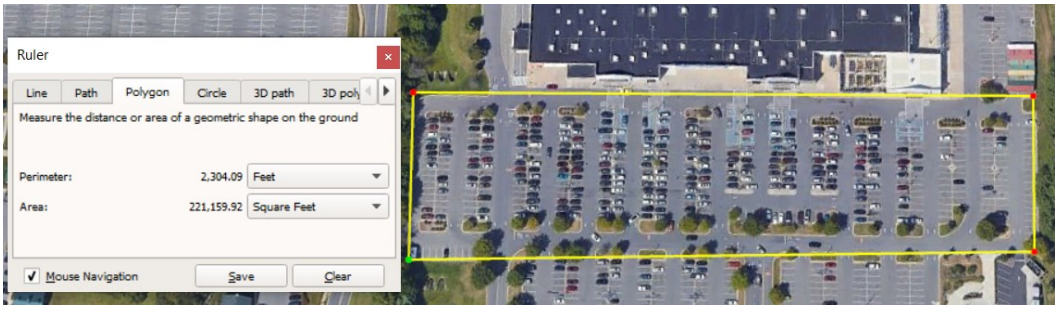
Area 1 (orange) = 10,786 square feet



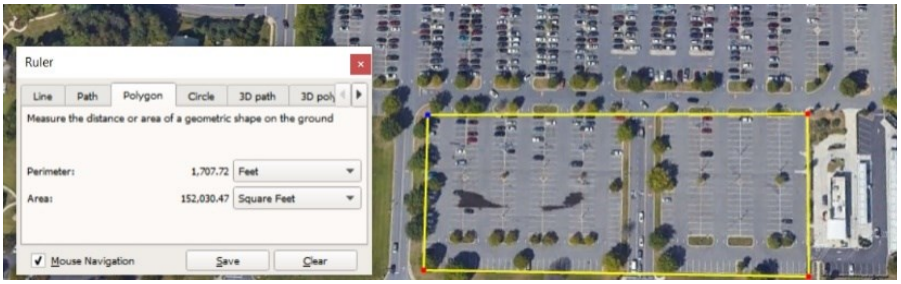
Area 2 (yellow) = 17,797 square feet



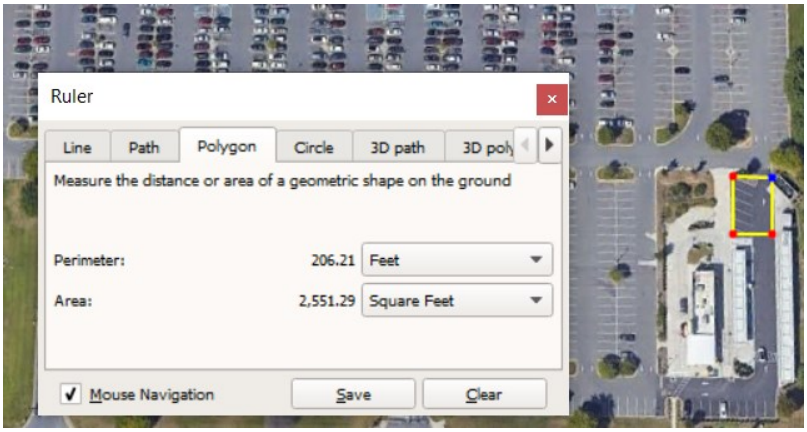
Area 3 (red) = 221,160 square feet



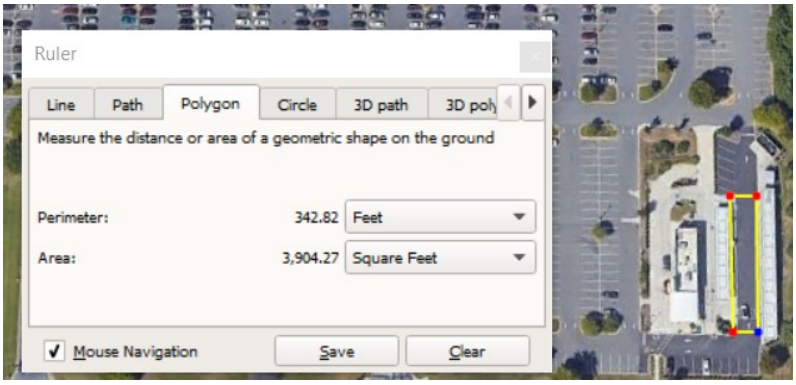
Area 4 (purple) = 152,030 square feet



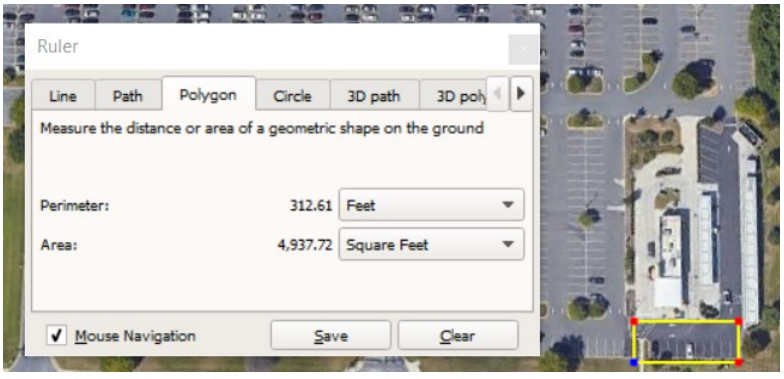
Area 5 (black) = 2,551 square feet



Area 6 (pink) = 3,904 square feet



Area 7 (light blue) = 4,938 square feet



Finally, the total area can then be calculating by summing all the parts:

Total Area = Area 1 + Area 2 + Area 3 + Area 4 + Area 5 + Area 6 + Area 7
Total Area = 10,786 + 17,797 + 221,160 + 152,030 + 2,551 + 3,904 + 4,938 = 413,116 square feet

TRAINING ACTIVITY: Use the map created in Module 3/4: Drainage *to show how Google Earth (or other applications) can be used to calculate square footage of a parking lot, driveway, or sidewalk.*

Snow pile locations

The proper location of snow piles will reduce product loss, assist in effective and efficient site planning, and aid in environmental protection efforts.

Tips for snow storage (list adapted from City of Madison, 2019) [4]:

1. Potential water contamination can occur if snow is stored near surface or ground waters, so locate snow piles away from surface water bodies (lakes, rivers, wetlands, ponds) or rain gardens as it may contain sand, trash, or other unwanted materials. In addition, consider protecting drinking water by storing snow:
    - at least 75 feet from non-community water supply;
    - 50 feet from private water supply; and
    - 200 feet from community water supply wells [5].
2. Trash can cause environmental and ecological damage and pollute land and water, so locate snow piles in an area where trash can be recovered after it melts.
3. Surface runoff from melting snow piles can carry the salt away, so store snow *downhill* of salt storage to avoid melt water from running into the salt pile.
4. Store snow on the downhill side of parking lots so that melting snow doesn't refreeze and create dangerous driving conditions or create the need for additional deicing applications (this example provided in MPCA) [6, 13].
5. Vegetation can be harmed by the snow pile so store snow away from sensitive vegetation.

The Boston Snow Farm Melt, March 27-July 6, 2015 timelapse video of a melting trash/snow pile may be an extreme case, but smaller snow piles can also contain trash that should be dealt with responsibly.

On-site storage of deicers

Proper storage of deicers saves money by reducing product loss and is important to protect plants, animals, and surface and ground water quality.

The type of storage needed varies depending on the situation. Contractors may need permanent structures for multi-year storage while property managers may only need temporary solutions for smaller, on-site storage needs. Choose the right solution for your situation.

The Salt Storage Handbook from the Salt Institute coined an easy-to-remember acrostic for considerations for on-site storage of deicer materials, using the abbreviation S-A-L-T-E-D.

Figure 40. Parking lot or sidewalk. Image from [3].

Safety

“Always make safety for workers and the general public a prime concern at a storage site. Equipment operators need good visibility in all directions. Access roads should not open directly into heavily traveled routes…Make sure the area is secure, preferably fenced, to prevent entrance by unauthorized persons.”

Accessibility

“Storage sites should permit easy access by trucks and other equipment entering and leaving these areas during storms, when visibility is low. Plan accordingly. The storage area must be large enough for front-end loaders to maneuver freely, safely, and expediently. If stored in a building, make sure the doors and openings are large enough to prevent interference with loading and unloading. Provide easy accessibility for delivery trucks, keeping in mind the prevailing wind and weather pattern.”

Legality

“You must comply with local zoning requirements, as well as local, state, and federal regulations, governing environmental concerns.”

For example, the Maryland General Discharge Permit for industrial activities includes Stormwater Pollution Prevention Plan Section B.1.b.vii that describes conditions for enclosing or covering stored piles of deicing materials.

Tidiness

“Make storage facilities blend with local surroundings, when possible, especially in residential areas. They should be well kept, with no junk or scrap material piled around that would give an impression of sloppiness or waste and allow the possibility of getting foreign objects in spreaders.”

Economics

“Locate and distribute storage facilities so that empty trucks don’t have to ‘dead-head’ long distances to reload. This reduces operating costs and speeds up spreading operations.”

Drainage

“Locate all storage structures to provide good drainage away from the stockpile. Pads should have a slope of ¼ inch per foot away from the center. Pads, aprons, and other adjacent work areas should be capable of supporting the stockpile and equipment. Ensure that your storage area does not accidentally drain into a freshwater reservoir, well, or groundwater supply. If needed, curbs can be installed around the storage area to direct drainage or run-off. All drainage/runoff should be properly contained. The brine collected can be reapplied to the stockpile during dry seasons or applied to spreader loads prior to street applications.”

Salt storage should be sturdy, undercover, and on a pad.

The Salt Institute's Salt Storage Handbook details the importance of putting salt on a pad, putting it under cover, and building it strong. Without a pad, salt can more readily contaminate groundwater. Without a cover, wind and water can cause the salt to be transported into the environment. Strong storage buildings withstand harsh winter working conditions.

Figure 42. Improper salt storage due to lack of containment Image from Fairfax County, Va.

Figure 41. Improper salt storage. Image from Lake County, Il.

Pads

- Use permanent, covered storage or outdoor stockpiles on bituminous or concrete pads.
- It should be located away from wells, reservoirs, and groundwater supplies.
- If concrete, it must be high quality, air-entrained, plus treated to keep salt out/prevent fracturing.
- It should be sloped to let surface water drain away with a minimum slope of one to two percent; it may be necessary to install pipes, tiles, or berms to promote good drainage.
- Pads can be framed on three sides to form a bin or storage buildings may be erected on top.

Covers

- Materials include polyethylene, polypropylene, Hypalon, polyurethane foam, water-resistant canvas, or other waterproof covers.
- Flexible coverings can be joined using a sewing machine or adhesive tape.
- Weigh down flexible covers with lashed old tires or sandbags. The base of the cover also needs to be weighed down.
- Small piles can be covered using ground level storage sheds, buildings, or pre-fabricated buildings; any materials should be treated and/or sealed.

Strong

- Design the building for 2-4' deep snow and 80 mph winds.
- Design should accommodate internal wind pressure.
- Trees may block strong winds and snow but putting a building too near the trees may cause snow to accumulate around the building.
- Buildings must be anchored securely as strong winds can lift roofs and collapse walls.
- Poor construction can cause the building to fail.

Figure 43. Correct vs. incorrect deicer storage. Image from [4].

Some other points to remember while designing on-site salt storage are the importance of consulting any local visual screening ordinances; ensuring that the floor is sloped away from the door [3]; keeping the buildings, pavement, and covers in good repair; and cleaning up excess salt or spills in a timely manner [4].

Storage of Liquid Deicer

Liquid deicers have many benefits as discussed throughout these modules; however, storage of liquid deicing materials requires special considerations, including [4]:

- Tanks should have secondary containment for recovery and containment of leaks. This could be a double-walled tank or a capture area.
- Know the freezing point of the liquid before storing it outside.
- Label all containers and/or tanks.
- Agitate liquid mixes that are stored for long periods of time.

Salt storage and snow piles are just some of the preplanning activities to explore when looking at the property where you will be performing winter maintenance. How will you handle entrances and exits on the property (these are sometimes called *ingress* and *egress*)? Where does the melting snow drain and how will that change your winter maintenance activities? These questions, and more, are answered in the next section.

Ingress and egress of property

Site accessibility before, during, and after winter storm events can be important for public health and safety such as allowing access to emergency vehicles, winter maintenance activities like getting access to equipment, and keeping businesses active and thriving.

While it is important to maintain access to the site, some areas of the site may be more critical than others. For example, some areas of the site may be able to be closed. Other areas are essential for winter maintenance operations like clear and open access to onsite winter maintenance material storage as well as requirements set forth in the Americans with Disabilities Act (ADA).

Figure 44. Closed stairway. Image by Jay Parker from Flickr Creative Commons.

Closing unnecessary entrances and exits during a winter storm can save time, money, and help the environment.

Closure of unused areas onsite

Closing unused, high risk, and/or high maintenance areas is one way to reduce the amount of time needed for winter maintenance and the amount of deicers needed for application while maintaining safety [4].

Areas to consider closing [6]:

- low-use sidewalks;
- duplicate staircases; and
- remote parking lots.

When closing entrances and exits, it may be important for the door to still be usable in the event of an emergency. Check fire codes and city ordinances first [6].

TRAINING ACTIVITY: Provide example site layout plans and discuss/brainstorm areas for possible season/event closure.

The off-season is a good time to address winter drainage problems.

Drainage

Drainage is an important consideration at deicer storage locations and when conducting site planning for winter maintenance activities. Each of these is considered in turn below.

Figure 45. Sidewalk closed sign, generic.

Site Drainage at Storage Facilities

Proper site drainage is just as important as proper storage of de-icing materials to safeguard natural resources.

Tips for drainage Best Management Practices for storage facilities [11]:

- Drainage, including run-off from roofs, should be directed away from the storage facilities and loading pads.
- Storage sites should be graded so that drainage is directed away from down gradient groundwater wells, storm sewers, and salt-vulnerable areas, including farmlands and freshwater streams, ponds, lakes, and wetlands.
- Salt-laden drainage should be intercepted and managed by directing it via tile ditches or pipes into lined detention ponds or holding tanks.
    - Any material left on the floor of the storage facility after the winter season should be rinsed into the drainage and holding system.
    - When appropriate, these holding systems should be drained and the material disposed of according to Maryland regulations.

Figure 46. Example of best drainage. Image from McHenry, Il 2017 Salting Workshop Presentation.

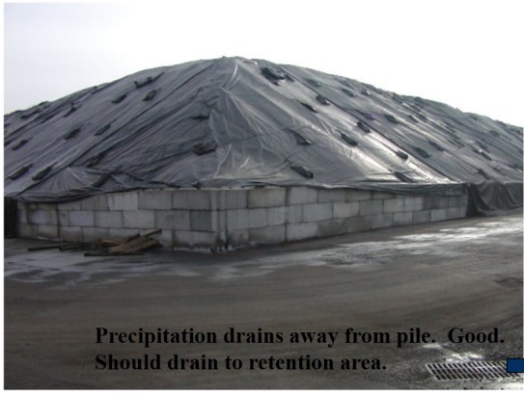


Figure 47. Example of good drainage. Image from McHenry, Il: 2017 Salting Workshop Presentation.

Figure 48. Examples of improper drainage. Images from McHenry, Il 2017 Salting Workshop Presentation.

Site Drainage on Properties

Drainage problems should also be addressed by property managers. Poor drainage can create hazardous, icy conditions during the winter season and lead to injuries. Drainage problems can be due to poor site design, broken infrastructure, roof run-off onto sidewalks or steps, improper winter maintenance, and other factors. [6]

It is advisable to identify and repair problem areas before the winter season and to note the location of icy spots during winter to be addressed later. Examples of drainage problems and solutions are provided in the table below.

Location	Problem	Possible solutions
Front steps	Roof drips onto steps	Add gutters to roof over the steps
Sidewalk	Downspout discharges directly onto sidewalk	- Divert discharge to grassy area. - Burry downspout under sidewalk. - Close off during winter.
Parking lot	Water pools in handicap spot	- If melting snow creates a problem, change its location. - Change location of handicap spot.

Table 10. Table adapted from Smart Salting for Property Management Manual [6].

Suggested maintenance plan template

The maintenance plan template on the following page is lightly adapted from MPCA from the Hennepin County Chloride Initiative. The information becomes increasingly complex to obtain when proceeding through the list. Therefore, it may be necessary to build this information over time. The information should be reviewed annually and shared with the site manager and winter maintenance crew as appropriate. [6]

Detailed salt Best Management Practice (BMP) tracking forms and instructions were also developed for the northern Virginia region as part of the Salt Management Strategy Toolkit, Appendix J. Those resources may serve as examples for even more detailed record-keeping.

Maintenance Plan Template

Basic information:

- ❑ Individual responsible for the winter maintenance at this site
    - Name: _____
    - Phone number: _____
    - Email: _____
- ❑ Completion of Maryland Smart Salting training of at least one person involved in winter maintenance operations at this site:
    - Name: _____
    - Company: _____
    - Phone number: _____
    - Email: _____

Choose from the recommended fields:

Easy to verify:

_____ % of winter maintenance crew have completed the Maryland Smart Salting program.

Easy to observe:

- ❑ No granular salt on surfaces after the event
- ❑ Proper storage of granular deicers
- ❑ Proper storage of liquid deicers
- ❑ Proper storage of snow (not near surface waters)
- ❑ Educational signs on property

Choose from the recommended lists:

- ❑ Documentation
    - ❑ Map or spreadsheet
        - ❑ Size of entire maintenance area
        - ❑ Estimated amount of deicer per pass*
        - ❑ Size of each maintenance area (i.e., main parking lot, front sidewalk…)
        - ❑ Level of service for each area
        - ❑ Estimated amount of deicer needed per pass for each area
    - ❑ Annual report
        - ❑ Total deicer use (in lbs./gal)
        - ❑ Challenges in reducing salt use
        - ❑ Successes in reducing salt use
        - ❑ Plans for Smart Salting next year

Choose from the list of best practices:

- ❑ Remove snow before applying deicer.
  - ❑ Snow removal early and often to prevent compaction.
  - ❑ Better and/or more snow removal tools (brooms, segmented blades, blowers, underbody blades, shovels by salt bucket...).
- ❑ Measure pavement temperature and trend, use this information to guide deicer selection and application rates.
- ❑ Have available a variety of deicer/abrasive materials so you can select the product that will work best in the lowest commodity depending on the conditions.
  - ❑ If deicers are being use, they should include liquid deicers
- ❑ Improve salt bucket situation (educate users, provide alternatives like shovels and brooms, provide application rate guidance, restrict use, provide small scoops).
- ❑ Calibrate spreaders, put calibration card on spreaders.
  - ❑ Use equipment capable of spreading at low, controlled rates or work towards this goal as you acquire new equipment.
  - ❑ Create application rate charts so applicators can see calibration card, and application rate guidance and be able to choose most appropriate setting on their spreaders.
  - ❑ If your application rate charts are higher than recommended values, explain why this is necessary.

    The Virginia Salt Management Strategy (SaMS) Toolkit provides the following example application rates for property management operations in Appendix D.d:

Rates derived from the Sustainable Salt Initiative[1]			
		Dry Rock Salt (NaCl)	
Pavement Temperature (°F) and Trend (↑↓)	Surface Condition and LOS	Pounds per 1000 ft²	Pounds per acre
15-20 ↑	The surface has been cleared of snow/ice; Application Rate for Bare Pavement LOS	14	610
15-20 ↓		13.5	588
20-25 ↑		13.25	577
20-25 ↓		12.75	555
25-30 ↑		12.5	545
25-30 ↓		11	479
30 ↑		11	479
>30 ↓		10	436

[1]The Sustainable Salt Initiative (SSI) rates are representative of the average of total rates collected from winter management companies participating in the Snow and Ice Management Association's SSI during 2015-2016 and 2016-2017 winter seasons. For more information and to access "Sexton, Phillip Charles. 2017. Sustainability Analysis of the Commercial Winter Management Industry's Use of Salt. Master's thesis, Harvard Extension School" visit https://dash.harvard.edu/handle/1/33826971.

Figure 49. Application Rates for Property Management Operations. Virginia SaMS.

- ❑ Sweep up extra salt after events.
- ❑ Hold post storm meetings or debrief with maintenance crew on what went well and how to continue to work toward Smart Salting goals.
- ❑ Educate building and grounds users on Smart Salting and the role they play wth safe driving and walking practices.
- ❑ Close areas not needed in winter so there is less surface area to salt.
- ❑ Consider areas where you might change the level of service from bare pavement to not bare pavement. (Salted walking path to a no-salt eco-path for dog walkers)
- ❑ Other:

Step by step guide for how to plan winter operations for any given site

Carefully consider the characteristics of each site by completing the six sections of the site planning checklist below [6]. The form should be re-evaluated each year before the winter maintenance season at each site to ensure accuracy and to account for changing site conditions. The checklist provided below may be used as a reminder for the six different site-specific considerations.

- ❑ Itemize your property
- ❑ Review potential snow storage problems on your property
- ❑ Review salt storage areas and methods
- ❑ Winter closures
- ❑ Find drainage problems and solutions
- ❑ Create a map

1. Itemize your property

Site Name:_____Date: _____

Area, square feet (see area calculation description in Section *Site Planning*): _____

Purpose (What are you trying to accomplish? Circle one):

Bare pavement (if so, how fast?)	Patches of bare pavement	Compact snow ok, could put sand on top for traction

What is the best time of day for snow maintenance? (Daytime, Evening): _____

2. Review potential snow storage problems on your property

Site Name:_____Date: _____

Consider whether the following apply to this site and add notes on site-specific considerations if needed:

Avoid pushing snow into wetlands, ponds, lakes, rain gardens, or rivers.

_____

Avoid snow pile(s) that melt and run across surfaces causing slippery areas where people walk or drive.

_____

Avoid snow pile(s) that melt and run into salt storage areas. _____

Avoid damaging trees, flowers, and/or grass. _____

What other snow storage problems could occur on your site and how can they be avoided?

_____

_____

3. Review salt storage areas and methods

Site Name:_____Date: _____

If salt is stored on site, it is important to have a storage plan and strategically locate the storage location. Use the table below to describe salt storage. As a reminder, helpful storage tips are available in Section *Site Planning*.

	Winter Storage		Summer Storage	
Type of Salt	**Where**	**How**	**Where**	**How**
Bulk salt				
Bulk sand/abrasives				
Bulk sand/salt mix				
Packaged deicer				
Liquid deicer				
Other				

4. Winter closures

Site Name:_____Date: _____

Are there areas of the site that are low use or high risk that could be closed for the winter season? If so, list them here.

Low use maintenance areas that could be closed for the winter season:

_____

_____

High risk maintenance areas that could be closed for the winter season:

_____

_____

5. Find drainage problems and solutions

Site Name:_____Date: _____

Identify and describe any drainage problems and possible solutions in the table below.

Location	Problem	Solutions

6. Create a map

Site Name:_____Date: _____

When finished completing the above assessments (#1-5), integrate the following into the map of your property:

- Size of maintenance areas
- Level or service goals
- Snow storage areas
- Salt storage areas
- Winter closures
- Drainage problems
- Special site considerations (e.g., porous concrete, fire hydrants)[2]

TRAINING ACTIVITY: Develop a real-world site example using a Google Earth image to clearly mark storage areas, snow pile areas, etc.[3]

[2] Communication from Jason Swope, CBLP, April 15, 2022: "Some of these items on a site plan might not directly affect how much ice melter is applied, but they do help limit potential property damage".
[3] Recommended by Jason Swope, CBLP, via email on April 15, 2022.

Contracts

Careful consideration should be given to the design of winter maintenance contracts that support multiple objectives including maintaining public safety, optimizing costs, and minimizing environmental impacts.

Contracts should be advocated to allow (and encourage) use of best practices rather than charging for the amount of deicing material applied, all while maintaining appropriate levels of service [4].

Contracts should be based on an agreed-on level of service that addresses safety concerns, traffic patterns, environmental factors, cost, and other items including [7]:

- Start date and length of service
- Location of and access to the site
- Hours of operation
- Location of priority access points and all areas that should be maintained
- Times when the area needs to be cleared (evening versus daytime, etc.); whether some entrances, parking areas, sidewalks, or paths can be closed during winter weather events or for the season
- Whether an area needs to be maintained only at certain times (during the holiday shopping season, on weekdays only, etc.)
- Locations where passive techniques such as snow fencing may be installed to prevent drift [14]
- Types of specialized surfaces that must be treated (e.g., heated surfaces, pervious asphalt, concrete, pavers) and which methods are suitable to treat these surfaces to avoid damage [14]
- Triggers for service (i.e., zero tolerance, certain depth of snow fall, icy conditions)
- Types of chemicals and/or abrasive materials that will be used
- The *when* and *how* of treatment (such as, apply brine before a winter event, treat chemically only at 1" of snowfall and under, plow and treat above 1" of snowfall, etc.)
- Suitable location(s) for snow piles if snow is not hauled off premises
- Steps taken to contain or collect contaminated melt water from snow storage areas. If applicable, these steps should be documented in a stormwater pollution prevention plan (SWPP) [8]
- Snow removal procedures and costs for loading and hauling when sufficient on-site storage is lacking
- Liability in case of damage to property, surfaces, or landscape features
- Liability in case of injuries due to accidents
- Insurance
- Indemnification
- Owner responsibilities

Example Contracts

Several example contracts are available that provide a starting point for proactive, sustainable contracting while broader regional efforts are underway to develop and adopt standard contracting models to promote the use of better practices (see Virginia SaMS, 2021) [15]:

- City of Edina, Minnesota example contracts available at: Model Contracts (www.wisaltwise.com)
- Minnesota model exhibit for private snow and ice service contract (www.pca.state.mn.us)

Convincing clients to adopt Smart Salting Concepts

Communicating the importance of Smart Salting work with property owners, site managers, and contractors will increase their buy-in to your economically and environmentally friendly practices.

To promote adoption of best practices for businesses and contractors [16,17]:

- Complete the Maryland Smart Salting training.
- Communicate concerns about oversalting, including reaching out to proper entities when oversalting is observed.
- Advertise use of Smart Salting practices on the property.
- Use contracts that are based on getting the job done rather than the amount of salt applied.

A contractor's perspective:

One contracting option is to price per application rather than per quantity. According to J. Swope of Chesapeake Bay Landscape Professional, this approach…

> …Reduces the incentive to over-apply, helps define exactly how much material should be applied, provides a better level of confidence and trust for the property manager, and motivates the contractor to reduce waste and be mindful of how much salt is applied. With 'per application' pricing, over-application of ice melter is not rewarded, but actually costs the applicator money because they are applying extra product that they are not being paid for. A range of application rates could still be used with per application pricing – such as 'light salting', 'heavy salting', or 'drive lane salting'….as long as those applications fall within the recommended rates as conditions dictate. Per application pricing would also make it easier for contractors to track and record salt usage. The costs in ice melter applications are more about the labor, equipment, and mobilization costs and less about the amount of material applied.

To promote adoption of best practices for do-it-yourselfers:

- Shovel before snow turns to ice. The more snow removed by shoveling, the less salt needed.
- A 12 oz. cup of salt will treat a 20-foot driveway or 10 sidewalk squares. Scatter salt, leaving space between grains.
- Sweep up excess salt after a snow event, especially before rainfall to prevent salt from washing down the storm drain into waterways.
- When pavement temperatures drop below 15°F, sodium chloride no longer works. Switch to sand or a different deicer designed to work at lower temperatures [16,17].

Free outreach materials from MDE

People may expect the "crunch" of salt on the sidewalk. But just like you don't want to feel the crunch of salt in your food, the sidewalk crunch can be a sign of over-salting. This can lead to negative human health, environmental health, and infrastructure impacts. Therefore, effective education and outreach at all levels — from elected officials to property managers and applicators to the general public — is an essential component needed to transition to more sustainable salt use strategies.

Effective message strategies include several common components: the importance of public safety; the unintended environmental impacts of salt use; why minimizing salt application matters; the pros and cons of winter salt use (keeping in mind the concerns of all stakeholders); and information on ways the target audiences can address the issue (Section 6 of the northern Virginia Salt Management Strategy).

Existing outreach materials are available from MDE, including the following brochures:

- Common salting mistakes
- Expecting ice
- Official attack the snow like a pro
- Salt dos and don'ts
- Salt savvy neighbor checklist
- Smart salt recipe
- Winter professionals

Figure 50. City of Baltimore Saltbox. Image by Colin Ford from Flickr Creative Commons

Outreach materials are available from plenty of existing programs and can be obtained and used with appropriate permissions. A few examples include Minnesota's Statewide Chloride Resources; YouTube (e.g., Snow and Ice Clearing for Homeowners; Watershed – the Hypoxic Punks); and Appendix I of the northern Virginia Salt Management Strategy Toolkit.

Example outreach efforts in Maryland include the Izaak Walton League of America's Winter Salt Watch program, Montgomery County's Salt-Wise campaign, the City of Gaithersburg's Paint the Plow, the Interstate Commission on the Potomac River Basin's webinar series for land use decision-makers, the City of Baltimore's Saltboxes; and the Chesapeake Bay Foundation, to name a few.

Find these online resources by using the terms used above on your preferred search engine.

Module 5. Storm Operations

Learning Objectives:

1. Demonstrate spill and equipment clean-up procedures.
2. Review use of best practices.
3. Evaluate successes and lessons learned, prepare documentation and records.

Step-by-Step Guide

The list of things to do to prepare for a winter storm can be overwhelming, especially if you are new to Smart Salting practices. The following steps cover most of your "to-do" list. Keep this in mind as you read through the rest of the module.

At the beginning of each storm event, you should:

1. Make sure all equipment is up-to-date on maintenance.
2. Have all winter maintenance materials, including deicers, ready to go.
3. Stay current on weather conditions.
4. Communicate the maintenance plan for the storm with team members and staff.
5. Determine if rain is anticipated before the winter storm.
    I. If there is no rain in the forecast, paved surfaces can be pretreated with anti-icing liquids anywhere from one hour to days prior to the winter storm [10].
    II. If rain is anticipated days prior to the winter storm, pretreat paved surfaces after the pavement is dry (from the rain) and at least one hour prior to the winter storm [10].
    III. If rain is expected to come in the beginning of the winter storm and transition into snow later, do not pretreat with anti-icing methods.
6. Determine the type of snow occurring during the winter storm. Depending on the type of snow, remove snow using the one or two-pass method:
    I. If the snow is light and fluffy, employ a one-pass snow removal method by using a broom or shovel to expose pavement.
    II. If the snow is heavier and dense, use a two-pass method, where the first pass will remove the bulk of the snow (i.e., a snowplow) and the second pass exposes pavement (i.e., a broom).
7. Repeat step 6 frequently to prevent excess ice formation.
8. Apply deicers, such as granular salt, in areas susceptible to additional ice buildup, concentrating on the center one-third of the pavement.
9. After the storm is over, remove excess deicers from pavement and surrounding areas.

Winter Maintenance Basics

Deicers are applied during winter storms to improve the safety of Maryland sidewalks, parking lots, and roads. They do this by breaking the bond that occurs between the ice and snow and the surface of the road [6]. The use of deicers is often the best way to increase safety during a winter storm in Maryland. Understanding the basics of winter maintenance leads to safe and efficient winter storm response.

Pre-storm treatment

Pre-storm treatment involves liquid deicers, and those deicers can be used in several ways [2]:

- *Pre-treated stockpiles* are granular deicer stockpiles that have a small amount of liquid deicer mixed-in prior to winter storm events.
- *Pre-wetting deicers* happens right as the deicers are being applied. In pre-wetting, liquid deicers are mixed with granular deicers at the time they are exiting the truck or equipment and being applied to pavement.
- *Anti-icing* occurs when only a liquid deicer is applied to pavement prior to a storm event to prevent ice and snow from bonding to the pavement.

Using a liquid deicer as part of the winter maintenance process can reduce the amount of product used because liquids stay in place better than granular deicers [2]. Bouncing, wind, foot traffic, and vehicular traffic moves rock salt all over the place [2]. **Deicers with even a small amount of liquid, like pre-treated stockpiles, stick to where they are applied.**

A benefit of using liquid deicers is that they begin to melt snow and ice faster than their granular counterparts [2]. As salt is often over applied in hopes of making ice and snow melt faster, using liquid deicers saves time and reduces the amount of product used.

Guidelines for Liquid Deicers

The guidelines for liquid deicers are dependent on the format of liquid deicer used.

Salt brine (NaCl) is the most common liquid deicer but is not suitable for pre-treating stockpiles. When salt brine is mixed with a granular deicer, it melts the granular deicer and forms a hard crust when it dries. This decreases the effectiveness. [2]

On the other hand, salt brine is a great option for pre-wetting and anti-icing if the temperatures aren't anticipated to go below 15°F. Salt brine, like dry rock salt, doesn't work below 15°F [2].

After salt brine, the next most common liquid deicers used are Magnesium Chloride ($MgCl_2$), Calcium Chloride ($CaCl_2$), and brine blends [2]. Magnesium Chloride and Calcium Chloride have the added benefit of working at significantly colder temperatures than the common rock salt, Sodium Chloride (NaCl) [4]. They work at temperatures above -10°F and -20°F, respectively [4]. If you are working at very low temperatures, consider using a blend of these options.

More information on pre-wetting, pre-treating, and anti-icing can be found in other areas of this manual under *Pre-storm Treatment* and *Pre-wetting and Pre-treating with Salt and Sand*.

Figure 51. Example of anti-icing applied to roadways. Notice the ideal application is with bare pavement between lines. Image by MPCA from Flickr Commons.

Brine doesn't work at temperatures below 15°F.

Mechanical snow removal

Mechanical snow removal is the process of moving snow from one location to another using manpower or vehicles, not chemicals. **Mechanical snow removal should always be the first step in winter maintenance operations before any chemical deicers are applied** [2]. By removing snow and ice mechanically first, it is less likely that chemical deicers will get diluted by the snow and ice [5] and icy compaction of snow is avoided [2]. To ensure the mechanical snow removal plays a main role in winter maintenance, staff schedules and hours may need to be adjusted accordingly [2].

There are two methods for mechanical snow removal — the one pass and two pass methods. The one pass removal method is ideal for lighter snows where a broom or shovel will expose bare pavement. [2]

In situations where one pass is not enough due to heavy snow, a two-pass removal method is ideal. This calls for two different tools to clear an area. The first tool is used to remove most of the snow while the second tool is used to expose bare pavement. For instance, a two-pass snow removal would plow an area to move most of the snow and then use a broom to remove the rest to expose pavement. [2]

When selecting the appropriate tool and method of snow removal (one pass or two pass), the goal should be to ultimately reduce the amount of salt needed afterwards [2]. In some instances, this may require investing in newer or more efficient equipment, but in the end, this will increase efficiency and reduce the operation's salt requirements [2]. Sidewalks and trails can easily be cleared using brooms or snow blowers, especially when the snow is light and fluffy [2]. Scoop shovels and plows are needed to efficiently remove wet and heavy snow [4]. When it comes to compacted snow, rubber or plastic plow blades and handheld scrapers or shovels with flexible blades are the ideal tools of choice. They can get under the compacted areas without damaging the sidewalk or trail [2].

All winter maintenance operations should be coordinated to ensure that one person's effort isn't removing deicers already applied by someone else [5].

Figure 52. Examples of mechanical snow removal. The top image shows a plow removing snow while the bottom shows a woman using a snow shovel. Top image by ReinhardThrainer from Pixabay and bottom image by Nataliya Vaitkevich from Pexels.

Early and aggressive mechanical snow removal should be the first step in winter maintenance.

New technology and plow blades are available to improve the efficiency of plowing and clearing pavement. One type of plow blade is the *segmented blade* which involves multiple smaller blades that can move independently and allow for plowing to contour to the pavement better [2].

When snow is removed from the paved surfaces, it must be put somewhere. **Snow should never be moved into nearby water bodies, wetlands, local traffic, or streets**. If snow piles become too large to safely store on site, they may need to be trucked elsewhere. [3]

Apply salt only where needed

When applying rock salt and other granular deicers, you should consider how foot and vehicle traffic is going to impact the spread of the salt. When people walk or drive over salted areas, the granules get pushed toward the outer edges of the paved surfaces. To keep salt in the area it was intended, application needs to be concentrated with a narrow-spread pattern in the center of the paved area. By focusing on these areas, less salt can be applied for the same level of safety to the public. Using a calibrated drop spreader is a great way to reduce salt and keep a narrow-spread pattern. If you only have a broadcast spreader, add a shield to keep the salt from spreading to the grass, trees, or other unintended areas. [2]

How do you know if too much salt has been applied? A visual inspection is a great way to determine if the correct amount of salt is applied. **Rock salt should be applied so that there are 3-inch spaces between each individual granule**. Can individual granules be distinguished? If individual granules can't be observed because there are piles or thick layers of salt, this means too much salt has been applied and the excess needs to be cleaned up. [2]

Figure 53. Example of the ideal salt application on pavement. There is space between the granules and no piles. Image by MPCA Photos from Flickr Commons.

Plenty of space between salt granules is safe, effective, and smart.

Remove excess

Cleaning up after winter storm events involves the removal of excess salts, sand, and even snow. Train your crew to clean up salt spills and overapplication. This can help avoid customer complaints and improve customer and operator relations. Clean up actions are also necessary after snow piles have melted. More information on post-storm cleanup can be found in *Module 6: Post-storm and End of Season Actions*. [2]

Post-storm cleanup keeps sidewalks clean and unnecessary salt out of storm drains.

Weather and Temperatures

Weather and pavement temperatures

Efficient winter maintenance operations require accurate and updated weather information [2]. **Weather conditions play a key role in deciding what winter maintenance strategies to use and when to implement them** [2]. For example, knowing when a winter storm will start, the relative temperature range during the storm, and whether precipitation will start as snow or rain, can determine if anti-icing is a good strategy to use for that storm event. Weather data for decision making should include:

- Type of precipitation
- Expected amount of precipitation
- Pavement temperature
- Air temperature
- Wind speed
- Wind direction

* List adapted from City of Madison - Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails [2]

The strategy chosen to address a storm depends on the type and predicted amount of precipitation, intensity of the precipitation event, temperature trends, and the winds anticipated with the storm event. For example, pre-storm treatment such as anti-icing is not an option when the winter storm event starts with rain that eventually transitions to snow or there are strong winds occurring with the snow. [2]

In winter road maintenance there are two types of temperature that are often recorded — pavement temperature and air temperature. Air temperature is largely the same for a particular city and is the temperature that is reported by local weather stations [2]. Alternatively, pavement temperature is more variable than air temperature due to small variations in shading, sunlight, and pavement composition from one area to the next [2]. In fact, pavement temperatures can be as much as 10 to 20 degrees different than air temperatures [1].

Think about it this way, on a hot summer day, a light gray pavement will be warm, but you can still walk outside barefoot to grab something from your car. However, if your driveway is black top, you would probably put your flip flops on before stepping outside.

Figure 54. Ever heard of the phrase "hot enough to fry an egg?". Image by Pockafwye from Flickr Commons.

Pavement temperatures are more important to consider when deciding which deicer, the amount of deicer, and the application rate. For example, as pavement temperatures fall into the extremely cold range, chemical deicers are no longer a viable option for winter maintenance. [2]

Frost will begin to form when pavement temperature is below or equal to freezing and below the dew point. By monitoring the dew point, winter maintenance operations can predict frost formation and proactively treat it. [5]

Measuring pavement temperature does not need to be complicated. An infrared temperature sensor can give you a fast and accurate reading. They can be found as hand-held devices or mounted devices that can be fixed to a vehicle's side-view mirror. [2]

When using infrared temperature sensors, here are some guidelines to consider, ensuring your crew stays safe while getting accurate readings:

- Calibrate temperature sensors by setting them outside for at least 10 minutes prior to use.
- You can test hand-held sensors prior to use by measuring the temperature of ice water, which should read at 32^{o}F.
- Do NOT use a hand-held sensor while driving.
- Mirror-mounted sensors provide continuous temperature data and are a good option for drivers.

*List derived from City of Madison – Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks, and Trails [2]

The Maryland Department of Transportation (MDOT) provides local weather data, including pavement temperature, precipitation type, dew point, wind speed, and wind direction through the online MDOT Coordinated Highways Action Response Team (CHART) for several locations across the state.

It is important for winter maintenance operations to have more than one reliable source for weather information. This allows winter maintenance professionals to double check predictions and ensures that information is still available if one location is not reporting data. Here are a few options.

- Maryland Department of Transportation (MDOT) Coordinated Highway Action Response Team (CHART) local weather station data
- National Oceanic and Atmospheric Association (NOAA) National Weather Service
- Personal infrared thermometer to measure pavement temperature
- Any weather app available on a smartphone

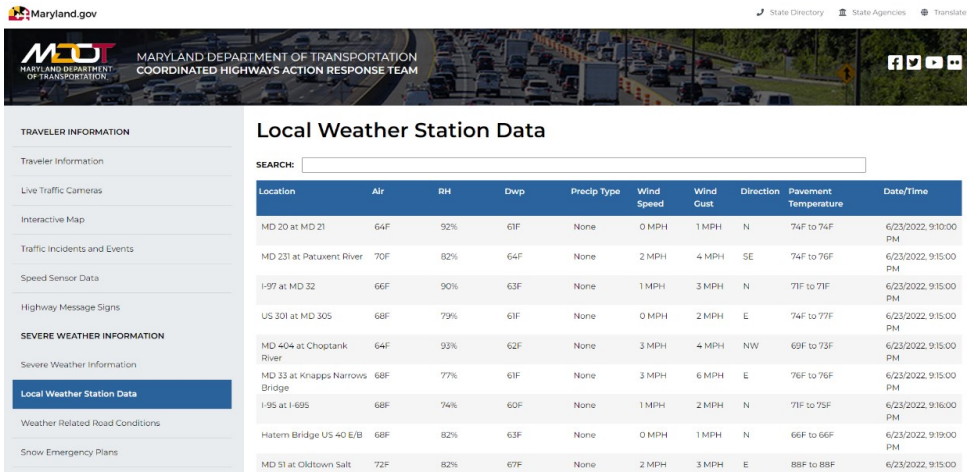


Figure 55. Example of the local weather data available through MDOT CHART. Image from maryland.gov.

Application rates for various precipitation types

There are several factors to think about when determining your application rate. These factors include the level of service goal, pavement temperature, type of pavement, products available, and the type of precipitation. With so many factors going into determining the ideal application rate, it is important for each operator to have the tools to make the most informed decisions. **Having all available information allows operators to choose the best strategy and timeline that is within their capabilities.** [13]

One of the tools that allow for the best decision possible is an easily accessible application rate chart that considers pavement temperature, weather conditions, multiple maintenance actions, and multiple chemical deicers [3]. Charts are available in the appendices of this manual that show ideal deicing application rates for various pavement temperatures during snow, ice, and freezing rain and anti-icing application rate for salt brine when the predicted weather is frost/sleet, black ice, freezing rain, light snow, and heavy snow [2,3].

Anti-icing prevents the ice from sticking, just like you grease the pan, so your egg doesn't stick.

Pre-Storm Treatment:

Anti-icing/deicing information

Anti-icing is a proactive practice that aims to avoid a bond forming between snow and pavement by applying liquid deicer prior to a storm. It can even be applied several days in advance, depending on the weather forecast [8]. By being proactive, you can reduce the amount of product that is necessary while still ensuring safe driving conditions.

Find more information on winter maintenance for small sites in the video check out the Mississippi WMO Winter Maintenance for Small Sites website.

Deicing, on the other hand, is a reactive practice that works to break bonds between snow and pavement that have already formed. It generally occurs during or after the storm [8].

Here's how it can be done:

- ***Anti-icing*** – applying liquid deicers to pavement prior to storm events to reduce or prevent bonding between snow/ice and the pavement.
- ***Pre-treated stockpiles*** – mixing liquid deicers with granular deicer stockpiles.
- ***Pre-wetting*** – mixing liquid deicers with granular deicer as they are being applied.
- ***Direct Liquid Application*** *(DLA)* – applying liquid deicers to pavement during or after the storm.

*List adapted from City of Madison – Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails [2]

The use of liquid deicers can reduce the materials used and the total workload in general, but even more so when used as anti-icing. Anti-icing brine uses about one-fourth the material as deicing. Additionally, less salt is needed later to keep paved surfaces safe, and less manpower is needed to clear the surfaces after the storm. [6]

Figure 56. Liquid deicing equipment being used for ant-icing prior to a winter storm. Image by Seth Granville from Flickr Commons.

Figure 57. Liquid deicer application during a winter storm event. Image by Oregon DOT from Flickr Commons.

To help winter maintenance operations decide when anti-icing is idea for implementation, the Michigan Winter Maintenance Manual has created the following decision flow chart:

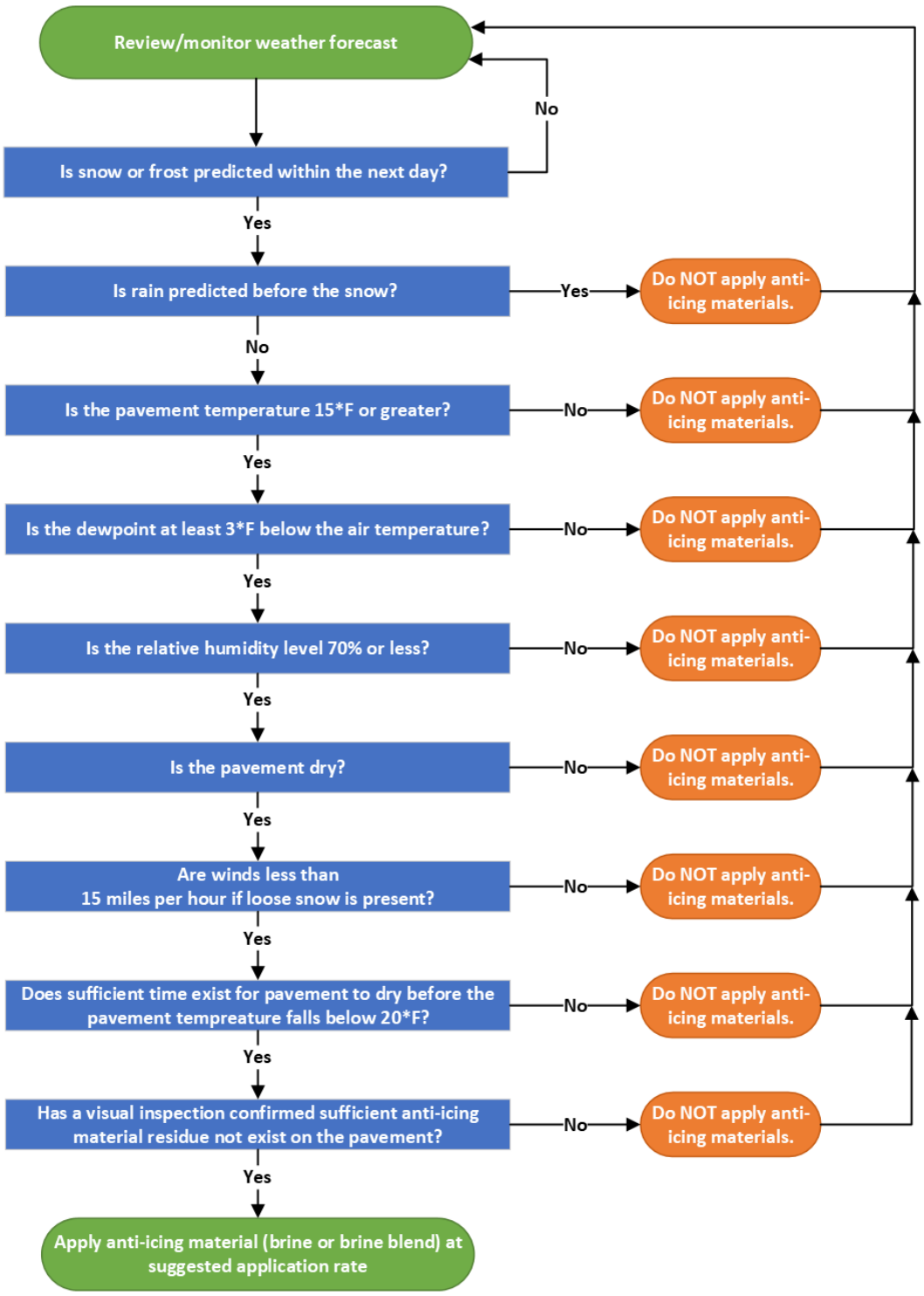


Figure 58. Anti-icing decision flow chart to determine if anti-icing methods should be implemented. Image adapted from Michigan Winter Maintenance Manual [5].

Tips for anti-icing:

- Anti-icing is extremely effective in maintaining safety during heavy frost and light freezing rain when applied early [7].
- Start with a slow application rate and increase the speed, if needed, to allow areas that may be more hazardous than others to receive additional spot applications [5].
- A slow application rate can avoid unnecessary slippery conditions. An overapplication of anti-icing products on dry roads can mix with vehicular oils and create slippery surfaces [5].
- Anti-icing applications should be scheduled for each predicted storm event [3].
- $CaCl_2$ or $MgCL_2$, products should not be applied to surfaces above 35°F as they are known to pull moisture toward the pavement and become slick [3].
- Using dyed deicing products can show the public that anti-icing actions have been taken but may have negative health and environmental impacts, be sure to research what dye is being used [13].
- Anti-icing products may still be on the pavement after several days, it is important to observe if anti-icing products are still present and avoid re-application if they are [3].
- Anti-icing is not a viable option when rain is expected prior to snow. It will wash it away [2].

Tips for deicing:

- As winter storm events are in progress or have already occurred, over-application of deicers is more common with deicing than anti-icing.
- Use accurate weather information, calibration charts, and best practices to avoid over-application of deicing products.
- Give the applied deicer time to work. Adding more deicer won't make it work faster.
- Avoid application to surfaces that are already wet. This means the bond between snow and pavement is already broken. [8]

What brine is and how it works

Brine, or salt brine, is a mixture of water and rock salt (NaCl) that melts ice and snow in the same temperature ranges as dry salt [2]. It can be used as an anti-icing product or during a storm as a deicing product.

Just like rock salt, brine doesn't work properly when pavement temperatures are below 15°F [2].

You can obtain salt brine by purchasing it from retailers or making your own by mixing rock salt with water manually or with brine making equipment [2,6]. There are several companies available for purchasing salt brine and other liquid deicers [2].

Making brine with equipment

Brine making equipment mixes rock salt and water in a hopper and stops adding water once the mixture reaches 23.3% salt concentration. The brine is then sent to an on-site storage tank to await being moved to the tanks on maintenance vehicles. [6]

Making brine manually

Manually making brine requires just rock salt and water. You will need a hydrometer to ensure the proper concentration of salt-to-water. There needs to be a 23.3% concentration of salt for the salt brine to be effective at the coldest temperatures possible. At concentrations above or below 23.3% the brine will freeze at temperatures warmer than 15°F. [2]

With rock salt, water, and a hydrometer in hand, follow these directions:

1. Combine rock salt and water at approximately 2.3 pounds of salt to 1 gallon of water.
2. Stir thoroughly before testing concentration, as brine can stratify in the tank.
3. Obtain a sample of the salt brine in a glass that is taller than the hydrometer and over 2 inches in diameter.
4. Use the salt brine hydrometer to check the concentration of the brine solution in the sample using the following procedure:
    a. Hold the top of the hydrometer and slowly put into the center of the brine sample,
    b. Release the hydrometer,
    c. Read the percent concentration where the hydrometer meets the top of the sample.
5. Adjust concentration as needed:
    a. If the concentration is below 23.3%, add more salt.
    b. If the concentration is above 23.3%, add more water.

* Directions adapted from City of Madison – Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails [2]

Recent developments in salt brine include adding other deicing products into the salt brine mixture to lower the freezing point of the solution. There are several additives that could make brine more effective in colder temperatures. When adding other products to salt brine, the vendor of the product should be consulted to ensure that the products are mixed using the proper procedures and in the correct amounts. All brine additives should be tested using the proper protocol prior to use. This protocol should be followed each time the additive is used. Not following the proper protocol may lead to equipment damage and potentially harmful chemical reactions. [2]

Figure 59. Example of a hydrometer. Image Qlaz from Wikimedia.

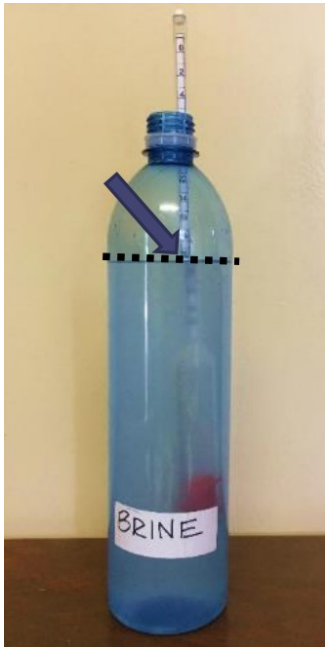


Figure 60. Example of hydrometer in salt brine. Notice, the percent concentration of the salt in the solution is where the dotted line meets the water. Image from [2].

The optimal concentration of rock salt brine is 23.3%, however, that is not true for all deicing products. The table below compares the optimal concentrations of various deicers.

Deicer	Optimal Concentration	Eutectic Temperature/ Freezing Point
Sodium Chloride (NaCl)	23.3%	-6°F
Calcium Chloride (CaCl2)	30%	-60°F
Magnesium Chloride (MgCl2)	27-30%	-28°F
Potassium Acetate (KAc)	50%	-76°F
Calcium Magnesium Acetate (CMA)	32%	-17°F
Urea	33%	+10°F

Table 11. Optimal concentration of various deicers for winter maintenance and the associated freezing point/eutectic temperature. Table adapted from NHDES – Snow & Ice Fact #18 – Chemical Concentration [10] and City of Madison – Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails [2].

Understanding the ideal concentration of each deicer is important. They have different chemical properties which means each deicer has a unique ideal concentration at which the freezing point of the deicer is the lowest. This freezing point is also referred to as the eutectic temperature. The lower the eutectic temperature is for a deicer, the lower the practical melting temperature is, as well. When the concentration of a given deicer is higher or lower than the ideal concentration, or magic number, the eutectic temperature and practical melting temperature are higher than that of the magic concentration. [10]

It has been suggested that other waste stream products (such as pickle juice, cheese brine, water softener discharge, and even soy sauce) can be used as liquid deicers, however, there is not enough research on the use of these products yet. Using them without ample research may create bigger problems in the long run [2].

Regardless of the material used, equipment should be completely cleared out and routine maintenance performed after each storm to stay in good working order [2].

Brine equipment

Brine and other liquid deicer application equipment requires an anti-icing unit and a stream nozzle. The anti-icing unit can be as simple as a hand-held pump or backpack sprayer or as complex as a vehicle with a tank and boom or sprayer attached. The stream nozzle directs the flow of the liquid deicer as it is applied to the paved surfaces. Stream nozzles can be made or purchased from a supplier. [8]

A good stream nozzle creates a solid stream with at least 8 holes that are 8-inches apart. A good solid stream nozzle should also have a psi of 30 to 35 at the bar and be roughly 12 to 14 inches above the ground. A fan stream nozzle is not as effective at preventing slippery situations and should be done very lightly. [8]

Additional equipment is needed if brine is being made and held on-site. In this case, operations also need a mixing tank, a holding tank, pumps to move liquid from the mixing tank to the holding tank to tanks on the anti-icing unit, and a way to measure the salinity concentration. Tanks should be double walled to prevent leaks, otherwise operations need to invest in a secondary form of containment. [13]

While the additional equipment may be an initial investment, they will lead to cost savings associated with materials and manpower. Additionally, having brine-making equipment will increase the use of liquid products for anti-icing, pre-treating, deicing, and pre-wetting. All of which leads to reduced salt-use and thus will lead to cost savings associated with the impacts the salt can have on public health, infrastructure, and the environment. [13]

Why invest in brine equipment?

The use of brine may come with an initial investment, but it can be more efficient than other winter maintenance strategies and can save you money [13].

Fay et al. (2015) found that salt brine was more cost-effective than the use of abrasives, dry rock salt, and Magnesium Chloride ($MgCl_2$) [13].

Winter Maintenance Strategy	Cost per Lane Mile ($USD)	Average Cost ($USD)
Salt Brine	$37.92 (average)	$0.16/gal.
Plowing	*$1,335.00 (average)*	*N/A*
Abrasives	*x*	*$9.32/ton*
Abrasive/Salt Mixtures	*x*	*$20.86/ton*
Solid Salt	*$68.41 (average for anti-icing use)*	*$71.04/ton*
Corrosion Inhibitors	*$695.55 - $1,652.93*	*$1.18/gal.*
Inhibited Salt Brine	*x*	*$0.31/gal.*
Magnesium Chloride	*x*	*Inhibited solid - $150.00/ton* *Inhibited liquid - $1.00-$1.50/gal.* *Uninhibited liquid - $1.20/gal.*

Table 12. Estimated cost of materials for winter maintenance in comparison to salt brine. Table adapted from Virginia – SaMS [13], adapted from Fay et al., 2015. Box marked with x indicates no data.

Brine for private surfaces

Liquid deicer, especially salt brine, is not just for roads. It can be used on any paved surface, such as sidewalks, building entrances, and parking lots, especially for anti-icing. [4]

Bare pavement is frequently the level-of-service goal for areas that receive significant foot traffic or are high risk maintenance areas. To achieve bare pavement, more manpower and chemical deicers are needed than when non-bare pavement is the level of service goal. **To achieve bare pavement as efficiently as possible, the ideal order should be anti-icing prior to storm events, mechanical snow removal early and often, and finally, deicing.** Additional chemical deicers should only be added if needed. [4]

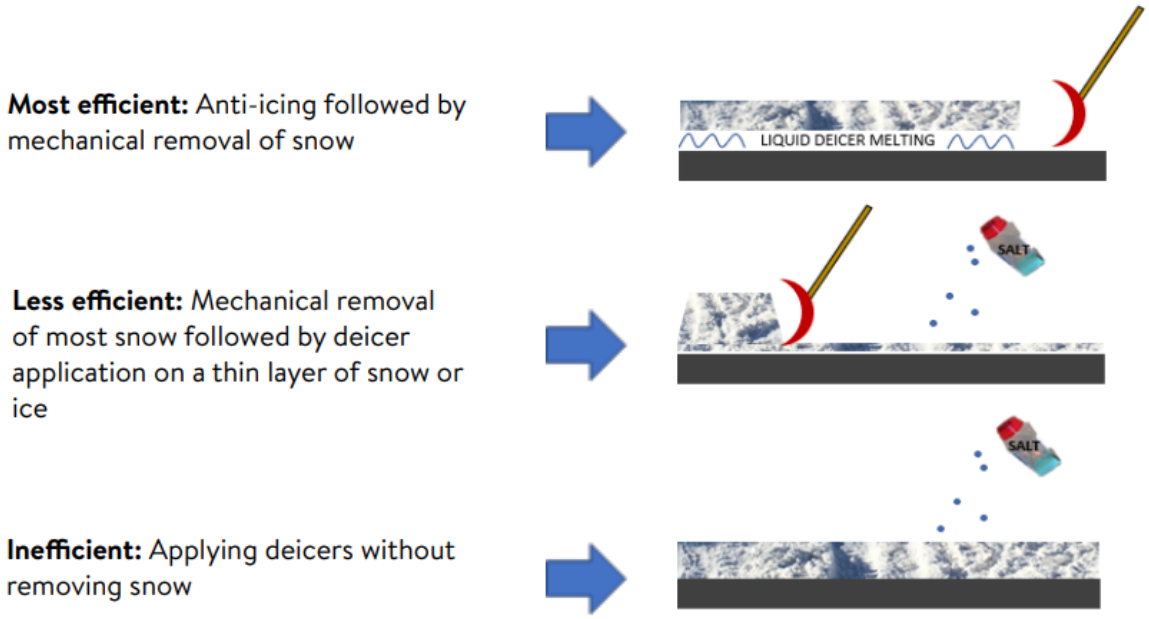


Figure 4-17 Efficiency of maintenance strategies.
Graphic credit: FCI

Figure 61. The efficiency of different maintenance strategies. Image from MPCA Smart Salting for Property Management Manual via FCI [4].

The location and traffic need to be considered when deciding if non-bare pavement is an appropriate level of service goal since it is typically the goal in areas where there is less traffic and a lower risk of incidents. For this goal, snow and ice are removed mechanically and deicers or abrasives are only used if needed. In this case, property managers and winter maintenance operators need to communicate with customers and residents how this level of service still maintains safety. [4]

Limitations

While there are several advantages to adding brine to your toolkit, especially for anti-icing, there are some disadvantages — as with any deicing method.

The equipment-needs for the production, storage, and application of liquid deicers are different than what is needed for granular deicers. For example, pre-treating deicer stockpiles with liquid deicers, including brine, can reduce the amount of material needed for application but requires additional storage measures to ensure that brine doesn't leach from the stockpile. Pre-wetting your deicer has the disadvantage of investing in new equipment or retrofitting existing equipment. Additionally, the equipment you already own may limit what liquid deicers may be used in pre-wetting. [13]

Additionally, liquid deicers directly applied to paved surfaces may experience dilution as snow and ice melt, requiring additional application of solid deicers [13]. Without the additional deicers, the diluted brine and liquid deicers can refreeze [12]. Even so, this would still be fewer total deicers applied than applying solely granular deicers. While direct liquid application of brine and other liquid deicers are found to greatly reduce the amount of salts applied, it is a relatively new method and may require more trial and error than other practices [13].

How to build a successful brine applicator cheaply

Brine applicators can be pulled by or mounted on vehicles or carried and operated by hand.

While other spray equipment, such as pesticide sprayers, can be used for brine application, the salt will eventually corrode components of the equipment. Ideally, brine should be applied with equipment designed for winter maintenance because it is made to resist corrosion. Regardless of the type of non-vehicle equipment used, the sprayer should create a solid stream, not a fan-shape. [2]

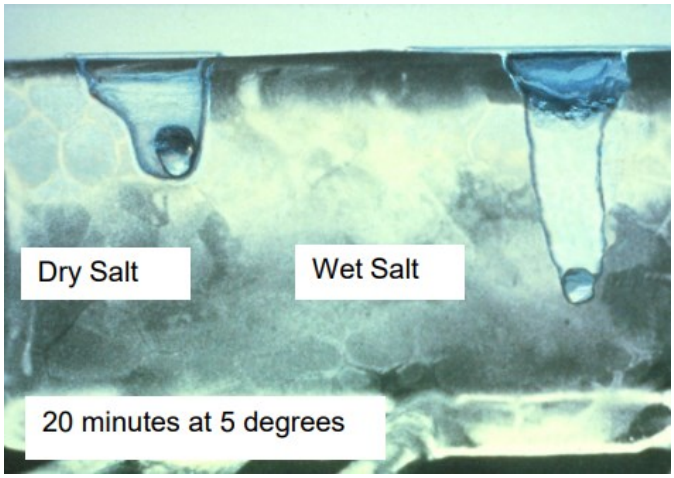


Figure 62. Salt that is already wet works faster at melting snow and ice. Image from [3].

Vehicle-based brine equipment needs to include tanks, hoses, and a boom with holes or nozzles. Outfitting vehicles for brine equipment can be as simple as creating a boom out of PVC pipe or as complex as purchasing a complete liquid deicer system. It should create a solid stream, not a fan-shape. Additionally, all nozzles or holes should be approximately 8 inches apart and the boom should be about 12-14 inches above the ground. All liquid deicers should be applied using a wet/dry spread patten where there are visible lines on the pavement. [2]

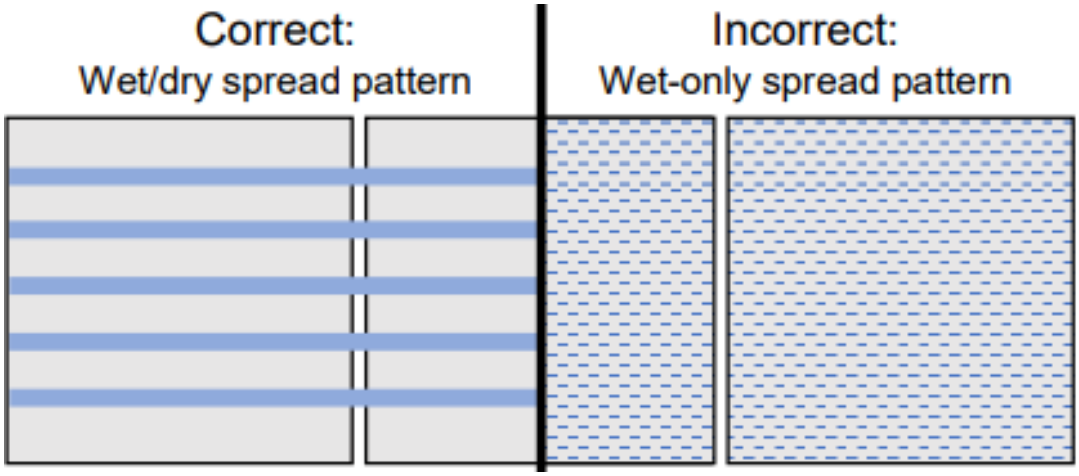


Figure 63. Correct versus incorrect application of liquid deicers for anti-icing. The correct application should have wet/dry spaces. Image from City of Madison - Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails [2].

All spray equipment should create a solid stream, not a fan-shape.

Pre-wetting and Pre-treating with Salt and Sand:

Pre-treating and pre-wetting reduces the ability of dry materials to bounce upon application or blow off the road. This allows you to apply 20% to 30% less materials for the same effectiveness [7]. That's a lot of savings on the cost of materials.

Mixing liquid deicers with granular material can jump-start the deicer's melting and therefore increase effectiveness. Depending on the liquid deicer chosen as part of the mixture, the effective working temperature of salt may also be lowered. This allows for melting at temperatures lower than 15°F, where salt is typically no longer effective. [7]

Figure 64. Example of pre-treated stockpiles. Image from McHenry County Untitled PowerPoint.

Guidelines for pre-treating stockpiles

You can purchase pre-treated stockpiles or pre-treat them on-site. [2]

Purchased pre-treated rock salt is less likely to leach (when the deicer leaves the stockpile as runoff) than when mixed on-site. They are blended at specific ratios and with specific ingredients that have been shown to avoid leaching. However, purchased pre-treated stockpiles are often larger in quantity than homemade ones and require proper storage to avoid excess moisture from making its way to the stockpile and causing leaching. Homemade stockpiles are frequently created in smaller quantities for one event at a time. This avoids the need for appropriate storage of the stockpiles. [2]

The most common liquid additions to salt stockpiles are non-sodium deicing liquids, organic additives, and dyes. Commonly added deicing liquids include magnesium chloride ($MgCl_2$) and calcium chloride ($CaCl_2$). Common organic additives include beet juice and corn syrup. [2]

There are some liquids that should not be added to stockpiles because they evaporate before they are applied. These include water and salt brine. Both will evaporate and form a crust on the stockpile. [2]

General guidelines for creating pre-treated salt stockpiles:

- Start with untreated dry salt.
- Perform mixing in an area with waterproof flooring.
- Combine dry salt with a liquid deicer or additive by spraying the liquid on the dry salt and then mixing. Do not mix with salt brine.
- Mix salts with additives using the ratio 4-6 gallons of additive for every 1 ton of salt.
    - Start with lower amounts of liquid as the dry product can only hold so much before leaching occurs [3]. It is important to remember the more liquid used in the mixture, the greater the risk of the stockpile leaching.
- The best practice when using homemade stockpiles is to mix a new batch before each storm to avoid the need for storage.

*Lists adapted from City of Madison – Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails [2]

Pros	Cons
It is available to purchase ready-for-us.	It requires extra time if using homemade stockpiles or extra expense for the purchase of pre-treated salt stockpiles.
It leads to less salt needing to be applied than dry rock salt for the same results.	It works faster than dry salt, but slower than other methods involving liquids mixed with dry salt (such as pre-wetting) because it only uses a small amount of liquid.
It does not require new equipment.	Storage can be challenging.
It can melt ice faster and at lower temperatures if the additive is $MgCl_2$ or $CaCl_2$.	x
Lower application rates can be used.	x

Table 13. Pros and cons of using pre-treated stockpiles.

As with any deicing method, there are pros and cons to using pre-treated stockpiles.

Pre-treated salt can be applied with most types of equipment already used for dry salts. It can be applied with pickup trucks, drop spreaders, rotary spreaders, or dump trucks. However, the application rate should be lowered because it requires one-third less material to melt the same amount of ice. [3]

Pre-treating with a liquid deicer can also be done with sand. Pre-treated sand stockpiles can be made homemade or purchased, just like deicing salts. [3]

Use 20-30% less salt with pre-treating and pre-wetting.

Guidelines for pre-wetting

As opposed to pre-treating, pre-wetting mixes the liquid deicer and dry rock salt as the salt is being applied [2]. This mixing occurs during application at the spinner or in the auger box through a soaker pipe that feeds into it [8]. By pre-wetting rock salt, the applied materials scatter less and approximately 20 to 30 percent more material stays stuck to the road [6]. The process of pre-wetting jump starts the salt melting and allows it to begin working faster [6].

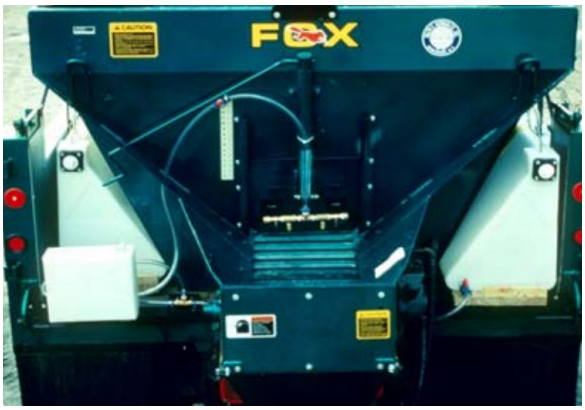


Figure 65. Example of a pre-wetting machinery on a winter maintenance truck. Image from NHDES BMP PreWetting.

General guidelines for pre-wetting:

- Application rate should range from 8 to 12 gallons of liquid deicer per 1 ton of dry rock salt.
- The more liquid per ton of granular salt leads to a faster start to melting.
- Application rate should be reduced to account for the one-third less dry material needed for the same melting.
- The flow of the granular and liquid materials needs to be in sync to achieve the correct mix.
- A dump truck is the most practical tool for pre-wetting to avoid weight limits associated with pickup trucks.
- Carefully consider which liquid deicers you use when mixing them together.

*List adapted from City of Madison – Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails [2] and MPCA – Winter Parking Lot and Sidewalk Maintenance Manual – Third Revision [3]

Pre-wetting, like with all deicing methods, has various pros and cons associated with it.

Pros	Cons
Liquid deicer can be changed easily.	Additional equipment is needed.
Salt brine is an option, which is cheap and easy to make.	Additional external liquid storage is needed to store liquid to refill the tanks on trucks.
Application rate can easily be modified.	Winter maintenance crews need additional training.
The ratio of liquid to granular materials is easy to change.	x
Using a liquid deicer other than salt brine can improve melt performance.	x

Table 14. Pros and cons of using pre-wetting materials. Lists adapted from [2,3].

Sand can be used when temperatures are too cold for chemical deicers, but they come with their own risks.

Traction/Abrasives

When temperatures are too cold for chemical deicers, abrasives are an alternative that provide traction for safer roadways. Although temperatures rarely get cold enough in Maryland to require abrasives, they can be used to provide traction immediately after a freezing rain. [5]

Once the snow and ice has melted and the abrasive is in contact with the paved surface it has served its purpose and is no longer needed. In fact, sand on dry surfaces may reduce safety by causing skidding. It is important to sweep up the remaining sand or abrasive. Sweeping can be done with powered equipment, hauled electronic sweepers, or manual based brooms and sweepers. Those performing the sweeping should wear appropriate gear to avoid inhaling fine particles that may be kicked up. [3]

Sand is the most common abrasive. It comes with its own set of pros and cons, some of which include several environmental risks [5].

Pros	Cons
They work in temperatures too cold for chemical deicers.	They require clean up after the storm event is over.
They provide short-term traction.	It is costly due to additional clean up and disposal costs.
They can improve safety in areas where traffic is slow moving.	It is easily moved from the intended place through foot traffic into buildings.
x.	Sand used for abrasives is contaminated afterwards and cannot be used for other typical sand uses such as sandboxes and beaches.
x	Abrasive particles are broken down after being driven over several times and can become small enough to cause air quality issues.
x	Abrasives should not be applied to pervious surfaces as they will fill tiny spaces.
x	Sand mixes with stormwater runoff and can clog sewers, ditches, and fill in receiving waterbodies.

Table 15. Pros and cons of using abrasives. Lists adapted from MPCA – Winter Parking Lot and Sidewalk Maintenance Manual – Third Revision [3].

How to Apply Salt

After mechanical removal of snow and ice, chemical deicers can be applied as liquids or in a granular form**. When using granular deicers, the most effective application avoids thick layers or clumps of salt.** The most effective application should be sporadic with space between individual granules. Spills or excess should be picked up. [2]

Figure 66. Example of abrasives used for traction. In this example they are using small rocks. Image by Mississippi Watershed Management Organization from Flickr Commons.

Consider how rock salt moves on the ground. When people walk over areas where granular deicers were applied, the deicers migrate toward the edges of the paved areas. To reduce the movement of deicers toward the edges of sidewalks and paved areas, the granular deicer should be applied with a narrow-spread pattern. This will allow the granular deicer to stay on the walkways and intended paths and melt ice and snow while also using less product and thus causing less damage to the environment. [2]

Figure 67. Example of overapplication of salt. Notice the piles of salt without space between granules. Image by MPCA Photos from Flickr Commons.

Drop spreaders are a great option to create a narrow-spread pattern when applying granular deicers. Broadcast spreaders may be too wide to create a narrow-spread pattern on sidewalks and other narrow paved surfaces. They can be made to have a narrow-spread pattern by adding a shield to the broadcast spreader. Regardless of the delivery method, the application should always occur at a slow speed to reduce the amount of deicer that bounces off the target surface. [2]

Applying the appropriate quantity of granular deicers is a delicate balance among the pavement temperature, application equipment, and the type of deicing material used. By knowing this information, you can determine the appropriate application rate for the given surface by using an application rate chart. [2]

The table below shows ideal application rates of various deicers and a general description of the speed of melting in the bottom row. To find the ideal application rate, find the intersecting cell of the pavement temperatures along the left side and the deicing type along the top of the table. When pavement is warming, less deicer in the range listed should be used. Likewise, when the pavement is cooling, more deicer in the suggested range should be applied [2].

Street application has the same general principles. Salt application should be concentrated toward the center of the road as traffic will cause the salt to spread toward the edges. Additionally, as with sidewalks and areas that receive foot traffic, pre-wetted salt sticks better to road and reduces the extraneous scatter when applied. [6]

The faster the speed that the deicing application vehicle is moving, the more salt bounces off the pavement [2].

There are different application tools and equipment modifications available for sidewalks to reduce deicer waste by ensuring an even, tight spread pattern. These tools include adding chutes directly from the spreader, skirts added around and below the spreader, using a zero-velocity spreader, or keeping the spreader off. The goal of modifying equipment or using new equipment is to apply deicers using a low application rate and a narrow, even spread pattern. [5]

Pavement Temp. (°F)	Application Rate in pounds per 1000 square foot area					
	Rock Salt	Bagged Blend – Mainly NaCl	Bagged $MgCl_2$ or $CaCl_2$	Wet at 6-12 gallons/ton		Winter Sand
				Rock Salt wetted with Salt Brine	Rock Salt wetted with Other Liquid	
28° to 32°	2.3	2.3	*	1.6	*	*
23° to 28°	2.3-4.5	2.3-4.5		1.6-3.2		
15° to 23°	2.3-6.8	2.3-6.8		1.6-4.8	1.6-4.8	
0° to 15°	*	*	2.3-6.8	3.2-4.8	3.2-4.8	Spot treat as needed
-5° to 0°			6.8		4.8	
< -5°	Plow Only					
Speed of Melting	Average	Faster than Rocker Salt	Above Average	Fast	Fast	None

Table 16. Application rate guidelines for various deicers for parking lots, sidewalks, and trails. Table adapted from Figure 9 in City of Madison – Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails [2].

Sidewalks and building entrances

When maintaining sidewalk and entryway safety during a winter storm event there are several tips and tricks available to make maintenance more efficient. **The number one tip is to remove snow prior to applying any deicer**! This helps prevent the accumulation of slush, which reduces the chance of refreezing. [3]

Tips for the professionals:

- Deicers should be applied in a sprinkle with space between each granule and focused on the center of the sidewalk.
- Mechanical snow removal should happen first and often. Aggressive snow removal means less snow, which means less deicers required to keep safe surfaces.

- Be aware of how much salt is applied. Oversalting is most common on sidewalks and especially on stairs.
- Drop spreaders should be chosen over rotary spreaders when possible. If rotary spreaders are the only option, they should have a shield installed to narrow the spread pattern.
- Most slip and fall incidents happen within the 10 feet closest to the curb lines; modify maintenance practices to be proactive in these areas.
- Be sure to include the party responsible for keeping the sidewalks safe during storms in discussions regarding winter maintenance operations for the season.
- Be sure to consider if sidewalks are heated. Deicers can be harmful to heated sidewalks.
- Be sure to consider if the sidewalks are made from permeable materials (i.e., permeable pavers or concrete). Abrasives can be harmful to permeable surfaces.
- Close extra building entrances to avoid the need to apply salt in multiple areas.
- Train an on-site employee to apply liquid deicers near entryways as an alternative to granular deicers.

*This list is adapted from MPCA – Winter Parking Lot and Sidewalk Maintenance Manual – Third Revision [3] & MPCA – Smart Salting for Property Management Manual [4]

Figure 68. Ideal salt application on a sidewalk with space between the granules. Image by Roland Tanglao from Flickr Commons.

Figure 69. Example of entry way maintenance tools. Notice the variety of tools available, including mechanical snow removal tools. Image from City of Madison, Wisconsin.

Building entrances and foyers are frequently subject to the impacts of over-salting outside. This can lead to indoor infrastructure and property damage to items like carpets, indoor concrete, doors, and flooring. Consider enacting and posting policies stating that only trained employees can apply salt.

However, if winter maintenance tools are left for building residents to use, here are a few tips to ensure their proper use: [4]

- If you are providing deicers in the entryway, also provide snow and ice removal tools as well. This encourages mechanical snow removal prior to applying deicers.
- Provide a broom and dustpan to clean up any spills or excess salt that may occur.

- Post instructional material for additional tools available to encourage use.
- Supplying small hand spreaders with a slow salt release rate will encourage a more even application and reduce salt use.
- When small hand spreaders are not an option, supplying smaller buckets of salt with smaller scoops can reduce salt use.
- Posting a sign in the entryway is a great way to communicate the importance of Smart Salting. Example messages include:
    - 1 teaspoon of salt permanently pollutes 5 gallons of water.
    - Apply deicer in an even spread with granules approximately 3 inches from each other.
    - Always remove snow and ice before applying salt.
    - If you can see deicers/salt on the ground, do NOT apply any more.
    - Salt takes time to melt, more salt doesn't speed up melting. It just wastes money.
    - If it is colder than 15°F, rock salt won't work.
    - Do NOT apply deicer to dry pavement.
    - Do NOT apply deicer in vegetation.
    - Do NOT create piles of deicers.
    - Sweep up salt on dry sidewalks.

*List adapted from MPCA – Winter Parking Lot and Sidewalk Maintenance Manual – Third Revision [3] & MPCA – Smart Salting for Property Management Manual [4]

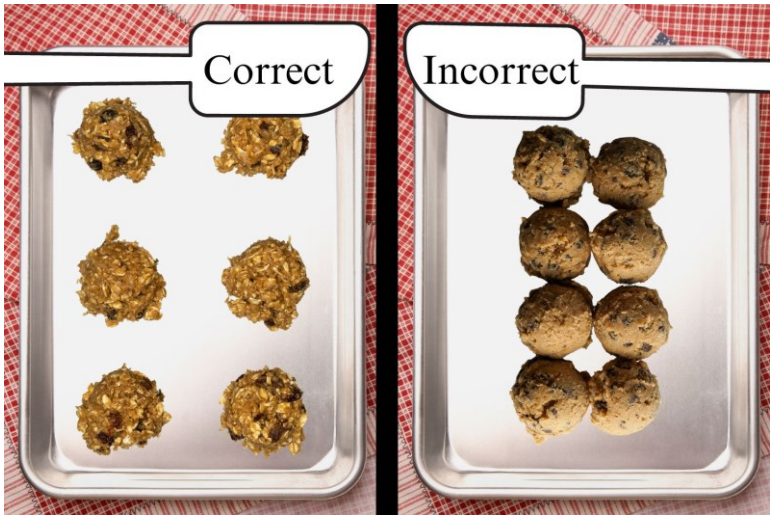


Figure 70. You wouldn't stack cookie dough in a pile and expect good results. It is the same with rock salt. Salt granules should be evenly spread, approximately 3 inches from each other. Image from ICPRB.

Applying salt prior to ice bonding to the pavement can save money since this removes the need for melting [3].

Parking lot tips

Parking lot salting is a balance between safety and excess. Too much sand or salt after a storm can mean potential slip events for cars and shopping carts [3].

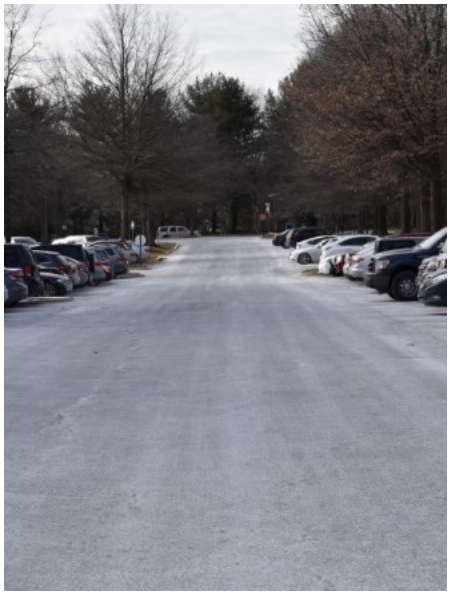


Figure 71. Example of a salt-treated parking lot in Maryland. Image from ICPRB.

Tips and tricks to maintain safe parking lots and reduce salt use:

- Sweep up excess sand and salt after winter storm events to prevent slip hazards.
- Handicap spots should receive the same quantity of deicers and abrasives as any other parking spot. Frequently, handicap spots are over-salted, and this can lead to additional slip hazards once the storm event is over.
- Generally, avoid using a sand/salt mixture. Instead choose the right material for the situation.
- Always mechanically remove snow before using a deicer.
- Traffic — foot and vehicular — tends to assist in mixing and melting snow and ice. This means that less salt/deicer can be used.
- Snow and salt should be stored in separate locations to avoid snowmelt running through salt storage.
- Calculate the area of the parking lot or sidewalk to best determine the amount of deicer needed. For more information on calculating the area see *Modules 3 and 4: Pre-Season Preparations, Site Planning, and Contracts*.

*List adapted from MPCA – Winter Parking Lot and Sidewalk Maintenance Manual – Third Revision [3]

Figure 72. Examples of incorrect salting. Images from McHenry County Public Works PPT.

How Much Is Too Much/ Too Little/ Just Right?

Deicers should be applied after manual snow removal has occurred, concentrated in the center of the application area, in the appropriate temperature ranges, and in the appropriate application rate and quality for the winter storm event at hand [1].

Above are three examples of excess salt application: piles of salt where there is less tire traffic and a large accumulation of salt outside the lanes of traffic.

Figure 73 figure on the right is an example of both excess salt application and appropriate salt application. The lane on the left shows appropriate salt application with granules spaced apart from each other. The lane on the right shows excessive salt application with piles toward the center of the lane and piles of granules.

Documentation of Application

To ensure the most efficient winter maintenance operations, all strategies used for each storm should be documented and later evaluated. Discuss the results during a post-storm debriefing with all individuals involved in winter maintenance. Share what went well and what parts of the operation still need improvement. When a post-storm debriefing isn't a viable option, results from each winter storm should be shared either through posting the results in a common area or a crew-wide email. [2]

Figure 73. Correct and overapplication of salt on the same road. Image from McHenry County Sensible Salting PPT.

Documentation of all winter maintenance strategies is important for the decision-making process. It can be used to improve performance, save money, save materials, and refine what strategies are most effective [2].

Appendix F contains blank forms for anti-icing application, deicing application, and mechanical snow removal. These forms can be used as an example or printed and used as-is.

Module 6. Post-storm and End of Season Actions

Learning Objectives:

1. Be able to calibrate the equipment you use to apply rock salt.
2. Apply concepts you learned in previous modules: Learn to calculate the amount of salt needed for a particular surface, identify correct and incorrect spread patterns.
3. Be able to use the fact sheet provided to assist in winter operations.

This module addresses post-storm and end of season actions including:

- clean-up, storage, and maintenance;
- documenting winter operation procedures; and
- evaluating their effectiveness.

Post-Storm

Several actions post-storm, when consistently taken, will improve winter operations. These include cleaning up salt and sand spills, maintaining equipment, checking supplies, and holding after-storm debriefing sessions with the maintenance crew to review and discuss successes and lessons learned.

Clean-up spills and debris

Every possible effort should be made to prevent unintentional releases of winter products into the environment at storage locations or while on the job. Problems, for example, can arise when:

- Trucks and other equipment are overloaded resulting in spills while leaving the facility or while on route.
- The auger in a truck's salt spreader box becomes jammed with debris or chunks of salt, requiring attention from the operator.
- Incorrect equipment calibration or a new batch of product with different granulation may result in over-application.

Therefore, it is advisable that crew members are:

- trained to be on the lookout for problems and to document these as they arise so that remedial actions can be taken, if necessary, before the next storm;
- instructed to clean up salt spills and excess applications as soon as safely possible to keep customers satisfied and minimize impacts to infrastructure and natural resources [2];
- aware that when salt remains on dry pavement after a storm, it is an

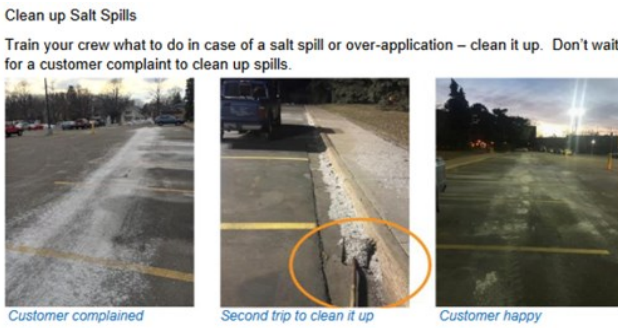


Figure 74. Image from Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails, City of Madison, WI.

indication that too much was applied and needs to be swept up;

- advised that all salt/abrasives remaining outside the storage area after the winter event be swept up and returned to covered storage as soon as possible [4];
- coached to sweep up sand early and often after snow melts. At the very least before rainstorms wash the material away. Sand sweepings must be disposed of in accordance with Maryland regulations as it may contain chemicals, oil, or other toxic substances [2];
- advised to be on the lookout for any debris remaining after a snow pile has melted and remove it [2]; and
- directed to inspect brine and/or other liquid storage tanks regularly, address drips or leaks immediately by placing a drip pan under the leak until it can be repaired [4].

Figure 75. Snow and debris. Image from iStock.

Figure 76. The facility in Washburn, Indiana, has inside loading, liquid loading, brine production and truck washing all housed inside the facility. Reprinted from Clear Roads Manual of Best Management Practices for Road Salt in Winter Maintenance.

Salt, sand, and debris can be swept up from sidewalks and other smaller areas using a simple broom or walk-behind power sweeper. Trailer-type power sweepers towed by a truck can be used on parking lots and service roads (see *Modules 3 and 4: Pre-Season Preparations, Site Planning, and Contracts*).

Equipment maintenance

Maintain and clean equipment according to manufacturer's guidelines as soon as possible after storm operations. This will lessen the corrosive effects of salt and other chemicals. Because salt truck wash water can be highly contaminated with sodium, chloride, cyanide, and other pollutants [1] several points need to be considered:

- Before washing, trucks and spreaders should be swept to remove as much salt or other solids as possible, thereby minimizing the amount of dissolved or solid products that could contaminate the wash water [5]. If possible, unused product should be returned to the storage facility [2].
- Equipment should be washed at a location where the wash water can:
    - be treated by a grid separator and oil separator to reduce the amount of pollutants that enter the environment [4];
    - be disposed of in accordance with applicable law[4]; or

[4] The wash facility may be required by MDE's General Permit No. 12-SW-A for Stormwater Discharges associated with Industrial Facilities to develop a site-specific Stormwater Pollution Prevention Plan (SWPPP).

    - preferably be stored such that it can be reused for brine production[5] [5]. (Depending on the size of their operations, some contractors may be able to optimize their facilities with this option.)
- Brine-making equipment and associated tanks, pumps, lines, and nozzles should also be flushed to reduce the potential for clogging and corrosion [5].

Assessment

There are several post-storm activities that are vital for running an efficient, cost-effective, and environmentally-sound winter maintenance operation.

- Document and evaluate the effectiveness of the winter maintenance protocol.
- Hold staff debriefings.
- Consult with property managers to evaluate satisfaction with the services provided.

Document and chart effectiveness

A good practice for both winter maintenance staff and property owners is to record the pros and cons of winter maintenance procedures and follow-up with post-storm meetings to constructively discuss what was successful and what could be improved. Discussions should focus on a positive tone, rather than finger-pointing.

For contractors and crew

Good documentation and analysis may help to reduce material usage, lower operation costs, lessen impacts to infrastructure and natural resources, and run an efficient winter maintenance program [7]. As has been said many times: “You can’t manage what you don’t measure” [6]; and “the data you measure can be optimized” [8].

A form such as the one provided below could be adapted for this purpose. The winter maintenance crew should be instructed to document information and observations either during or after each storm. The record should be kept for each winter event and season, which allows for seasonal and yearly analyses. The form was adapted from several sources [2,6,7,9].

[5] A paper by Alleman et al. (2004) [1] describes innovative salt truck wash water reuse, which involves 1) wash water collection, 2) wash water pretreatment, 3) temporary wash water storage, 4) brine manufacturing hardware and operational details, 5) product brine storage, and 6) brine application procedures and timing.

POST-STORM DEBRIEFING FORM
Parking Lot, Sidewalk, and Trail Winter Maintenance Operations

Complete one form for each storm event.

Date:_____ Location:_____

Individual responsible for the winter maintenance:

Name:_____

Phone:_____

Email:_____

Equipment

Type:_____ ☐ Equipment was calibrated

Truck #:_____ Milage
Starting:_____ Ending:_____ Total:_____

Property – Total Area Treated

Roads (miles)		Sidewalks (sq feet or acres)		Other	
Trails (feet or miles)		Parking Lots (sq feet or acres)			

Conditions

Air Temperature	Pavement Temperature	Relative Humidity	Dew Point

Beginning Time of Precipitation		**End Time of Precipitation**	

Storm Intensity: *Check one* ☐ Light ☐ Medium ☐ Heavy

	Dry Snow	Wet Snow	Sleet	Freezing Rain	Ice
Depth (inches)					

Pavement Condition: *Check one* ☐ Almost bare ☐ Very clean, less than 1/8-inch snow/ice ☐ More than 1/8-inch snow/ice

Procedures					Result		
Mechanical Snow Removal			**# of Passes**		**Excellent**	**Good**	**Poor**
Plowing							
Other							
Chemical Used	**Type**	**Application Rate (lbs or gallons /1,000 sq ft)**	**Total Amount (buckets, lbs., tons, gallons)**	**# of Passes**	**Excellent**	**Good**	**Poor**
Salt							
Anti-icer							
Deicer							
Abrasive							

Observations

Describe hazards encountered, areas that may ice-over or are prone to snow drifts, etc.

Clean Up

Describe spills, over-application, etc. and actions taken to remedy:

Damage

Note any damage to property:

Please retain the debriefing form for the entire season. The record will only be used to evaluate the winter maintenance procedures and to make improvements.

For Property Owners

Property owners may want to adopt the following form to evaluate the success of the snow removal operations and then share the results with their contractor and/or site supervisor. The form was adapted from [3].

Evaluation

Does your contractor/crew adhere to best practices to fight snow and ice?

Location:_____

Date:_____

Check all that apply

- ☐ Stores product in a dry, covered area with appropriate drainage
- ☐ Is knowledgeable about best winter maintenance practices
- ☐ Mechanically removes snow/ice early and often
- ☐ Applies anti-icing products before the storm if warranted by surface and weather conditions
- ☐ Uses deicer only when needed and after removing snow
- ☐ Does not use deicers on extreme cold days when they are ineffective
- ☐ Chooses products depending on surface temperatures and weather conditions
- ☐ Calibrates all equipment
- ☐ Uses application rates suitable for prevalent weather conditions
- ☐ Uses a light spread pattern
- ☐ Sweeps up excessive salt/abrasives after a storm
- ☐ Provides advice on drainage or other problems that could lead to slippery conditions
- ☐ Records their actions.

If fewer than eight practices are checked, encourage your contractor or crew to attend a Smart Salting certification training.

The Minnesota Pollution Control Agency developed the Smart Salting Assessment tool (SSAt), "as a resource of all known salt saving BMPs. The SSAt is a free, web-based tool that can be used to assist public and private winter maintenance organizations in determining where opportunities exist to improve practices, make reductions in salt use, and track progress."

Knowing what went well (and what didn't) can make your operations more efficient for the next storm.

Analyzing data

Conducting an in-depth analysis of winter operations after an event and especially at the end of the season helps to identify problems and opportunities for improvement, as well as detect trends of material usage and costs. The analysis can be used to formulate recommendations for further operations [4] and to optimize equipment, products, and time [8].

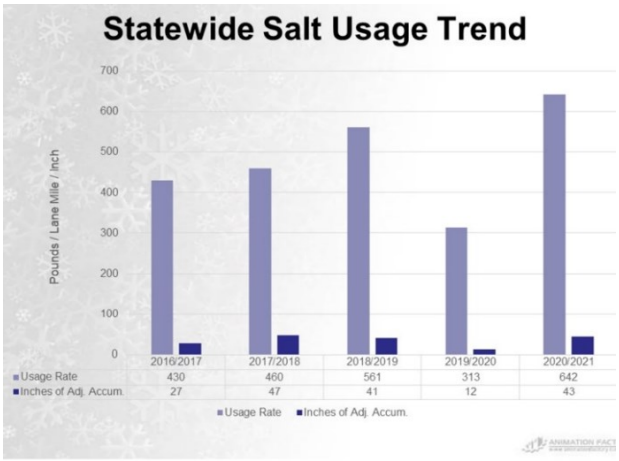


Figure 77. Statewide Salt Use Trends. Image from MDOT, 2021

A winter maintenance training organization, Sustainable Winter Management (SWiM), discusses their top five guidelines for analyzing snow and ice management operations in their Standard Analysis article.

Recommendations include [8]:

Analyze data per storm

Material inventories including product type (e.g., rock salt, brine), product form (e.g., bulk, bagged, granular, liquid), and usage (e.g., application rate, total amount applied) should be analyzed for each winter event and if applicable for each vehicle and operator. When large areas need to be treated, salt-tracking GPS-enabled technology makes tracking easier, more efficient, and more reliable than manual tracking.

Analyze production efficiency

"Production efficiency and waste are two sides of the same coin to analyze." Analyzing time spent on tasks such as loading/unloading, travel, snow and ice removal procedures (e.g., anti-icing, plowing, de-icing), as well as how much material was applied, will provide the true cost of winter maintenance. For larger operations, it might be advantageous to "analyze by person, crew and event to determine where inconsistencies and waste exist". [8]

Track service levels

Client feedback can be used to assess whether expectations are being met as was agreed upon in the service agreement. When service is consistently requested outside what was not part of the service agreement, it might be advisable to adjust the agreement accordingly for the next season. Keeping a visual record of services can aid in analyzing snow management. One simple way to do so is to take pictures with cell phone cameras and to download them "to a customized cloud-based data capture system (e.g., Google, Dropbox, etc.)" [8].

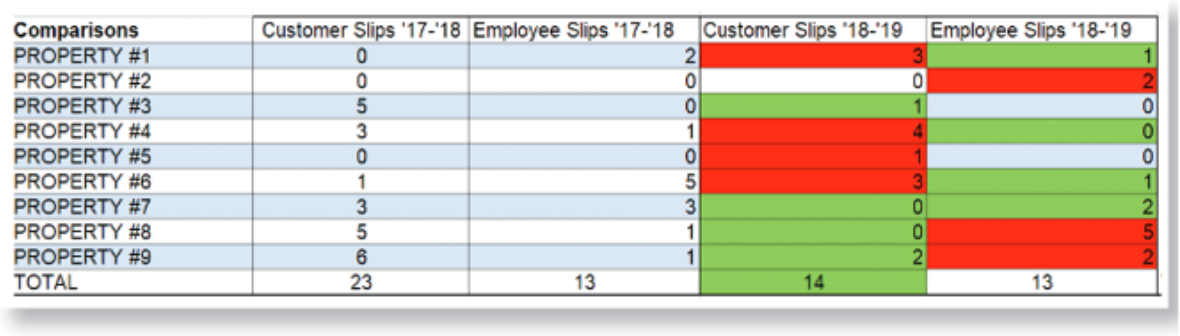
Figure 78. Analyzing salt application data. Image from Sexton, 2019 [8].

Analyze historical weather data

Because no two winters are alike, analyzing historical weather data can serve as a yardstick to develop seasonal budgets or service agreements. The analysis can aid in deriving seasonal averages of types and amounts of winter precipitation, which then can be figured into budgets.

Manage risks

To analyze and manage risks, the number of incidents (slips and falls, other injuries, etc.) can be compared season-to-season, between years, or for the type and severity of winter events. Tracking and reporting can be as simple as maintaining a spreadsheet model. This may enable contractors to manage risks and improve winter operations.



Comparisons	Customer Slips '17-'18	Employee Slips '17-'18	Customer Slips '18-'19	Employee Slips '18-'19
PROPERTY #1	0	2	3	1
PROPERTY #2	0	0	0	2
PROPERTY #3	5	0	1	0
PROPERTY #4	3	1	4	0
PROPERTY #5	0	0	1	0
PROPERTY #6	1	5	3	1
PROPERTY #7	3	3	0	2
PROPERTY #8	5	1	0	5
PROPERTY #9	6	1	2	2
TOTAL	23	13	14	13

Figure 79. Risk management example. Reprinted from Sexton 2019 [8]

Staff debriefings: General lessons learned

A post-storm debriefing with staff provides an important opportunity to:

- Discuss and evaluate the snow and ice removal procedures that were followed — what went well, what didn't work well, and what could be improved.
- Share observations.
- Learn from each other.

Examples of what could be covered include the type and amount of products used, how well they worked under the storm conditions, and how procedures and material usage could be refined if necessary [2,6]. The findings should be posted for all crew members if an in-person meeting is not possible [2].

End of Season

End-of-season meetings are a great opportunity to reinforce lessons learned from post-storm reviews and should be scheduled for crew members and property owners. Discussions should focus on a positive tone, rather than finger-pointing.

Performance evaluation and crew debriefing

- Evaluate the crew's performance. At a minimum discuss what went well and what led to success, what didn't go well and why, what improvements could be made to prevent or mitigate obstacles. Encourage sharing of experiences and ideas.
- Review salt management procedures.
- Determine if (additional) Smart Salting training is warranted based on an analysis of the season's performance and feedback from clients.
- Ensure that all equipment was or will be thoroughly cleaned, inspected, repaired, and stored.
- Determine if acquiring new equipment is necessary to replace aging ones [2] or if existing equipment could be modified to improve performance.
- Evaluate whether it is advisable to incorporate new technologies or materials that could reduce product usage and cost and be kinder to the environment.
- Schedule necessary tasks to be completed well before the next winter season.
- Take stock of unused products and storing any remaining de-icing and abrasive materials in a dry, covered area to prevent runoff and contamination of natural resources (*Modules 3 and 4: Pre-Season Preparations, Site Planning, and Contracts*). When storage is not an option, consider contacting your city or county to inquire if they are willing to purchase, take, or store any left-over products [3]. **Never apply chemicals just to use them up.**

Client debriefing: Specific site lessons learned to optimize for next season

End of season debriefings between the contractor and client are a critical component of a successful snow removal business. Debriefing sessions should focus on constructive feedback and collective learning for both the contractor and client. The client's satisfaction should be considered such as:

- What were their expectations based on the service agreement?
- Were expectations met or is there room for improvement?
- Were triggers for service adequate (i.e., zero tolerance, certain depth of snow fall, icy conditions)?
- What should be done the same or differently during the next season?
- Does the client have recommendations for the contractor or crew based on the results of the season?

The client should also receive constructive feedback including:

- What made the job easy or difficult, such as location and/or marking of obstacles, ease of access to the premises, etc.?
- Did the property owner adhere to their agreed upon responsibilities?

Contractors should share feedback with their crew and post a relevant recap of the meeting including topics discussed and action items that must be taken.

Hands-On Classes

** The following information can be used either by instructors to teach a hands-on class or as a manual for salt applicators to use on their own. **

By now you have already read about the impact of winter salt use on our environment, infrastructure, and human health. Winter salt is a forever pollutant that, once in our environment, is close to impossible to remove.

Figure 80. Salt granules should be approximately 3 inches apart. Image from Canva.

A Review of Smart Salting Key Concepts:

Plowing and physical removal: Physically remove the snow before applying chemical deicers.

Calibration: You wouldn't take aspirin without first reading the recommended dose, right? Calibrating your equipment is ensuring you are getting the correct recommended dose of winter salt. Reading the recommended application rates on your materials and figuring out the right setting on your equipment is like taking the right amount of medicine. Providing easy access to the calibration results (e.g., attaching the sheet in a waterproof plastic bag) will allow salt applicators to apply the correct amount of material. *Appendix C* provides deicing application rates for a variety of materials.

Material storage: Smart Salting starts with smart storage. Correctly storing materials prevents unnecessary material loss and salty runoff. See *Module 3: Storage* for more information.

Temperatures: Using a smart phone app or website to check the weather and an infrared temperature sensor to test the pavement temperature will inform your winter maintenance strategy. Having the right information will tell you what material to use, and when and where to apply it. See *Module 5: Weather and Pavement Temperatures* for more information.

Application rates: Using the correct application rate at the right time will save time, money, and help the environment. Property managers and supervisors can post flyers with application rates at easily accessible areas to help salt applicators know the correct rates for the weather. See *Appendix C* for a printable flyer. Making flyers easily visible and consistently referring to them will remind everyone of the importance of Smart Salting.

Figure 81. Salt on a parking lot surface. Image from ICPRB.

Deicing and anti-icing: Just like spraying a pan with cooking spray keeps an egg from sticking, using liquid deicer keeps the ice from sticking to the surface. See *Module 5: Deicing/Anti-icing* for more information.

What does “too much salt” and “just right” look like in real life?

It’s easy to identify too much salt. When the salt looks like a small salt mountain or looks more like snow than salt, that’s too much salt. The more difficult question to answer is, “What does correct salt application look like?” When done correctly, the salt granules will have roughly 3 inches of space between the granules (Figure 83) [2]. There won’t be mountains or blankets of salt, just a light layer on the sidewalk, parking lot, or road.

Figure 82.Winter salt spreader. Image from Canva.

Just one coffee cup of salt will cover 250 square feet of sidewalk. That’s slightly larger than your average one-car garage.

For correct and even application, it is recommended to use a salt-shaker spreader or a calibrated walk-behind spreader instead of tossing the salt by hand. Always read the directions for your specific product.

Just one coffee cup of salt will cover 250 square feet of sidewalk.

Focus on salting the center of the walkway and high traffic areas. Salt spread on the edge of walkways is wasted salt. Foot traffic in the center will naturally spread the salt to the edges [3].

TRAINING ACTIVITY: To help illustrate correct salt application, tape off areas along the ground with examples of correct and incorrect salt application. Have students guess which squares are correct and which are not. Sweep up the salt when the activity is completed.

Remember, oversalting does not increase safety. However, it does waste time and materials, looks messy, and increases post-storm cleanup activities.

Figure 4-14 Too much salt and spread too far to the edges of the pavement.

Figure 4-15 The deicer should have space between the granules.

Figure 83. Salt application examples. Images from MPCA [5].

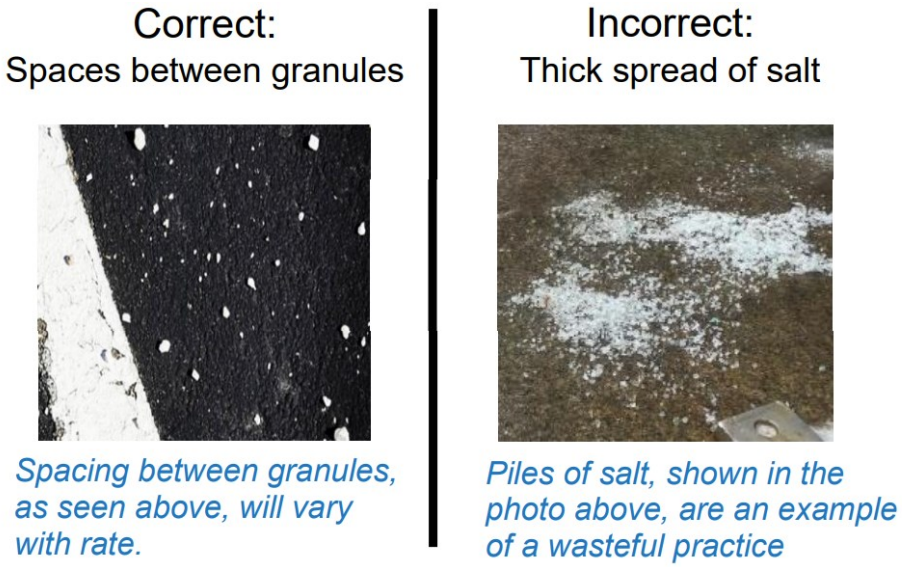


Figure 84. Examples of correct and incorrect salt application. Image from [2].

Salt/Brine Spreading Demonstration and Practice (hand/push spreader and heavy-duty equipment)

Salt applicators should spend time practicing with their equipment before the winter season to make sure they are comfortable and familiar with the settings, application rates, and materials.

TRAINING ACTIVITY: Have several pieces of equipment available for trainees to practice correct salt application. Take time to read the calibration guides for each piece of equipment. Practice applying salt until everyone is familiar and comfortable with correct application amounts.

Calibration of Rock Salt Spreaders

Calibration is learning how much salt is being applied to a given area from a specific piece of equipment. Most pieces of equipment operate by opening the gravity feeder or adjusting the auger speed which changes the amount of salt discharged onto the ground. The same piece of equipment from the same manufacturer can have different discharge rates, so it's important to calibrate each piece of equipment every year. For the most accurate calibration, your equipment should be set up for how it would typically be used in the field (typical speed, installed augers, attached spreader guards, etc.). Once calibration is completed, the applicator will know which setting is best while using it in on the job. Additional information on calibration can be found in *Module 5: Calibration of Equipment*.

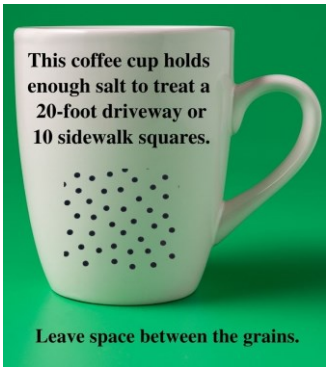


Figure 85. The coffee cup holds enough salt to treat a 20-foot driveway or 10 sidewalk squares. Image from ICPRB.

TRAINING ACTIVITY: Tape off a 25 foot by 10 foot (250 square feet) area. Give each student a coffee cup of salt and have them practice correctly spreading the salt. Sweep up the salt after each student.

The following are important tips for correct equipment calibration (adapted from McHenry [4]):

- Calibrate each piece of equipment annually. It is recommended that you recalibrate equipment with each new shipment of salt as the consistency may change.
- Because of wear and tear, each truck, spreader, or other piece of equipment will behave differently.
- Keep the calibration records with each piece of equipment.
- When purchasing new equipment, look for equipment that can be calibrated easily and that can deliver small amounts of material. It is hard to use less if your equipment wants to use more.
- Any piece of equipment can be calibrated. Just find a way to determine how many pounds of material per minute is landing on the pavement or sidewalk over a measured area and at different speeds.
- Follow the manufacturer's guidelines. If you don't have your owner's manual, look on the manufacturer's website, contact the manufacturer for training, or search for videos online.
- Keep a copy of the calibrated application rate chart with each piece of equipment.

Hands-On Calibration Grouped by Equipment Type

All winter salt application equipment should be calibrated annually, when there seems to be a problem, and with any maintenance or repair.

Most salt application equipment for parking lots and sidewalks falls under two categories: gravity-fed or auger and conveyor systems. Gravity-fed equipment operates by selecting a setting which changes the size of the discharge opening. The auger and conveyor systems will change the rate of salt discharge depending on the speed of the application [1].

Gravity-fed salt drop/push spreaders (adapted from WI Salt Wise PDF [7])

The following instructions are for a gravity-fed drop or push spreader. Calibration for motorized systems is slightly different (see below).

A video of the calibration steps for the drop spreader can be found on the WI Salt Wise YouTube page.

What you will need:

- Push/drop spreader
- The material(s) you are spreading
- Tarp or bare concrete (10x25 feet or larger)
- Bucket, bag, or similar container to measure the material
- Scale (bathroom scale, fish scale, hunting scale, etc.)
- Broom and dustpan
- Shovel
- Copies of the Calculating the Application Rate spreadsheet

Figure 86. Calibration Step. Image from [2].

Calibration steps:

See Table 17 below for an example of the Application Rate spreadsheet.

1. Fill the push spreader with the product you plan to apply.
2. Make a note of the position/setting of the gate/chute (**A**). Use a permanent marker to write numbers along the settings if they are not already included on the equipment.
3. Measure a 10-foot by 25-foot test area on the tarp or the concrete (**C**). Tape can be used so the area can be easily identified.
4. Using a constant speed similar to what would be used in the field, apply the material, walking back and forth through the taped off area.
5. Sweep or gather the material into a bucket to weigh the amount that was applied (**B**). Make sure to zero-out the scale so that you are not including the weight of the bucket. The swept-up material can be used again.
6. Repeat steps 2-5, until all settings have been calibrated. Make sure to take notes along each step. For more accurate results, the process can be repeated 3 times at each setting to calculate the average weight of material applied.
7. Once the calibration is complete, create a chart for each spreader then attach a laminated copy of the guide to the spreader and keep a copy in the shop. Each spreader will have a unique chart.

Please note: The suggested manufacturer application rates are usually given in pounds per 1000 square feet. In this example we are using 250 square feet, so results will need to be calculated accordingly (**D**). Other coverage areas can be used based on what training facilities are available to you.

Calculating application rate

Example calculations are seen in Table 17. *Appendix A* is a blank copy of the calibration chart.

Example: Calibration Chart for Gravity-fed Salt Drop/Push Spreaders

Date _____ Spreader #_____ Material _____

A	B	C	D
Lever Position or Gate Setting	**Weight of material spread in test area (lbs.)**	**Coverage area (sq. ft.)**	**Application Rate (B/C * 1000)**
1	*0.4 lbs.*	*250 ft^2*	*1.6 lbs. per 1000 ft^2*
2	1.0	250 ft^2	4 lbs. per 1000 ft^2

Table 17. Calibration Chart for Gravity-fed Salt Drop/Push Spreaders.

Spreader guide (example)

Setting	Square Feet	Pounds	Pounds/1000 ft^2
3	250	0.4	1.6
4	250	1.2	4.8
5	250	3.5	14

Motorized auger or conveyor systems

Manual motorized auger and conveyor systems for ATVs and trucks automatically release deicing material based on the speed of the auger/conveyor. When calibrating this type of equipment, ensure the auger and all other pieces, like salt guards, are in place so that the results are as accurate as possible.

What you will need [1]:

- Equipment to be calibrated
- The material(s) you are spreading
- Tarp, bucket, bag, or other container to catch the material
- Scale (bathroom scale, fish scale, hunting scale, etc.)

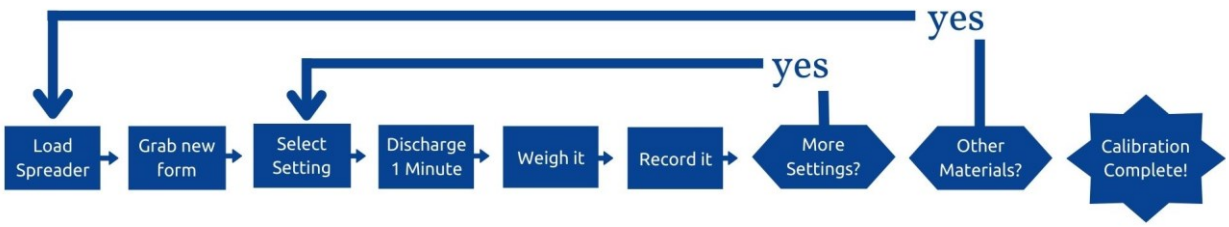


Figure 87. Steps for calibrating an auger or conveyor system. Adapted from MPCA training manual [1].

Calibration steps:

See Table 18 for an example of the Application Rate spreadsheet.

1. Load your equipment with the material you plan to use during a snowstorm. If there is more than one type of material, you will need to repeat all the steps for each material using a new form each time.
2. Choose a setting (**A**). Use a permanent marker to write numbers along the settings if they are not already included on the equipment.
3. Using a bucket, tarp, or other catchment device for the salt, run the augur for a timed interval (usually one minute).
4. Weigh the discharged material and record the weight on your chart (**B**). Make sure to zero-out the scale so that you are not including the weight of the bucket. Repeat steps 2-4 for each setting.
5. Once the calibration is complete, finish the calculations on the chart for each piece of equipment, attach a laminated copy of the chart to the equipment and keep a copy in the shop. Each piece of equipment will have a unique chart.

The example calibration chart for auger and conveyor systems shows the calculations you will need to complete for both the pounds per lane mile and the pounds per 1000 square feet. You will find a blank copy in *Appendix B*.

Example: Calibration Chart for Auger or Conveyor Systems

Date ____ Spreader #_____ Material _____

A	B	C	D	E	F	G	
Setting	**lbs./ Minute**	**3 MPH Walking (x20)**	**5 MPH (x12)**	**10 MPH (x6)**	**15 MPH (x4)**	**20 MPH (x3)**	
1	10	*200*	*120*	*60*	*40*	*30*	*lbs./lane mile**
		3	*2*	*1*	*.6*	*.5*	*lbs./1000 ft²***
2	25	*500*	*300*	*150*	*100*	*75*	*lbs./lane mile**
		8	*5*	*2.5*	*1.6*	*1*	*lbs./1000 ft²***
3	33	*660*	*396*	*198*	*132*	*99*	*lbs./lane mile**
		10.5	*6*	*3*	*2*	*1.5*	*lbs./1000 ft²***

Table 18. Calibration Chart for Auger and Conveyor Systems.

The grey numbers are example calculations. A blank form can be found at the end of this module (*Appendix B*).

* The top half of each row is the lbs. per lane mile calculated by multiplying the lbs./minute (**B**) by the factor shown for each speed.

** The bottom half of each row is the lbs. per 1000 square feet. This is calculated by dividing the top half by 63.

Trucks: Pony motor-run and hydraulic-run spreader calibration

It is a similar process to calibrate a pony motor-run truck spreader and a hydraulic-run truck spreader except for the control settings in step 2. (Adapted from Quick Resource Guide for Winter Maintenance BMPs [6])

What you will need:

- Equipment to be calibrated
- The material(s) you are spreading
- Tarp, bucket, bag, or other container to catch the material
- Scale (bathroom scale, fish scale, hunting scale, etc.)

Calibration steps:

1. Load the truck with the material you will be using. Half of a full load is sufficient for calibration purposes.
2. This step is different depending on your equipment:

Hydraulic-Run Spreader

Gate Height: Begin at the lowest gate height setting (typically 2”). If this does not produce enough material, slowly increase the setting to a height that works better. This height should stay consistent throughout the calibration process. Make a note of the setting number in the calibration chart (**A**) found under *Appendix D*.

Engine Speed: Make sure the truck is warmed up before starting your calibration. Run the engine at a typical speed you would use in the field during application (typically 2000 rpm).

Pony Motor-Run Spreader

Gate Height: Begin at the lowest gate height setting (approximately 1”-1.5”). After calibrating at the lowest setting, continue up the ladder at .5” increments until all gate heights have been calibrated. Make a note of the setting number in the calibration chart (**A**) found under *Appendix D*.

Engine Speed: Set the engine speed to the maximum or the typical setting you would use during application.

3. Measure the spread width of the material. Repeat this process for each setting you are calibrating. Round the number to the nearest half foot and write the number down on the calibration chart (**B**).
4. After running the spreader for 1 minute into a container or tarp, weigh the discharged material and record the weight on your chart (**D**). Make sure to zero-out the scale so that you are not including the weight of the container. Repeat steps 2-4 for each setting. For the most accurate calibration numbers, repeat the process 3 times for each setting, then calculate the average weight by adding the 3 numbers together and dividing by 3.
5. Calculate the discharge rate in pounds per lane mile by using the following formula: E = D x F

   Calculate the discharge rate in pounds per 1,000 square feet (**E**) by using the following formula where (**F**) is the number of minutes it takes to travel one mile at a specific speed: E = D x F ÷ C

   This calculation will need to be done for each setting. More instructions on the calculations can be found in the Hydraulic/Pony Motor Run Calibration Chart [*Appendix D*].

6. Once the calibration is complete, finish the calculations on the chart for each piece equipment, attach a laminated copy of the chart to the equipment and keep a copy in the shop. Each piece of equipment will have a unique chart.

Other equipment

Ground-Speed Controlled Calibration

Ground-speed controlled spreaders are the simplest salt spreaders to calibrate since the computers do the math for you. Each piece of equipment is different, so it is important to use the manufacturer’s instructions to determine correct calibration before it is entered into the computer. Once the equipment is calibrated, the computer senses how fast or slow the vehicle is travelling and adjusts the

auger or conveyor belt input accordingly. Read the instruction manual or contact the manufacturer or vendor for calibration instructions.

Other equipment

If it is unclear how to calibrate specific equipment, contact the equipment vendor or manufacturer for more information on correct calibration.

> You may find instructions for your specific truck or ATV attachment by searching popular online video platforms such as YouTube. The City of Farmington Hills, Michigan features a YouTube video on how to calibrate a manual drop tail gate spreader with manual valves. The City of Cudahy provides a YouTube video on calibration of the computers on Force America brand trucks. Iowa DOT's video provides an overview of calibration on large salt application trucks. There are many other videos for a variety of equipment.

Manufacturers Represented

If you are performing a training course for a large group of winter maintenance professionals, consider bringing in a manufacturer or vendor representative to walk the trainees through the proper calibration of a variety of equipment. They will be able to answer detailed questions about specific equipment while introducing cutting-edge winter maintenance equipment.

Application Rates

Once the equipment is calibrated, use the manufacturer's recommendation for application rates or consult an application rate guideline such as *Appendix C* [2]. You will need to determine the pavement temperature and the product you are using to use the chart. Wisconsin Salt Wise provides a variety of winter maintenance guidelines as well as an online product application calculator.

De-icing Application Rate Guidelines for Parking Lots, Sidewalks and Trails
For best results remove as much snow and ice as possible before applying deicers

Pavement Temp. (°F)	Application Rate in lbs./per 1000 square foot area Apply with calibrated equipment					
	Rock Salt*	Bagged Blend Mostly Sodium Chloride	Bagged $MgCl_2$ or $CaCl_2$	Wet at 6-12 gal/ton		Winter Sand**
				Rock Salt wet with Salt Brine	Rock Salt wet with other liquids	
28 ° to 32 °	2.3	2.3		1.6		
23 ° to 28 °	2.3-4.5	2.3-4.5		1.6-3.2		
15 ° to 23 °	2.3-6.8	2.3-6.8		1.6-4.8	1.6-4.8	
0 ° to 15 °			2.3-6.8	3.2-4.8	3.2-4.8	Spot treat as needed
-5° to 0°			6.8		4.8	
< -5°	Plow Only					
SPEED of melting	AVERAGE The colder it is the slower it works	Faster than rock salt if gradation is finer	ABOVE AVERAGE	FAST	FAST	NONE

*** Dry rock salt is not recommended in cold temps. It is slow to melt and leads to over application.**
****Winter sand contains ≤ 5% salt. It will not melt snow or ice. It is used for traction only.**
For subsequent passes use ½ rate to the full initial rate.

Figure 88. Deicing Application Rate Guidelines Reprinted from WI Winter Parking Lot Manual [2].

Training Activity: Winter Maintenance Practical

By now you have learned how salt can damage our environment, infrastructure, and drinking water. You've read about Smart Salting and how reducing your salt use during winter maintenance can not only help the environment, but also your bottom line. You've learned about deicing and anti-icing, rock salt, and brine and the equipment that can be used to apply the material. You've seen what proper salt storage looks like and what proper salt application looks like. So, now what?

This section is where the rubber (or the salt, in this case) meets the road. The section will walk you through a winter maintenance practical activity to apply the previous lessons in a "real world" context.

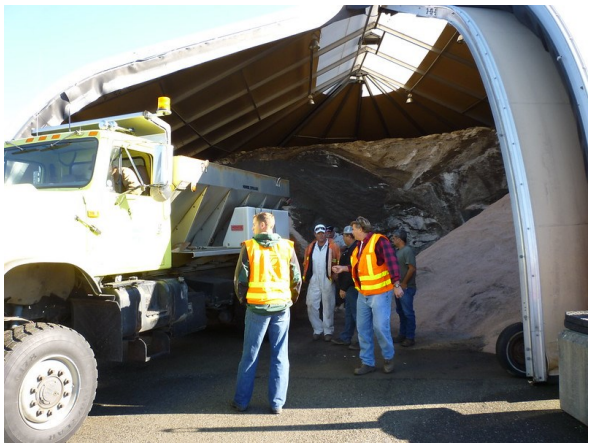


Figure 89. The sand shed. Image by WSDOT from Flickr.

This can be done individually or as a group activity in a class setting. An instructor may choose to use the training facility as an example site or choose a site from an online platform such as Google maps (similar to the site example given in *Module 4: Site Planning*).

The following steps are based on the Minnesota Pollution Control Agency's Winter Parking Lot and Sidewalk Maintenance Fact Sheet (*Appendix C*) [5]. The sheet can be used as a companion piece to the activities. It can also be posted in a prominent place in the work area to help remind and inform winter maintenance professionals.

1. **Create a Site Plan.**

   See *Module 4: Site Planning* for step-by-step instructions on creating a site plan for your area. A good site plan reduces the time, energy, and material used during winter maintenance, while maintaining public safety and economic activity. Your site plan should contain contact information, the size of area that will be treated, where the snow piles will be located, the storage location of deicer material (if applicable), notes on site accessibility before, during, and after a storm event, areas that may be closed (if applicable), and other important information about the site.

   TRAINING ACTIVITY: Choose a site (either real or virtual) to practice creating a site plan. Go over the step-by-step instructions in Module 4: Site Planning.

2. **Check the weather.**

   Is the temperature going up or down? Will it rain before the storm? This information is important for guiding your maintenance actions and material application rates. See *Module 5: Weather and Pavement Temperatures* for more information.

TRAINING ACTIVITY: Create a practice storm scenario (i.e., rain is expected before the storm, heavy winds, a quick drop in temperature, etc.) then discuss how it will influence your plan.

3. **Check the temperature.**

   The temperature of the pavement will be different than the air temperature. Both are important to know when deciding your winter maintenance strategy. The pavement temperature will inform what deicer to use, the amount of deicer, and the application rate. Would rock salt or brine work better? When should it be applied?

   You can ascertain the pavement temperature by using an infrared temperature sensor. See *Module 5: Weather and Pavement Temperatures* for more information.

   TRAINING ACTIVITY: Practice testing the pavement temperature. An instructor can create temperature scenarios and have the trainees figure out the best course of action based on those scenarios.

Figure 90. Sand/salt spreader on the snowplow. Image by WSDOT from Flickr.

4. **Calibration.**
   Ensure each piece of equipment is calibrated and that a copy of the calibration guide is attached to the equipment. Using the proper application rate will ensure public safety, reduce the amount of salt used, and protect the environment. See the last section, *Hands-On Classes: Hands-On Calibration Grouped by Equipment Type* for more information on calibration.

   TRAINING ACTIVITY: Practice calibrating a variety of equipment. Get familiar with the calibration charts.

5. **Check the Chart.**

   Now that you are armed with site information, weather information, and properly calibrated equipment, you'll need just one more piece of the puzzle to put it all together — a deicing application chart. The second page of the Minnesota Pollution Control Agency's Winter Parking Lot and Sidewalk Maintenance Fact Sheet (*Appendix C*) [5] contains Deicing Application Rate Guidelines for Parking Lots and Sidewalks chart for reference. These charts are just a starting place for you and your crew. Make observations, take notes, and adjust your practices to see what works best for your site/s.

   TRAINING ACTIVITY: Using an application chart and looking at your site plan, decide what materials you will use, where you will use them, at what point in the storm you will use them, and how much you will apply.

Glossary

Abrasives – Typically sand, this product is used to increase traction on top of snow and ice.

Anti-Icing – Applying liquid deicers to pavement prior to storm events to reduce or prevent bonding between snow/ice and the pavement.

Calibration – Measuring the amount of chemicals or abrasives applied to a known area size at varying equipment settings and speeds over a specified time.

Deicer – A product used to melt snow and ice.

Direct liquid application – Applying liquid deicers to pavement during or after a storm.

Eutectic temperature – The lowest possible temperature at which the deicer can melt ice.

Ice melt capacity – How much snow and ice a given amount of deicer can melt.

Ice melt speed – How fast the deicer works to melt snow and ice.

Practical melting temperature – The ambient temperature a deicer will melt snow in a reasonable amount of time.

Pre-treating – Mixing liquid deicers with granular deicer stockpiles

Pre-wetting – Mixing liquid deicers with granular deicer as they are being applied.

Optimal concentration – The ideal concentration of deicer in a liquid brine.

Organic compound deicers – Products that contain a carbon-hydrogen or carbon-carbon bond, such as beet juice, molasses, and acetates.

Winter salt – Another term for deicer.

Appendices

Appendix A: Example: Calibration Chart for Gravity-fed Salt Drop/Push Spreaders

Date _____ Spreader #_____ Material _____

A	B	C	D
Lever Position or Gate Setting	**Weight of material spread in test area (lbs.)**	**Coverage area (sq. ft.)**	**Application Rate (B/C * 1000)**

Appendix B: Calibration Chart for Auger or Conveyor Systems

Date ____ Spreader #____________________ Material ______________________________

A	B	C	D	E	F	G	
Setting	**lbs./ Minute**	**3 MPH Walking (x20)**	**5 MPH (x12)**	**10 MPH (x6)**	**15 MPH (x4)**	**20 MPH (x3)**	
							lbs./lane mile*
							lbs./1000 ft^2**
							lbs./lane mile*
							lbs./1000 ft^2**
							lbs./lane mile*
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							lbs./1000 ft^2**

* The top half of each row is the lbs. per lane mile calculated by multiplying the lbs./minute (**B**) by the factor shown for each speed.

** The bottom half of each row is the lbs. per 1000 square feet. This is calculated by dividing the top half by 63.

Appendix C: Winter Parking Lot and Sidewalk Maintenance

Winter Parking Lot and Sidewalk Maintenance

Key Information Needed:

- Pavement Temperature (it will be different than air temperature)
- Parking lot area (or drive lane distance) = Length x Width
- Amount of material your truck or sander delivers at each setting and speed.

TIPS:

- De-icers melt snow and ice. They provide no traction on top of snow and ice.
- Anti-icing prevents the bond from forming between pavement and ice.
- De-icing works best if you plow before applying material.
- Pick the right material for the pavement temperatures.
- Sand only works on top of snow as traction. It provides no melting.
- Anti-icing chemicals must be applied prior to snow fall.
- NaCl (road salt) does not work on cold days, less than 15º F.

Use less! About one tsp. of salt contaminates 5 gallons of water.

Help protect our lakes, streams, wetlands, and drinking water!

Use best practices for winter maintenance.

Melt Times for Salt (NaCl) at Different Pavement Temperatures

Pavement Temp. ºF	One Pound of Salt (NaCl) melts	Melt Times
30º	46.3 lbs of ice	5 min.
25º	14.4 lbs of ice	10 min.
20º	8.6 lbs of ice	20 min.
15º	6.3 lbs of ice	1 hour
10º	4.9 lbs of ice	Dry salt is ineffective and will blow away before it melts anything

Pick your material based on lowest practical melting temperature, not eutectic temperature which is often listed on the bag.

Melting Characteristics	
Chemical	**Lowest Practical Melting Temp.**
$CaCl_2$ (Calcium Chloride)	-20º F
KAc (Potassium Acetate)	-15º F
$MgCl_2$ (Magnesium Chloride	-10º F
NaCl (Sodium Chloride)	15º F
CMA (Calcium Magnesium Acetate)	20º F
Blends	Check with manufacturer
Winter Sand/Abrasives	Never melts—provides traction only

Variables affecting application rate

Increase rate:	*Decrease Rate:*
Compaction occurs & cannot be removed mechanically	Light snow or light freezing rain
There is a lot of snow left behind	Pavement temperature is rising
	Subsequent applications

Minnesota Pollution Control Agency · Fortin Consulting, Inc. serving the environment · CTAP Circuit Training and Assistance Program · Envirotech Services, Inc. · University of Minnesota · minnetonka · Minnesota Department of Transportation · Cudwell Lawn Care & Landscaping · Scott Celebrating 150 Years · LTAP Minnesota Local Technical Assistance Program · GGP General Growth Properties, Inc.

October 2010 revision File available at www.pca.state.mn.us/roadsalt

Deicing Application Rate Guidelines for Parking Lots and Sidewalks

These rates are adapted from road application guidelines (Mn Snow & Ice Control Field Handbook, Manual 2005-1). Develop your own application rates using the guidelines as a starting point and modify them incrementally over time to fit your needs. The area should first be cleared of snow prior to applying chemical.

Pavement Temp. (ºF) and Trend (↑↓)	Weather Condition	Maintenance Actions	Application Rate in lbs. per 1000 square foot area			
			Salt Prewetted/ Pretreated With Salt Brine	Salt Prewetted/ Pretreated With Other Blends	Dry Salt	Winter Sand (abrasives)
>30º↑	Snow	Plow, treat intersections only	0.75	0.5	0.75	not recommended
	Frz. Rain	Apply chemical	1.25	1.0	1.5	not recommended
30º↓	Snow	Plow & apply chemical	1.25	1.0	1.5	not recommended
	Frz. Rain	Apply chemical	1.5	1.25	1.75.	not recommended
25 - 30º ↑	Snow	Plow & apply chemical	1.25	1.0	1.5	not recommended
	Frz. Rain	Apply chemical	1.5	1.25	1.75	not recommended
25 - 30º ↓	Snow	Plow & apply chemical	1.25	1.0	1.5	not recommended
	Frz. Rain	Apply chemical	1.75	1.5	2.25	3.25
20 - 25º ↑	Snow or Frz. Rain	Plow & apply chemical	1.75	1.5	2.25	3.25 for frz. rain
20 - 25º ↓	Snow	Plow & apply chemical	2.0	2.0	2.75	not recommended
	Frz. Rain	Apply chemical	2.5	2.0	3.0	3.25
15º to 20º ↑	Snow	Plow & apply chemical	2.0	2.0	2.75	not recommended
	Frz. Rain	Apply chemical	2.5	2.0	3.0	3.2
15º to 20º ↓	Snow or Frz. Rain	Plow & apply chemical	2.5	2.0	3.0	3.25 for frz. rain
0 to 15º ↑ ↓	Snow	Plow, treat with blends, sand hazardous areas	not recommended	3.0	not recommended	5.0 spot treat as needed
< 0º	Snow	Plow, treat with blends, sand hazardous areas	not recommended	4.5	not recommended	5.0 spot treat as needed

To determine the amount of material needed, take the application rate x parking lot area / 1000 ft^2 . ***Example:*** Given a 300,000 sq. ft. parking lot and an application rate of 1.5 lbs/1000ft^2 1.5 x 300,000 = 450,000 450,000/1000 = 450 lbs (nine 50 lb. bags).

Anti-Icing Guidelines

These are a starting point only. Adjust based on your experience.

Condition	Gallons/1000 sq. ft.		Other Products
	$MgCl_2$	Salt Brine	
1. Regularly scheduled applications	0.2 - 0.4	0.3 – 0.6	Follow manufacturers' recommendations
2. Prior to frost or black ice event	0.2 - 0.4	0.3 – 0.6	
3. Prior to light or moderate snow	0.2 - 0.4	0.3 – 0.8	

CAUTION: Too high an application rate may result in slippery conditions or tracking.

Appendix D: Calibration Chart for Pony-Run and Hydraulic-Run Spreaders

Date _____ Truck/Spreader ID #_____ Material _____

A	B	C	D	E						
Setting	**Spread Width (ft.)**	**5.28 x B**	**Discharge Rate (lb./min)**	Pounds of material discharged.						
				5 MPH (F = 12)	**10 MPH (F = 6)**	**15 MPH (F = 4)**	**20 MPH (F = 3)**	**25 MPH (F = 2.4)**	**30 MPH (F = 2)**	
										lbs./lane mile*
										lbs./1000 ft²**
										lbs./lane mile*
										lbs./1000 ft²**
										lbs./lane mile*
										lbs./1000 ft²**
										lbs./lane mile*
										lbs./1000 ft²**
										lbs./lane mile*
										lbs./1000 ft²**
EXAMPLE	15	79.2	87	1,044	*522*	*348*	*261*	208	174	lbs./lane mile*
				13.18	*6.59*	*4.39*	*3.3*	2.63	2.2	lbs./1000 ft²**

* The top half of each row is the lbs. per lane mile calculated by multiplying lbs./minute (**D**) by the factor shown for each speed (**F**): E*= D x F

** The bottom half of each row is the lbs. per 1000 square feet. This is calculated by dividing the top half by (**C**), for a final calculation that looks like this: E** = D x F ÷ C

Appendix E: Deicing Application Rate Chart

Instructions

Calibrated Spreaders

1. Find the row with the appropriate pavement temperature, temperature trend (increasing or decreasing), and weather conditions.
2. Choose the column with the type of material intended for use.
3. Identify the box where the chosen row and column meet.
4. Compare the application rate to the calibration chart for the selected spreader.
5. Choose the spreader setting that is associated with the application rate found in the deicing application rate chart.

*Directions adapted from MPCA Winter Parking Lot and Sidewalk Maintenance Manual – Third Revision

Spreaders that are NOT Calibrated

1. Calculate the size factor by dividing the size of the treatment area (in square feet) by 1000 square feet (example: 54,000 square foot parking lot/1000 square feet = size factor of 54).
2. Find the row with the appropriate pavement temperature, temperature trend (increasing or decreasing), and weather conditions.
3. Choose the column with the type of material intended for use.
4. Identify the box where the chosen row and column meet, this is the *application rate*.
5. Multiply the application rate by the size factor (example: application rate of 2.0 x size factor of 54 = 108 pounds).
6. The result of step 5 is the amount in pounds of the material chosen needed to treat the treatment area.
7. As the spreader is not calibrated, the settings for the spreader are unknown.
8. Even with unknown calibration settings, this still increases the efficiency of deicer use by establishing the total quantity needed for the treatment area.
9. Using the tools available, determine the best method for applying the calculated quantity of deicer to the treatment area.

* Directions adapted from MPCA Winter Parking Lot and Sidewalk Maintenance Manual – Third Revision

Anti-icing Application Rate Chart		
Predicted Weather	Recommended Rates	
	23.3% Salt Brine (NaCl) Gallons/1000 ft.2	Other Products
Frost/Sleet	0.3	Follow manufacturers' directions/recommendations
Black Ice	0.5	
Freezing Rain	Not recommended	
Light Snow (< ½ inch per hour)	0.5	
Moderate or Heavy Snow (≥ ½ inch per hour)	0.6	

Deicing Application Rate Chart						
Pavement Temp. (ºF) and Trend (↑↓)	Weather Condition	Maintenance Actions	Application Rate in lbs./1000 ft.² area			
			Salt Pre-wetted/ Pretreated with Salt Brine	Salt Pre-wetted/ Pretreated with Other Blend	Dry Salt	Winter Sand (Abrasives)
>30ºF	Snow	Plow; treat intersections only	0.75	0.5	0.75	Not recommended
	Freezing Rain	Apply chemical deicers	1.25	1.0	1.5	Not recommended
30ºF & ↓	Snow	Plow & apply chemical deicers	1.25	1.0	1.5	Not recommended
	Freezing Rain	Apply chemical deicers	1.5	1.25	1.75	Not recommended
25-30ºF & ↑	Snow	Plow & apply chemical deicers	1.25	1.0	1.5	Not recommended
	Freezing Rain	Apply chemical deicers	1.5	1.25	1.75	Not recommended
25-30ºF & ↓	Snow	Plow & apply chemical deicers	1.25	1.0	1.5	Not recommended
	Freezing Rain	Apply chemical deicers	1.75	1.5	2.25	3.25
20-25ºF & ↑	Snow or Freezing Rain	Plow & apply chemical deicers	1.75	1.5	2.25	3.25 for freezing rain
20-25ºF & ↓	Snow	Plow & apply chemical deicers	2.0	2.0	2.75	Not recommended
	Freezing Rain	Apply chemical deicers	2.5	2.0	3.0	3.25
15-20ºF & ↑	Snow	Plow & apply chemical deicers	2.0	2.0	2.75	Not recommended
	Freezing Rain	Apply chemical deicers	2.5	2.0	3.0	3.25
15-20ºF & ↓	Snow or Freezing Rain	Plow & apply chemical deicers	2.5	2.0	3.0	3.25 for freezing rain
0 to 15ºF & ↑ or ↓	Snow	Plow, treat with blends, & sand hazardous areas	Not recommended	3.0	Not recommended	5.0 for spot treatment as needed
<0ºF	Snow	Plow, treat with blends, & sand hazardous areas	Not recommended	4.5	Not recommended	5.0 for spot treatment as needed

* Chart adapted from MPCA Winter Parking Lot and Sidewalk Maintenance Manual – Third Revision

Appendix F: Data Recording Forms

Anti-Icing Data Form

Name:				
Date:				
Location:				
Air Temp.	Pavement Temp.	Relative Humidity	Dew Point	Sky/Conditions
Reason for applying:				
Pavement condition prior to application:				
Chemical(s) Used (Type & quantity):				
Equipment Used:				
When was the equipment last calibrated?				
Application Time:				
Observation (1st Day):				
Observation (After event):				
Observation (Before next application):				
Other Notes:				

Deicing Data Form

Name			
Location:			
Event Began:	Date	Time	
Event Ended:	Date	Time	
Event Type:	Snow	Rain	Both
Dew Point:			
Temperature Trend:			
Pavement condition prior to application:			
Material(s) Used:			
Amount Used (For each material):			
Application Rate (For each material):			
Equipment Used (For each material):			
When was the equipment last calibrated?			
Observations:			

Mechanical Removal Data Form

Name			
Location:			
Event Began:	Date	Time	
Event Ended:	Date	Time	
Event Type:	Snow	Rain	Both
Dew Point:			
Temperature Trend:			
Equipment Used:			
Number of passes for each piece of equipment:			
Observations:			

References

In preceding sections, the reference number applies to the sentence if it is found before the period. The reference number applies to the entire paragraph if it is located after the period at the end of a paragraph.

Module 1 References

1. Fortin, C. (2015). *Winter Parking Lot and Sidewalk Maintenance Manual – Third Revision*. Minnesota Pollution Control Agency. Minnesota. https://www.pca.state.mn.us/sites/default/files/p-tr1-10.pdf
2. Fortin Consulting. (2014). *The Real Cost of Salt Use for Winter Maintenance in the Twin Cities Metropolitan Area.* Report prepared for the Minnesota Pollution Control Agency.
3. Fortin Consulting Inc. (2019). *Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails.* City of Madison, Wisconsin. https://wisaltwise.com/documents/PDFs/Madison-Parking-Lot-Manual-Final-7-19-2019.pdf
4. Fortin Consulting Inc. (n.d.). *City of Madison Salt Wise Certification Training: Parking Lots, Sidewalks & Trails – Best Practices*. City of Madison, Wisconsin.
5. Fortin, C. & Jacobson, J. (2020). *Smart Salting for Property Management Manual*. Minnesota Pollution Control Agency. Minnesota. https://www.pca.state.mn.us/sites/default/files/p-tr1-11.pdf
6. Fortin, C. & Mulhern, N. (2013). *Michigan Winter Maintenance Manual: Promoting Safe Roads and Clean Water.* Michigan State University. http://miwintermaintenance.weebly.com/uploads/1/7/1/6/17161926/mi_winter_maintenance_manual_2013.pdf
7. Kelly, V.R., Findlay, S.E.G., Weathers, K.C. (2019). *Road Salt: The Problem, The Solution and How to Get There.* Cary Institute of Ecosystem Studies. https://www.caryinstitute.org/sites/default/files/downloads/report_road_salt.pdf
8. Maryland Department of the Environment (MDE). (n.d.). *Winter Salts.* ArcGIS Online. https://maryland.maps.arcgis.com/apps/Cascade/index.html?appid=b3c8425c387348659273eb889b007edb
9. McHenry County (2009). *Groundwater Protection Program: Chapter 8 – Winter Snow and Ice Operations.* McHenry County, Illinois. https://www.mchenrycountyil.gov/home/showpublisheddocument/15432/635676237918170000
10. McHenry County (2010). *McHenry County: Snow & Ice Control Handbook for Sidewalks and Parking Lots*. McHenry County, Illinois. https://www.mchenrycountyil.gov/home/showpublisheddocument/8310/636223347449500000
11. County of McHenry (2010). *Winter Snow and Ice Operations: Roads, Parking Lots, and Sidewalks* [PowerPoint slides]. Division of Water Resources. McHenry County, Illinois.
12. New Hampshire Department of Environmental Services (NHDES). (n.d.) *NH Best Management Practices: How Salt Works.* New Hampshire. https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/bmp-salt-works.pdf

13. Nixon, W.A. & Williams, A.D. (2001). *A Guide for Selecting Anti-Icing Chemicals – Version 1.0*. College of Engineering. The University of Iowa. Iowa City, Iowa.
14. Virginia Department of Environmental Quality (DEQ) (2021). *Virginia Salt Management Strategy (SaMS): A toolkit to reduce the environmental impacts of winter maintenance practices.* https://www.novaregion.org/1498/SaMS-Toolkit

Module 2 References

1. Asleson, B. & Morreim, M. (2016, February 4th). *TCMA Chloride Management Plan: Out of the Box and Into the Hands of the Users* [PowerPoint slides]. 15th Annual Road Salt Symposium. Minnesota Pollution Control Agency. Minnesota.
2. Fortin Consulting. (2014). *The Real Cost of Salt Use for Winter Maintenance in the Twin Cities Metropolitan Area.* Report prepared for the Minnesota Pollution Control Agency.
3. Fortin, C. (2015). *Winter Parking Lot and Sidewalk Maintenance Manual – Third Revision*. Minnesota Pollution Control Agency. Minnesota. https://www.pca.state.mn.us/sites/default/files/p-tr1-10.pdf
4. Fortin Consulting Inc. (2019). *Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails.* City of Madison, Wisconsin. https://wisaltwise.com/documents/PDFs/Madison-Parking-Lot-Manual-Final-7-19-2019.pdf
5. Fortin, C. & Jacobson, J. (2020). *Smart Salting for Property Management Manual*. Minnesota Pollution Control Agency. Minnesota. https://www.pca.state.mn.us/sites/default/files/p-tr1-11.pdf
6. Maryland Department of the Environment. (n.d.). Retrieved April 29, 2022, from https://mde.maryland.gov/programs/Water/TMDL/Integrated303dReports/Pages/303d.aspx
7. McHenry County (2010). *McHenry County: Snow & Ice Control Handbook for Sidewalks and Parking Lots*. McHenry County, Illinois. https://www.mchenrycountyil.gov/home/showpublisheddocument/8310/636223347449500000
8. Virginia Department of Environmental Quality (DEQ) (2021). *Virginia Salt Management Strategy (SaMS): A toolkit to reduce the environmental impacts of winter maintenance practices.* https://www.novaregion.org/1498/SaMS-Toolkit
9. Kelly, V.R., Findlay, S.E.G., Weathers, K.C. (2019). *Road Salt: The Problem, The Solution and How to Get There.* Cary Institute of Ecosystem Studies. https://www.caryinstitute.org/sites/default/files/downloads/report_road_salt.pdf
10. Maryland Department of the Environment (MDE). (n.d.). *Winter Salts.* ArcGIS Online. https://maryland.maps.arcgis.com/apps/Cascade/index.html?appid=b3c8425c387348659273eb889b007edb
11. Fortin Consulting Inc. (n.d.). *City of Madison Salt Wise Certification Training: Parking Lots, Sidewalks & Trails – Best Practices*. City of Madison, Wisconsin.

Module 3 and 4 References

1. Blackburn and Associates. (2009). *Calibration Guide for Ground-Speed-Controlled and Manually Controlled Material Spreaders.* Clear Roads and Wisconsin Department of Transportation. Wisconsin.

2. CTC & Associates LLC. (2008). *Limitations of the Use of Abrasives in Winter Maintenance Operations.* Bureau of Highway Operations & Wisconsin Department of Transportation. Wisconsin. http://clearroads.org/wp-content/uploads/dlm_uploads/tsr-limitations-of-abrasives.pdf
3. Fortin, C. (2015). *Winter Parking Lot and Sidewalk Maintenance Manual – Third Revision*. Minnesota Pollution Control Agency. Minnesota. https://www.pca.state.mn.us/sites/default/files/p-tr1-10.pdf
4. Fortin Consulting Inc. (2019). *Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails.* City of Madison, Wisconsin. https://wisaltwise.com/documents/PDFs/Madison-Parking-Lot-Manual-Final-7-19-2019.pdf
5. Fortin, C. & Mulhern, N. (2013). *Michigan Winter Maintenance Manual: Promoting Safe Roads and Clean Water.* Michigan State University. http://miwintermaintenance.weebly.com/uploads/1/7/1/6/17161926/mi_winter_maintenance_manual_2013.pdf
6. Fortin, C. & Jacobson, J. (2020). *Smart Salting for Property Management Manual*. Minnesota Pollution Control Agency. Minnesota. https://www.pca.state.mn.us/sites/default/files/p-tr1-11.pdf
7. Hensel, B., Kilcullen, V., Kuykendall, S. Veugeler, J. & Wittum, M. (2017). *Untitled* [PowerPoint slides]. McHenry County, Illinois.
8. Maryland Department of Environment. (2017). *MDE Industrial Stormwater Pollution Prevention Plan Template.* Maryland. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiTtMCDnbL3AhX_kIkEHXX-COgQFnoECBAQAQ&url=https%3A%2F%2Fmde.maryland.gov%2Fprograms%2FPermits%2FWaterManagementPermits%2FDocuments%2FGDP%2520Stormwater%2FSWPPPTemplate.docx&usg=AOvVaw3UjKc-0ldQCEHdbPLbAOQG
9. McHenry County. (2010). *McHenry County: Snow & Ice Control Handbook for Sidewalks and Parking Lots*. McHenry County, Illinois. https://www.mchenrycountyil.gov/home/showpublisheddocument/8310/636223347449500000
10. Minnesota Pollution Control Agency (MPCA). (2022). *Main Page.* Minnesota Stormwater Manual. https://stormwater.pca.state.mn.us/index.php?title=Main_Page
11. City of River Falls. (n.d.). *Winter Maintenance Operations Policy. River Falls Municipal Utilities.* River Falls, WI. https://www.rfmu.org/ArchiveCenter/ViewFile/Item/761
12. The Salt Institute. (2007). *The Snowfighters Handbook: 40th Year Edition*.
13. Snow & Ice Management Association. (n.d.). *Best Practices: Guidelines for Sustainable Salt Use.* Wisconsin. https://share.hsforms.com/1cN-PKWIITquczgKFOu0CiA59y9n
14. Southwestern Pennsylvania Commission Water Resource Center. (2016). *Quick Resource Guide for Winter Maintenance BMPs.* Southwestern Pennsylvania Commission Water Resource Center

& Pennsylvania Department of Environmental Protection. Pennsylvania. https://spcwater.org/wp-content/uploads/2020/01/WinterMaintGuidebook.pdf

15. Virginia Department of Environmental Quality (DEQ). (2021). *Virginia Salt Management Strategy (*SaMS*): A toolkit to reduce the environmental impacts of winter maintenance practices. https://www.novaregion.org/1498/SaMS-Toolkit*
16. Wisconsin Walt Wise. (n.d.). *Be a Salt WIse Business.* Wisconsin. https://wisaltwise.com/documents/PDFs/WI%20Salt%20Wise%20Business%20Flyer%2018%20v2.pdf
17. Wisconsin Salt Wise. (2019). *Talking Points for Businesses.* Wisconsin. https://wisaltwise.com/documents/PDFs/Outreach%20Kit/Talking-Points-for-Businesses.pdf
18. Wisconsin Salt Wise. (n.d.) *Application Guidelines & Calculator*. https://www.wisaltwise.com/Tools/Application-Guidelines-Calculator

Module 5 References

1. De Vries, M. (2009). *Public Works Steering Committee: Snow Removal – Chemical Use and Winter Operations* [PowerPoint slides]. Intergovernmental Risk Management Agency. McHenry County, Illinois.
2. Fortin Consulting Inc. (2019). *Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails.* City of Madison, Wisconsin. https://wisaltwise.com/documents/PDFs/Madison-Parking-Lot-Manual-Final-7-19-2019.pdf
3. Fortin, C. (2015). *Winter Parking Lot and Sidewalk Maintenance Manual – Third Revision*. Minnesota Pollution Control Agency. Minnesota. https://www.pca.state.mn.us/sites/default/files/p-tr1-10.pdf
4. Fortin, C. & Jacobson, J. (2020). *Smart Salting for Property Management Manual*. Minnesota Pollution Control Agency. Minnesota. https://www.pca.state.mn.us/sites/default/files/p-tr1-11.pdf
5. Fortin, C. & Mulhern, N. (2013). *Michigan Winter Maintenance Manual: Promoting Safe Roads and Clean Water.* Michigan State University. http://miwintermaintenance.weebly.com/uploads/1/7/1/6/17161926/mi_winter_maintenance_manual_2013.pdf
6. Hensel, B., Kilcullen, V., Kuykendall, S. Veugeler, J. & Wittum, M. (2017). *Untitled* [PowerPoint slides]. McHenry County, Illinois.
7. McHenry County. (2009). *McHenry County: Snow & Ice Central Handbook – Field Handbook for Snowplow Operators.* McHenry County, Illinois.
8. McHenry County. (2010). *McHenry County: Snow & Ice Control Handbook for Sidewalks and Parking Lots*. McHenry County, Illinois. https://www.mchenrycountyil.gov/home/showpublisheddocument/8310/636223347449500000

9. New Hampshire Department of Environmental Services (NHDES). (2003a). Rock salt's action on the roadway. Snow & Ice Fact. #14 Department of Environmental Services. New Hampshire.
10. NHDES (2003b). Chemical Concentration. Snow & Ice Fact. #18. Department of Environmental Services. New Hampshire.
11. North Dakota Department of Transportation (NDDOT). (n.d.). *Anti-Icing Fact Sheet.* NDDOT. Bismarck, North Dakota. https://www.dot.nd.gov/divisions/maintenance/docs/anti-icingfacts.pdf
12. The Salt Institute. (2007). *The Snowfighters Handbook: 40th Year Edition*.
13. Virginia Department of Environmental Quality (DEQ). (2021). *Virginia Salt Management Strategy: A toolkit to reduce the environmental impacts of winter maintenance practices.* https://www.novaregion.org/1498/SaMS-Toolkit

Module 6 References

1. Alleman, J.E, B.K. Partridge, & L. Yeung. (2004). *Innovative Environmental Management of Winter Salt Runoff Problems at INDOT Yards.* TRB Waste Water and Sewer Disposal Publication No.: TRB 23-5 12/04 JTRP-2001/27. INDOT Division of Research, West Lafayette, IN. https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1601&context=jtrp
2. Fortin Consulting Inc. (2019). *Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails.* City of Madison, Wisconsin. https://wisaltwise.com/documents/PDFs/Madison-Parking-Lot-Manual-Final-7-19-2019.pdf
3. Fortin, C. & Jacobson, J. (2020). *Smart Salting for Property Management Manual*. Minnesota Pollution Control Agency. Minnesota. https://www.pca.state.mn.us/sites/default/files/p-tr1-11.pdf
4. Maryland Department of Transportation (MDOT). (2021/2022). *Maryland Statewide Salt Management Plan*. MDOT, State Highway Administration. Maryland. https://www.roads.maryland.gov/OOM/Statewide_Salt_Management_Plan.pdf
5. McHenry County. (2009a). *Groundwater Protection Program: Chapter 8 – Winter Snow and Ice Operations*. McHenry County, Illinois. https://www.mchenrycountyil.gov/home/showpublisheddocument/15432/635676237918170000
6. McHenry County. (2009b). *McHenry County: Snow & Ice Central Handbook – Field Handbook for Snowplow Operators.* McHenry County, Illinois.
7. McHenry County. (2010). *McHenry County: Snow & Ice Control Handbook for Sidewalks and Parking Lots*. McHenry County, Illinois. https://www.mchenrycountyil.gov/home/showpublisheddocument/8310/636223347449500000
8. Sexton, P. (2019). *Standard analysis: Increase your ability to manage risk and enable continuous improvement*. SNOW BUSINESS. SIMA. September 2019. https://witadvisers.com/wp-content/uploads/2021/05/Article-5-PS-Standard-Analysis-No-Ads.pdf
9. Virginia Department of Environmental Quality (DEQ). (2021). *Virginia Salt Management Strategy (SaMS): A toolkit to reduce the environmental impacts of winter maintenance practices.* https://www.novaregion.org/1498/SaMS-Toolkit

Hands-On Classes References

1. Fortin, C. (2015). *Winter Parking Lot and Sidewalk Maintenance Manual – Third Revision*. Minnesota Pollution Control Agency. Minnesota. https://www.pca.state.mn.us/sites/default/files/p-tr1-10.pdf
2. Fortin Consulting Inc. (2019). *Wisconsin Winter Maintenance Manual: Parking Lots, Sidewalks and Trails.* City of Madison, Wisconsin. https://wisaltwise.com/documents/PDFs/Madison-Parking-Lot-Manual-Final-7-19-2019.pdf
3. Fortin, C. & Jacobson, J. (2020). *Smart Salting for Property Management Manual*. Minnesota Pollution Control Agency. Minnesota. https://www.pca.state.mn.us/sites/default/files/p-tr1-11.pdf
4. McHenry County. (2010). *McHenry County: Snow & Ice Control Handbook for Sidewalks and Parking Lots*. McHenry County, Illinois. https://www.mchenrycountyil.gov/home/showpublisheddocument/8310/636223347449500000
5. Minnesota Pollution Control Agency (MPCA). (2010). Winter Parking Lot and Sidewalk Maintenance. Minnesota. www.pca.state.mn.us/roadsalt
6. Southwestern Pennsylvania Commission Water Resource Center. (2016). Quick Resource Guide for Winter Maintenance BMPs. https://spcwater.org/wp-content/uploads/2020/01/WinterMaintGuidebook.pdf
7. Wisconsin SaltWise. (n.d.) Calibration of a Push Spreader. Wisconsin. https://wisaltwise.com/documents/PDFs/Calibration-of-a-push-spreader.pdf

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