

Planning Report No. 57

A CHLORIDE IMPACT STUDY FOR SOUTHEASTERN WISCONSIN

Chapter 8

OPTIONS TO MANAGE CHLORIDE TO THE ENVIRONMENT

This Chapter utilizes information and data from a series of Technical Reports developed by the Southeastern Wisconsin Regional Planning Commission (Commission or SEWRPC) for the Chloride Impact Study (Study). These reports include SEWRPC Technical Report No. 65, *Mass Balance Analysis for Chloride in Southeastern Wisconsin*, December 2025 (TR-65); SEWRPC Technical Report No. 66, *State of the Art in Chloride Management*, Month 2026 (TR-66); and SEWRPC Technical Report No. 67, *Legal and Policy Considerations for the Management of Chloride*, April 2024 (TR-67). Refer to these reports for additional details.

8.1 INTRODUCTION

Chloride contributions to surface water and groundwater can come from a variety of sources including road salt applied for anti-icing and deicing of public and private roads, sidewalks, and parking lots; water softening systems and other chloride sources that discharge to sanitary sewers or private onsite wastewater treatment systems; large agricultural feedlots; fertilizers; landfills; chemical manufacturing; food processing; and deposition from the atmosphere. Increased concentrations of chloride can have several effects on the natural and built environment including:

- Physical and chemical impacts on soil, sediment, surface water, and groundwater.
- Biological effects such as acute and chronic toxicity to organisms, reductions in the viability of individual species, and changes to the structure and functioning of aquatic communities and ecosystems.

- Damage to materials such as metal and concrete and affect the condition, structural integrity, and useful life of infrastructure such as roadway pavements, water mains, and street and highway bridges.
- Damage private property such as automobiles.

Chloride is a conservative contaminant, meaning it is not physically or chemically transformed to a non-toxic substance in soil or receiving waters. Once chloride enters the environment, it can accumulate to levels that can be detrimental to the built infrastructure and biological integrity of ecosystems of the Region. Dissolved chloride also has high mobility in water and can move easily between groundwater and surface water resources.

Chloride concentrations in the surface water and groundwater of southeastern Wisconsin have been increasing over time. This trend indicates that past and present practices introducing chloride to the environment are unsustainable. Because it is not practical to remove chloride pollution once it is in the water, source reduction is the most viable option to minimize its impact. The following sections present the most viable strategies to limit chloride inputs from major sources, including public and private winter maintenance, water and wastewater utilities, water softening, agriculture, and industrial food processing.

8.2 PUBLIC WINTER ROAD MAINTENANCE

Why is public winter road maintenance a concern for chloride pollution?

Winter road maintenance is crucial for public safety and economic activity throughout the Southeastern Wisconsin Region (Region). Since the 1950s, this maintenance has relied heavily on the application of deicing agents, primarily sodium chloride rock salt. The reliance on deicing materials was driven by the expansion of highway networks and the public expectations of “bare pavement” conditions during and directly after winter storms. However, the widespread use of these materials has caused significant chloride pollution, threatening aquatic ecosystems, drinking water, soil health, vegetation, and infrastructure. Public road deicing accounts for over 40 percent of the average annual chloride load in the Regional chloride budget (see SEWRPC TR-65).

While municipalities are making notable strides in adopting salt reduction strategies, the high volume of salt applied to public infrastructure remains a critical focal point for reduction efforts. The reduction of environmental and infrastructure damage from chlorides requires a holistic strategy which includes policy adjustments, ongoing training, appropriate material selection and precise application, data-informed

operations, improved mechanical removal technology, environmentally sound storage practices, and ongoing research.

Shifting Public Expectations and Policy

One of the greatest challenges to reducing chloride use is the long-standing public expectation of “bare pavement” and the demand to drive at normal speeds during or immediately after a major winter storm. Achieving this unsustainable standard requires continuous, high-volume application of chemical deicers. Historically, the goal of bare pavement was guided by subjective visual assessments from snowplow operators, often resulting in an abundance of caution and over-application of deicing salt.

Many modern municipal winter road maintenance operations are transitioning from the “bare pavement” model to a more sustainable and realistic “passable roadway” standard. This shift includes:

- Prioritizing functionality and safety over appearance.
- Recognizing that some snow and ice will likely remain on the pavement for a certain amount of time after a winter storm.
- Adopting tiered service prioritization, focusing on high-volume arterial streets before shifting to residential routes.
- Adopting measurable time-to-clearance metrics, replacing subjective visual assessments with objective and time-based goals.

For this transition to be successful, robust public education and transparency are essential. As a first step, communities should make their winter road maintenance policies readily available to the public via online resources. Beyond simply posting these guidelines, proactive outreach campaigns must focus on three critical messages:

- The Environmental Cost: The public must understand the link between bare pavement expectations and unacceptable levels of chloride contamination in local surface water and groundwater as well as premature aging of critical infrastructure.

- Discourage Non-Essential Travel: Communities must strongly encourage the public to limit travel during major winter storms to allow maintenance crews to safely remove snow and ice.
- Adjusting Driving Behavior: A “passable” road is not a “normal” road. Drivers must drive at significantly reduced speeds and increase following distances when winter road conditions are not ideal.

Personnel and Continued Training

Why is continuous personnel training critical for state-of-the-art snow and ice management?

Adopting modern chloride management strategies requires updates to procedures and equipment, which are only effective if personnel receive continuous training. The success of the policy shifts described previously relies heavily on buy-in from administration, managers, and front-line operators. State-of-the-art training and certification programs emphasize the science of snow and ice management. Key training components include:

- Temperature Monitoring: Understanding how to monitor pavement temperatures and select appropriate treatment options, such as recognizing that standard deicing salt effectiveness drops significantly when pavement temperatures dip below 15°F.
- Chemistry: Understanding the relationship between chemical concentration and freezing points to determine the best materials for specific conditions.
- Equipment Calibration: Mastering how to verify that the amount of salt dispensed matches the spreader controller settings, which reduces over-application caused by mechanical error.

Public agencies frequently participate in formal training programs to master these best management practices. Prominent training resources include Wisconsin Salt Wise (which provides municipal workshops and equipment open houses), the Minnesota Pollution Control Agency’s “Smart Salting” program (which has helped organizations reduce salt use by 30 to 70 percent), and the American Public Works Association (APWA).

Winter Maintenance Materials and Material Blends

What materials are used by public agencies for winter road maintenance and how do these materials work?

Despite common beliefs, most deicing chemicals do not melt ice by generating heat. Instead, they function through a process known as freezing point depression. When a chemical dissolves in water, it interferes

with the ability of the water molecule to bond into ridged ice crystals, lowering the temperature at which the water freezes. Every chemical has a “practical working temperature” which is the real-world temperature limit at which it can melt ice within a reasonable timeframe.

The selection of snow and ice control materials is a critical operational decision that needs to balance performance, safety, environmental and infrastructure preservation, and cost. While traditional public winter road maintenance operations relied mostly on mechanical removal, rock salt, and abrasives, modern maintenance standards require a diverse toolbox of chemical agents to maintain safe and passable roadways in varying weather conditions while preserving natural resources and critical infrastructure. The attributes and operational considerations for various winter maintenance materials are provided in [Table 8.1](#) and summarized below:

- Sodium Chloride: This is still the most common deicing agent and is applied in two distinct forms depending on specific operational needs.
 - Solid Rock Salt: Rock salt is best utilized for traditional, reactive deicing after snow has already bonded to the pavement on moderate to high-traffic roadways. Because rock salt absorbs heat when dissolved (endothermic), it relies on the heat and tire agitation from traffic to crush the granules and generate the friction needed to create a melting brine. Rock salt is most effective when pre-wet with a liquid at the plow spinner. However, its effectiveness plummets at pavement temperatures below 15°F and effectively stops working around 10°F. Dry salt is also prone to significant "bounce and scatter" losses, with 10 to 45 percent of material bouncing off the road into ditches upon application. Rock salt is often ineffective on low-volume rural roads due to a lack of traffic friction, and environmentally, it is highly corrosive to steel and concrete, and harmful to soil, vegetation, and aquatic life.
 - Salt Brine: Sodium chloride salt brine is a liquid solution of 23.3 percent salt and 76.7 percent water and serves as the primary tool for proactive anti-icing applications. It is typically applied 24 hours before a winter storm to prevent the snow-pavement bond from forming. It is also the standard agent for pre-wetting solid rock salt and can be used for direct liquid application (DLA) to instantly melt falling snow without the scatter of solid salt. Like rock salt, its practical operational use is generally limited to pavement temperatures above 15°F. Because it is already mostly water, salt brine risks quick dilution by heavy snowfall or rain, potentially refreezing if storm intensity

overcomes the application rate. Furthermore, because salt brine does not generate heat, it cannot easily “punch through” thick, compacted ice or hardpack.

- **Magnesium Chloride:** This agent is used in colder temperatures, remaining practical down to -10°F. Because this material releases heat (exothermic) and actively attracts moisture (hygroscopic), it is an ideal pre-wetting agent. The slightly oily consistency of magnesium chloride helps coated rock salt granules adhere to the pavement, burrow into ice, and stay wet longer than plain salt brine. It can also be used in high-speed direct liquid application deicing blends. On the downside, magnesium chloride is more expensive than rock salt and can be more damaging to concrete. Because it actively attracts moisture, magnesium chloride applications can stay wet longer and potentially lead to slick conditions if applied incorrectly.
- **Calcium Chloride:** This is the most aggressive low-temperature chloride agent, with a practical working limit down to -20°F. It is exothermic and releases significant heat upon contact with water, making calcium chloride the preferred agent for emergency deicing to rapidly penetrate thick ice and hard-packed snow in deep freeze conditions. However, it is the most expensive form of chloride salt, so it is often used as a blend rather than a straight product. It is considered highly corrosive to both steel and concrete and its moisture-attracting properties can create slippery roads if not managed properly.
- **Acetates (Potassium Acetate, Calcium Magnesium Acetate, Sodium Acetate):** Acetates are biodegradable and non-corrosive to structural steel, making them valuable for critical infrastructure like bridge decks, parking ramps, and airports. Potassium acetate (KAc) works in deep freezes down to -15°F, while Calcium Magnesium Acetate (CMA) is safer for vegetation and new concrete, making it ideal for roads passing through wetlands or near drinking water reservoirs. Despite these benefits, acetates are often considered cost-prohibitive for general municipal roadway maintenance. Additionally, CMA is slow acting, requires more material by weight, and is limited to temperatures around 20°F. Some acetates can also cause accelerated corrosion on galvanized steel, such as guardrails. Environmentally, their decomposition can temporarily deplete dissolved oxygen and increase biological oxygen demand (BOD) in surface waters, which can stress aquatic life.
- **Formates (Potassium Formate, Sodium Formate):** These agents are biodegradable and non-corrosive to structural steel, performing well in low temperatures (down to -20° for potassium formate). They generally have a lower BOD profile compared to acetates or bio-based additives, making them

attractive for airports or bridges directly adjacent to highly sensitive waterways. However, their usage in municipal operations is extremely low because they are very cost-prohibitive, running 15 to 20 times the cost of rock salt. Formates can also be corrosive to galvanized steel, concrete, and asphalt.

- **Bio-Based Additives (Beet Juice, Corn Additives, Cheese Brine):** Derived from agricultural and food processing byproducts, when these additives are used in public winter road maintenances, they are typically blended with chlorides (usually 80/20 brine/additive or 90/10 ratios) to enhance performance. The complex sugars in these additives increase the viscosity and stickiness of rock salt and salt brine, further reducing scatter loss. Beet juice and corn additives also can provide significant corrosion protection, reducing equipment damage by up to 70 percent compared to straight salt brine. Cheese brine is widely available in some parts of Wisconsin at little to no cost, providing potential budget savings. The primary environmental drawback of bio-based additives is a risk of increased BOD in surface waters – when these organic materials wash into local streams, their decomposition consumes dissolved oxygen, which can suffocate aquatic life. Negative impacts of these additives include that beet juice can leave brown, sticky stains on roads and track into buildings, corn additives can settle in tanks and smell like fermentation, and cheese brine requires significant filtration to prevent dairy solids from clogging application spray nozzles.
- **Propylene Glycol:** Primarily associated with aviation deicing, propylene glycol in municipal roadway use is rare and is typically limited to Fixed Automated Spray Technology (FAST) systems on bridges to prevent corrosion of automated nozzles. It is prohibitively expensive and has an extremely high BOD profile that can harm aquatic life.
- **Abrasives (Sand):** Sand is strictly a traction agent and does not melt ice. It is a critical tool of last resort for emergency traction during extreme cold (below -20°F) when chemical agents do not work, and it is also useful on rural roadways where low traffic volumes prevent rock salt from activating. Because it is chemically inert, it does not corrode steel or concrete. While cheap to purchase, total operational costs are high due to the required spring cleanup, such as street sweeping, catch basin clearing, and ditch cleaning. Sand physically chips vehicle paint and windshields, and environmentally it settles on stream bottoms, smothering critical aquatic habitats, and can become airborne particulate pollution. Furthermore, it decreases traction if resting directly on bare pavement rather than on top of snow or ice.

Modern public winter maintenance operations frequently use blends of multiple materials to maximize performance while reducing costs, material waste, and environmental impact. By combining the complementary properties of different materials, agencies can overcome the limitations of using a single material like dry rock salt. Some commonly used material blends include:

- The "Hot Mix": This liquid blend combines standard sodium chloride brine with magnesium chloride or calcium chloride to extend the effectiveness in colder conditions. Because these added chlorides release heat as they dissolve and possess lower freezing points, they improve melting speeds when pavement temperatures fall below the effective range of plain salt brine. Typical blend ratios range from 90/10 to 80/20 salt brine to magnesium or calcium chloride.
- Organic-Enhanced Brine: This adds bio-based agricultural additives, such as beet juice or corn-derived products, to standard salt brine. The complex sugars increase the viscosity of the liquid, helping it adhere to the pavement and resist being blown away by wind or traffic. Additionally, the bio additives form a protective barrier on metal surfaces, reducing chloride-induced corrosion on maintenance equipment by up to 70 percent.
- Triple Blends ("Super Mixes"): Triple blends combine salt brine, a "hot" chloride (magnesium or calcium chloride), and a bio-based additive to achieve the combined benefits of all three. The hot chloride accelerates melting in extreme cold, while the organic additive improves adhesion, adds corrosion resistance, and stabilizes the mixture so the hot chlorides do not make the road surface overly oily in high humidity. Common blend ratios are 80/10/10 (salt brine/hot chloride/bio-based additive) for general use and 70/20/10 for extreme cold conditions.
- Treated/Pre-Wetted Rock Salt: Modern operations increasingly rely on this solid/liquid hybrid, which coats dry rock salt with customized liquid blends just before application. When salt is treated with a "hot mix," the resulting blend becomes exothermic, releasing a heat boost that aggressively burns through thick ice. When treated with organic-enhanced brines, the salt becomes significantly stickier, ensuring the liquid stays bonded to the salt granule when thrown from the truck and resists washing off the road surface during active melting and traffic.

Winter Maintenance Equipment and Technology

The tools used to clear roads during and after winter storms have advanced significantly in recent years. Modern maintenance agencies utilize a combination of smart environmental sensors, advanced mechanical

plows, and precision material application systems. Together, these technologies allow municipalities to keep roads safe, reduce operational costs, and minimize their environmental impact.

Monitoring and Sensing Technologies

What technologies are used to monitor winter road conditions?

State-of-the-art public winter road maintenance relies on gathering real-time data to transition from a reactive approach to a predictive and proactive science. Critical advancements for monitoring and sensing technologies include:

- Maintenance Decision Support Systems (MDSS): These are sophisticated, centralized computer platforms that integrate advanced weather forecasts, pavement temperatures and condition modeling, and a municipality's specific operational rules and strategies. While the heavy data processing happens at a central hub, the MDSS communicates directly with in-cab displays to provide truck operators with real-time route-specific recommendations for treatment locations, timing, and chemical application rates.
- Road Weather Information Systems (RWIS): These fixed environmental sensor stations collect vital atmospheric and pavement condition data (see **Figure 8.1**).
 - Active and Passive Sensors: Active sensors embedded in the road create heating and cooling cycles to find the exact freezing point of the pavement, while passive sensors track surface conductivity to estimate how much deicing chemical concentration remains on the road.
 - Multi-Community Networks: Agencies in Southeastern Wisconsin are forming partnerships to bundle the purchase of wireless pavement sensors. These devices measure road temperature and residual chemicals, providing the real-time ground data needed to improve local predictive modeling and winter road maintenance strategies.
- Mobile Sensors: To fill the gaps between fixed RWIS stations, plow and salt trucks act as rolling data collectors using Automated Vehicle Location (AVL) systems. Mobile sensors include non-contact infrared pavement temperature sensors, friction measuring devices, and advanced chemical concentration sensors (see **Figure 8.2**).

- Artificial Intelligence (AI) and Machine Learning: Smart MDSS systems are beginning to use AI to learn from past storm events, refine pavement predictive models, optimize fleet routing, and precisely calculate the minimum effective dose of deicing chemicals for an event.

Mechanical Snow and Ice Removal

What equipment is used by modern winter road maintenance agencies to physically remove snow and ice?

The primary tool for any winter road maintenance operation should be the mechanical removal of snow and ice using advanced plow technologies. By prioritizing physical removal, agencies can significantly reduce the volume of chemicals required to treat the remaining snow and ice. Modern public snow and ice removal operations look to a variety of tools, both time-tested and new technologies.

State and municipal winter maintenance agencies utilize a variety of plow configurations based on specific needs as well as characteristics of the road systems. Typical plow configurations include:

- Front-Mounted Plows: One-way plows are used for high-speed highway clearing because they throw snow far off the shoulder, while reversible plows are standard for municipal streets because their angle can be adjusted left, right, or straight to avoid blocking intersections.
- Wing Plows: Mounted on the side of the truck, these allow a single vehicle to clear an adjacent lane or shoulder in one pass.
- Underbody Scrapers: Positioned beneath the truck chassis, these scrapers use massive hydraulic cylinders to apply over 200 pounds per square inch (PSI) of downward pressure to physically break up hardpack snow and ice.
- Tow Plows: Large 26-foot steerable trailers pulled behind standard trucks that swing out to clear two to three interstate lanes simultaneously.

Snowplow blades, or cutting edges, are bolted to the snowplow moldboard and are the component of the plowing system that makes contact with the road surface. The field of winter road maintenance has seen a rapid advancement in plow blade technology. When all factors are considered, upgrading to advanced cutting edges offers a high return on investment by extending the life of the equipment and reducing the amount of chemical deicers needed to efficiently clear snow. Advanced snowplow blade technology includes the following innovations:

- **Multi-Layered Blades:** Often built with a tungsten-carbide insert sandwiched between steel or rubber, these blades reduce damaging vibrations and last longer (see **Figure 8.3**).
- **Sectional and Live-Edge Blades:** Instead of a single 12-foot piece of steel, these blades are composed of smaller 12 to 24-inch segments. These blades offer flexibility and simplified maintenance allowing damaged segments to be replaced rather than the whole blade. Live-edge systems put each segment on an independent suspension, allowing the blade to contour to uneven surfaces and scrape away significantly more snow (see **Figure 8.3**).
- **Multi-Blade Systems:** These use separate blades on a single plow frame, each optimized for a specific function. A typical setup might include a primary cutting edge for heavy snow removal, followed by secondary blades designed to clear slush or scarify hard-packed snow and ice (see **Figure 8.3**).

Material Application Equipment

What specialized equipment is used to precisely apply deicing and anti-icing materials?

Implementing these advanced chemical road treatment strategies requires highly specialized equipment. Modern equipment ensures that deicing and anti-icing agents are applied accurately, keeping materials on the road and out of local waterways. Some of the critical material spreading tools and technologies currently being used include:

- **Granular Spreaders:** Trucks utilize large hoppers or tailgate spreaders to hold rock salt and mechanically deliver it to the application point at the rear of the truck.
- **Spinner Assemblies:** As the salt is discharged from the truck, a rotating disk (spinner) broadcasts it across the pavement. Traditional spinners can lose up to 40 percent of material due to “bounce and scatter,” but simple additions to a spinner assembly, like rubberized skirts, help keep the salt in the travel lane. Modern fleets increasingly use advanced spreading technologies to maximize precision:
 - **Directional Spinners:** Allow operators to adjust the spread pattern (left, center, or right) directly from the cab to target specific areas of the road.
 - **“Zero Velocity” Systems:** Discharge salt backward at the exact speed the truck is moving forward, allowing the material to drop straight down onto the road and reducing salt waste by up to 70 percent.

Examples of each of these spinner assemblies are shown in [Figure 8.4](#).

- **Pre-Wetting and Liquid Systems:** To support pre-wetting, trucks are outfitted with onboard liquid saddle tanks and delivery pumps (see [Figure 8.5](#)). For direct liquid applications, agencies use specialized equipment, from slide-in 1,000-gallon tanks to massive 5,000-gallon highway tankers equipped with extendable spray bars (see [Figure 8.6](#)).
- **Brine Production Systems:** Modern winter road maintenance relies on the precision of brine making equipment to achieve a specific salt-to-water ratio to maximize effectiveness while minimizing chloride loading to the environment. Producing salt brine in-house provides significant operational and financial advantages. Municipalities with their own production systems eliminate the need to travel to neighboring communities to refill their trucks, which can save valuable time and resources. Economically, on-site production can lower the cost of brine to approximately \$0.13 to \$0.20 per gallon, compared to the \$0.40 to \$0.60 per gallon typically charged by outside vendors. In-house brine making equipment can range widely in sophistication from shop-built manual-batch units to fully automated systems. Examples of both are shown in [Figure 8.7](#).
- **Electronic Spreader Controls:** Perhaps the most critical advancement in application equipment is the electronic in-cab controller (see [Figure 8.8](#)). These systems monitor the speedometer of the truck to automatically adjust the material output. If a truck accelerates, the system dispenses more material. If a truck stops at an intersection, the application instantly pauses. Modern controllers have sophisticated software capable of managing granular, pre-wet, and liquid applications.
- **Dynamic Spreading Systems:** Representing the current state-of-the-art, dynamic spreading systems link directly to external infrared sensors on the truck (see [Figure 8.2](#)). The system continuously scans the road surface and automatically adjusts the salt output in real-time based on the exact temperature and friction of the pavement passing beneath the vehicle. The goal is to provide the exact amount of chemical needed to achieve the targeted friction levels, thereby reducing both costs and chloride loading.
- **Fixed Automated Spray Technology (FAST) System:** FAST systems are typically installed on high-risk infrastructure such as bridges. These are permanent systems that use real-time sensors to monitor pavement conditions. When freezing conditions are imminent, the system automatically sprays anti-icing liquids directly onto the road surface (see [Figure 8.9](#)). This instant response eliminates the delay

of dispatching plow trucks and has been shown to reduce friction-related accidents on bridges by up to 66 percent.

Methods of Chemical Treatment

What are the primary methods used by modern winter road maintenance agencies for applying chemical treatments?

State-of-the-art winter road operations rely on the strategic application of the right material, in the right place, at the right time to achieve the intended results. These precision chemical application strategies are based on significant amounts of scientific data and studies to provide effective results while minimizing material waste, which are described in more detail in SEWRPC TR-66. Modern strategies are divided into two distinct categories: proactive prevention and reactive treatment.

Anti-Icing/Pretreatment

A significant advancement in winter road maintenance is the shift away from solely reactive deicing during an event. Anti-icing is a proactive strategy that involves applying a liquid freezing point depressant (typically salt brine) to dry pavement 12 to 24 hours before a forecasted winter storm. The liquid brine is typically applied with streamer nozzles in a wet/dry striping pattern in driving lanes (see [Figure 8.10](#)).

- The primary goal of anti-icing is not to melt accumulated snow, but to prevent a strong bond from forming between the frozen precipitation and road surface.
- By establishing this chemical barrier, snow plowing becomes significantly easier and more efficient. In fact, removing established snowpack after it forms requires approximately ten times more energy than preventing the initial bond between snow and pavement in the first place.
- Transitioning to a liquid anti-icing program can reduce an agency's total winter salt usage by 20 to 50 percent, providing cost savings while drastically reducing the volume of chloride entering the environment.

There are several critical conditions that must be present before initiating an anti-icing operation. Operations managers can refer to an anti-icing decision flow chart developed by APWA (see [Figure 8.11](#)) to determine if conditions are suitable for pretreatment applications.

Precision Deicing

Deicing is a reactive strategy used when snow or ice has already bonded to the roadway. Instead of trying to melt all the snow, modern public road deicing aims to penetrate the snowpack and create a brine layer at the pavement surface so plows can effectively scrape the rest away. The selection of a specific technique and best application rate is determined by complex relationships between pavement temperatures, precipitation type and intensity, and roadway level of service goals. Common precision deicing techniques include:

- **Pre-Wetting:** This strategy involves coating solid rock salt with a liquid chemical agent or blend (like salt brine) just before it is spread onto the road. This makes the rock salt heavier and stickier, ensuring it stays on the pavement instead of bouncing into roadside gutters and ditches. Pre-wetting also jump-starts the melting process by adding the liquid that rock salt needs to activate, typically reducing salt usage by 25 to 30 percent.
- **“Shake and Bake” (Slurry Application):** For severe winter road conditions, some agencies use a high-volume pre-wetting technique to create a fast-acting, oatmeal-like slurry. Because this slurry uses significantly more liquid than standard pre-wetting techniques, it can “punch through” hardpacked ice and works 30 to 45 minutes faster than dry salt, making it ideal for clearing roads quickly during rush hour traffic.
- **Direct Liquid Application (DLA):** Instead of dropping rock salt, DLA involves spraying liquid deicing brines or other agents directly onto actively accumulating snow. By skipping the time it takes for solid salt to dissolve, the liquid works instantly. Studies show that DLA can clear roads up to two hours faster than dry rock salt while using 23 percent less material. DLA strategies are typically most effective for light snow accumulation.

Material Application Rates

How do agencies determine the right amount of chemical agent to use, and why is calibration important?

All snow and ice control materials and high-tech application equipment rely on the foundational principle of precision. The goal for modern public winter road maintenance is to apply the minimum amount of chemical required to achieve a safe roadway, which minimizes costs and chloride loading to the environment while maintaining public safety.

There is no correct “one-size-fits-all” application rate for any snow and ice control material. Modern winter maintenance agencies must determine appropriate rates based on factors such as material type, application method, pavement temperatures and trends, weather trends, snowfall intensity, and plow cycle times. Agencies must also consider their local experiences and specific community needs when determining application rates. Factors like micro-climates, traffic volume, and available resources may require an operator to adjust standardized guidance for local application rates.

- Temperature-Based Guidance: Wisconsin Salt Wise has provided general recommended deicing application rates for dry and pre-wetted salt for municipal operations based on pavement temperatures. As outlined in [Table 8.2](#), for pavement temperatures above 15°F, dry rock salt is generally recommended to be applied at 150 to 350 lbs/lane-mile, and pre-wetting allows for lower dry salt application rates (100 to 300 lbs/lane-mile) because the added liquid helps the salt adhere to the road, reducing the bounce and scatter losses.¹ For standard pre-wetting, Wisconsin Salt Wise recommends using at least 15 gallons of brine per ton of rock salt. The Shake and Bake deicing method calls for a higher liquid-to-solid ratio, using 40 or more gallons of brine per ton of rock salt with a reduced rock salt application rate of 100 to 200 lbs/lane-mile.

When temperatures fall below 15°F, dry rock should not be used alone. Instead, operations are recommended to switch to pre-wetted salt (250-350 lbs/lane-mile), with a specialized liquid such as an 80/20 organic blend or a 90/10 calcium chloride blend. Similarly, the Shake and Bake method should transition to a brine blend at temperatures below 15°F (see [Table 8.2](#)).

- Detailed Application Guidance: For precise, day-to-day operational planning, [Appendix B](#) in SEWRPC TR-66 provides comprehensive application rate recommendations from the *Material Application Methodologies Guidebook* developed by Washington State University and Clear Roads. Grounded in scientific research and field experience, these guidance tables recommend the exact amount of solid rock salt, liquid brine, abrasives, or chemical blends needed for any given winter storm. The guidebook tables cover a wide range of real-time road conditions (such as dry pavement, slush, or icy patches) and weather events, from light to heavy snow and freezing rain, while also providing specialized rates for direct liquid application (DLA). Because optimal application requires flexibility,

¹ Similarly, for highway maintenance, WisDOT provides recommended application rates for rock salt in its *Highway Maintenance Manual*. These application rates range from 100 lbs to 400 lbs/lane-mile for dry rock salt and from 100 lbs to 300 lbs/lane-mile for pre-wetted salt.

these guidance tables provide a target range rather than a single number. Operators are instructed to use the lower end of the range for lower service goals or shorter plow cycle times and the higher end for long cycle times and severe storms where heavy precipitation will rapidly dilute the chemicals.

Equipment Calibration

Equipment calibration is the most critical process for winter maintenance agencies to reduce chloride pollution. Without routine calibration, application errors of 20 to 50 percent are common, leading to massive environmental waste and unnecessary costs.

- Calibration involves rigorously testing the equipment to ensure that the physical weight and volume of the salt or liquid hitting the road exactly matches the target rate programmed into the truck's electronic spreader controller.
- Agencies must carefully calibrate their application equipment separately for every specific material type (such as straight rock salt, liquid blends, and pre-wetted salt). Calibration should occur when a spreader or controller unit is first put into service, before every winter maintenance season begins, after any equipment repairs, when material stockpiles are replenished, and any time a material calculation shows a discrepancy. Additionally, advanced agencies will spot-check equipment during the season to make sure that units are properly functioning and within calibration specifications. For more detailed calibration processes, see SEWRPC TR-66.
- Frequently Overlooked Equipment: While material spreaders are often the primary focus, agencies must also remember to calibrate other critical hardware. This includes external road temperature sensors, spinner speed controls, spreader gate opening sensors, pre-wetting flow meters, vehicle speed sensors, and the plow control joysticks in the cab. Neglecting to calibrate these components can generate inaccurate data that undermines salt reduction goals and leads to incorrect application rates.

Winter Maintenance Material Storage and Handling

How are winter maintenance materials stored and handled to protect the environment?

Protecting the surface water and groundwater of the Region also requires rigorous management of deicing materials before they are used. How agencies store winter maintenance materials and equipment is critical to reducing chloride pollution in their communities.

- **Solid and Liquid Storage:** In Wisconsin, bulk rock salt storage is strictly regulated. Salt must be housed in fully enclosed buildings or completely covered on impermeable asphalt or concrete pads to prevent salty runoff from entering nearby waterways or leaching into groundwater. Modern liquid facilities utilize double-walled storage tanks equipped with secondary containment basins.
- **Tracking Control and Housekeeping:** To prevent deicing salt from being tracked out of storage yards and into the environment by vehicle tires, facilities often utilize one-way traffic patterns and heavy-duty rumble strips or shaker grates at exits to remove loose salt from truck undercarriages.
- **Water Reclamation:** State-of-the-art facilities capture salt-contaminated stormwater and truck wash-water. Instead of discharging the contaminated water into the environment, some agencies recycle it as “pre-charged” water to manufacture new salt brine, saving taxpayer money and reducing their chloride footprint.
- **Snow Storage Areas:** Meltwater from relocated snow piles can contain highly concentrated deicing chemicals. Agencies must carefully select snow storage sites to ensure that this meltwater is directed safely away from sensitive habitats, wetlands, and storm drains.

To further protect local waterways, some municipalities are implementing centralized drop-off locations where residents and private contractors can return unused rock salt for free. Programs like the “Sweep the Salt” campaign from Wisconsin Salt Wise encourage the public to sweep up excess salt from dry sidewalks and driveways. By treating this salt as a reusable asset, municipalities can integrate the collected material into their own brine production, saving money on future purchases and preventing the excess salt from washing into sewers and streams.

Potential Future Advancements

What might the future of public winter road maintenance look like?

While the chloride reduction strategies discussed up to this point are already being implemented with measurable successes, emerging advancements offer a glimpse into the next generation of winter maintenance. These future technologies aim to reduce chloride loading through innovative structural design and material science rather than chemical treatments. Currently these technologies are used for only portions of driveways, streets, and parking lots due to higher installation and/or maintenance costs. More research and development is needed to be able to utilize these technologies more broadly on municipal roads and highways.

- **Permeable Pavements:** Porus asphalt and pervious concrete use interconnected voids to drain water through the surface and into the soil below, significantly minimizing ice formation. Research indicates these surfaces can maintain safety with up to 77 percent less deicing salt, though they require regular vacuum sweeping to prevent the voids from clogging with fine materials like dusts, soils, and crushed leaves.
- **Heated Pavements and Conductive Concrete:** While traditional heated roads circulate warm water or use electric mats beneath the surface, new “electrically conductive concrete” (ECON) integrates carbon fibers or steel shavings directly into the pavement mix. When low voltage current is applied, the concrete itself acts as a uniform heating element to melt snow on contact, effectively eliminating the need for chemical deicers.
- **Phase Change Materials (PCM):** PCM-modified pavements act as a thermal sponge. They absorb and store heat during warm days and release that thermal energy back into the pavement as temperatures drop. This latent heat release can delay the onset of freezing by over an hour, preventing the initial formation of frost and black ice.
- **Solar Roadways:** This technology integrates heavy-duty, textured solar panels directly into the driving or walking surface. The photovoltaic panels generate electricity from sunlight to power internal heating elements that melt snow and ice on contact. While highly effective in pilot programs, this technology is still being refined to improve durability under heavy traffic and lower high installation costs.

8.3 PRIVATE WINTER MAINTENANCE

While a lot of attention is paid to winter roadway salting on public roads and highways, chloride loading contributions from private practices is not inconsequential. Private roads and parking lots are typically serviced by winter maintenance practitioners that are contracted to remove snow and ice and provide safe ground conditions. Residential driveways, walkways, and adjacent public sidewalks are often maintained by individual homeowners or contracted winter maintenance service providers. As with public winter maintenance practices, the initial step for private practices is mechanical snow removal via shoveling, plowing, snowblowing, or other methods prior to use of deicing materials. Efforts to reduce or eliminate chloride loading to the environment include education, policy initiatives, equipment calibration, appropriate application rates, alternative deicers, smarter site design and layouts, and other methods discussed in TR 66.

What is the recommended amount of salt to be applied to driveways, sidewalks, and parking lots?

The recommended amount of salt to be applied to a driveway or sidewalk is 3.6 lbs/1,000 ft² and to a parking lot is 3.5 lbs/1,000 ft², which is approximately equivalent to spreading a 12-ounce coffee mug volume of salt over a 20-ft long driveway or ten standard sidewalk squares.² This amount of salt, when distributed evenly over the pavement, can provide adequate melting while reducing the amount of excess salt. **Figure 8.12** presents a visual of this salt application rate. This rate of salt spreading can be achieved by broadcasting the salt by hand, using a walk-behind spreader, or truck-mounted equipment. When using a spreader, it is essential that it is properly calibrated to apply this recommended amount of salt; a spreader that is not properly calibrated can over apply salt, potentially a significant amount of excess. In addition to reducing chloride pollution, avoiding over application of salt can help protect plants and other landscaping from salt runoff, reduce damage to concrete surfaces, save money on salt purchases, and reduce the amount of cleanup needed after the storm event.

Is sand a more sustainable option than salt?

While sand does not facilitate melting of snow or ice, it can be applied to improve traction for both vehicles and pedestrians. Proper application of sand is important, where it should be applied on top of the snowpack or ice; sand applied onto bare pavement can decrease traction. Sand is most effectively used in conjunction with physical snow removal, where most of the snow should first be removed with shoveling or plowing and the sand is applied on top of the remaining layer of snow and ice. After the snow and ice have melted, the sand should be swept up to avoid an accumulation of sand on the pavement surface and to keep it from entering adjacent waterways via runoff.

Because sand does not contain chloride, it can be a viable alternative to salt to reduce chloride pollution. However, the use of sand can have other negative environmental impacts. Sand that gets washed off the pavement can end up in streams and other aquatic systems, harming habitat. In streams, the sand can fill the voids of gravel and other substrates that are critical habitat for some fish and invertebrates, increase turbidity, and lead to sedimentation. Sand can also accumulate in stormwater infrastructure such as catch basins, sewers, and stormwater ponds, decreasing their functionality and capacity and requiring costly maintenance to remove the accumulated sand. Most of these disadvantages of sand can be reduced by sweeping up and collecting the sand once the snow and ice have melted.

² Wisconsin Salt Wise, www.wisaltwise.com/take-action/smart-salting, accessed July 2025.

Are there other alternatives to using salt?

Other alternatives to using salt include timely removal of snow, heated pavement, porous pavement, and designing buildings and landscaping to maximize direct sun exposure on the pavement to facilitate melting. Timely removal of snow entails shoveling, snow blowing, or plowing during a snowfall event and/or directly after it to make the pavement functional without the excess use of salt. Physical removal of snow is an important first step for winter maintenance before applying any deicing materials and can be made easier with the use of anti-icing materials prior to a snowfall event to reduce the binding of snow and ice to the pavement as discussed earlier in this Chapter. Completing the physical snow removal in a timely manner is crucial, as snow that has been compacted by vehicular or pedestrian traffic can be substantially more difficult to remove down to the pavement surface.

Heated pavement utilizes heating systems installed underneath the pavement that warm the surface to above freezing, preventing snow and ice buildup. Heated pavement systems typically use either hydronic heating, which circulates hot fluid through a piping network, or electric coils to provide the heat. It is important to design the pavement surface to drain the meltwater away from any location where ponded water will cause a safety hazard when it refreezes.

Porous, or permeable, pavements are designed to allow water to quickly infiltrate through the material surface before it pools. Properly designed porous pavement can allow water to infiltrate before it freezes during winter storm events or melting events. Porous pavement also typically has better traction compared to traditional pavement, which, along with the rapid surface drainage, can reduce deicing material needs by up to 77 percent compared to traditional asphalt.³ Proper maintenance is critical to maintain the infiltration capacity of porous pavement. Snow should be removed by shoveling or snow blowing, and when plowing is needed, the plow height should be raised to avoid damaging the pavement surface. Sand and salt should not be used on porous pavement, as the particles can clog the pores and inhibit infiltration. Additionally, the high infiltration rate can easily transport chloride into underlying soils and groundwater.

Lastly, increasing the amount of direct sun exposure onto pavement can be effective at melting snow and ice with the use of less or no deicing salt. The location and orientation of landscaping features can impact the amount of direct sunlight that reaches pavement surfaces. Trees, benches, and other objects can be located on the northern side of the pavement to avoid casting a shadow onto the pavement. If located on

³ R.M. Rosen, T.P. Ballester, K.M. Houle, D. Heath, and J.J. Houle, "Assessment of Winter Maintenance of Porous Asphalt and its Function for Chloride Source Control," *Journal of Transportation Engineering*, 140(2), 2013.

the southern edge of the pavement, deciduous trees should be selected over conifers to allow more sunlight through during winter. During the design phase of a site, the main entrance(s) of the building can be located to have southern exposure, and the parking lots and sidewalks should be located on the southern side of the building to provide maximum sun exposure and reduce reliance on salt, as illustrated in [Figure 8.13](#). SEWRPC TR-66 details additional site design aspects that can reduce the need for winter deicing materials.

8.4 PUBLIC WATER AND WASTEWATER UTILITIES

Wastewater treatment plant (WWTP) effluent that is discharged to surface water or groundwater can be a major source of chloride in the environment. Most of the chloride in WWTP effluent is not generated at the plant but rather originates from sources throughout the service area, ultimately being discharged to local waterways at the WWTP outfall location. The sources of chlorides to WWTPs can vary depending on whether the water supply source for the community is groundwater or Lake Michigan water. Public WWTPs face increasingly stringent limits on discharge chloride concentrations, necessitating WWTPs to undertake efforts to reduce their effluent chloride concentrations.

What are the sources of chloride to public wastewater treatment plants?

Chloride can enter public WWTPs from a variety of sources. The main sources are illustrated in [Figure 8.14](#) and include the following:

- Ion-exchange water softener regeneration discharge in communities that use groundwater as their water supply.
- Winter deicing products inadvertently entering the sanitary sewer system via infiltration and inflow at manholes and cracks in sanitary pipes and joints.
- Chloride-containing household products as well as salt from food preparation and human excreta.
- Chloride-containing chemicals used in the wastewater treatment process as coagulants to remove contaminants during wastewater treatment.
- Industrial and commercial facilities, such as laundromats, car washes, hotels, and others.
- Background chloride concentrations in the water supply from the source groundwater.

Can chloride be removed from wastewater?

While traditional wastewater treatment processes do not remove chloride, additional processes could be installed and operated at WWTPs to remove chloride from wastewater. This could be achieved using reverse osmosis, electrodialysis reversal, or ion exchange systems.

- Reverse osmosis is a membrane filtration technology that forces water through a membrane under pressure. Most impurities, including chloride, can be removed with reverse osmosis.
- Electrodialysis reversal utilizes semipermeable membranes to remove dissolved solids similar to reverse osmosis systems, however movement into the membrane is driven by electrical charge rather than pressure. Electrodialysis reversal is effective at removing contaminants with an electrical charge, including chloride, but does not remove contaminants with a neutral charge.
- Ion exchange systems contain a column of ion exchange resin that is engineered to react with a specific target ion, such as chloride. An exchange ion on the resin would swap with the chloride, removing it from the wastewater.

While each of these technologies are effective at removing chloride from wastewater, they would create a waste stream with a high chloride concentration. In addition to the high cost of operating these technologies at scale, management and disposal of this waste stream is typically very costly, to the extent of making chloride removal at WWTPs cost prohibitive.

How can the amount of chloride in wastewater be reduced?

Because removal of chloride at wastewater treatment plants is typically not feasible due to the exorbitant costs as discussed previously in this Chapter, source reduction of chloride to the treatment plants must be achieved to reduce effluent chloride levels. The primary approach is to reduce the amount of chloride from residential and commercial water softening. Water softeners can be optimized, upgraded to more efficient systems, or operated with a bypass valve to use less salt and generate less chloride. Additionally, homes in the Region that use Lake Michigan as their water supply could remove their softeners altogether. Residential water softener improvements are discussed in more detail later in this Chapter.

An alternative approach to reducing chloride generation from water softeners to wastewater treatment plants is centralized softening, which entails construction and operation of a central plant that removes

hardness in the municipal water supply prior to entering the distribution system.⁴ Centralized softening plants typically use lime softening, reverse osmosis, or electrodialysis reversal technologies. Lime softening uses lime and soda ash to settle out hardness-causing ions, which removes most of the hardness. Reverse osmosis pushes water through membranes under pressure to remove impurities such as hardness. Electrodialysis reversal utilizes electrical charge to draw hardness-causing ions into membranes, removing the ions from the water.

Each technology produces a waste stream that needs to be managed and disposed of appropriately. **Table 8.3** summarizes the various considerations for each alternative central softening technology. Centralized softening may not remove all hardness from the water supply, however the reduction in hardness may allow for more limited water softener use at homes and businesses or removal of water softeners entirely. The cost to construct and operate a centralized softening plant can be substantial (see TR-66 for detailed cost estimates), however it is generally more cost effective than removal of chloride at the WWTP, and it can lead to significant reduction in chloride in WWTP effluent.

8.5 PRIVATE WATER SOFTENING

Homes that receive hard drinking water often use water softeners to remove hardness and produce soft water. Hardness is primarily due to natural levels of calcium and magnesium in the water supply. While hardness does not pose a health concern, it can have negative impacts on plumbing systems and appliances via mineral buildup, or scale, that can reduce flow capacity in pipes and decrease appliance efficiency. Hard water can also inhibit lathering of soap, leave mineral buildup on dishes and fixtures, and make laundered clothes feel stiff and not adequately cleaned. Operation of water softeners can be a major source of chloride to the environment, as discussed previously in this Chapter.

How do water softeners produce chloride?

Most water softening in homes is currently done using ion exchange technology in water softeners. Ion exchange water softeners use salt (sodium chloride) to replace the calcium and magnesium in the water supply (either municipal water or well water) with sodium on an exchange resin. Once the resin material gets saturated with calcium and magnesium and can no longer soften additional water, a regeneration, or

⁴ Another option for centralized softening is softening the water at individual municipal wellheads prior to distribution, however this is generally considered infeasible due to the extensive piping and systems needed for waste stream management at each well location.

recharge, cycle flushes the system with a salt brine solution. The brine is made by dissolving the salt pellets, creating a solution containing sodium ions and chloride ions. The sodium ions displace the calcium and magnesium on the resin, and the displaced calcium and magnesium, along with the chloride in the brine, are discharged from the system as wastewater. **Figure 8.15** illustrates the water softening and regeneration processes.

How can the amount of chloride waste from water softeners be reduced?

The amount of chloride from existing water softeners can be reduced by optimizing existing softeners for efficient performance, upgrading older ion exchange systems to more efficient newer systems, installing bypass valves, and reducing water usage.

Optimization, or calibration can make a water softener run more efficiently and reduce the amount of salt used. Calibration of an ion exchange water softener requires adjusting the equipment settings based on the water supply conditions and water usage parameters specific to the household. Data and parameters used to optimize water softeners include the hardness level of the source water, the volume of household water usage, and the water softener capacity, defined in grains of hardness or grains per pound of salt. The source water hardness can be determined using a test kit or can often be obtained from the municipality for public water supplies. The capacity of a water softener system can be found on the specification label. TR-66 details the calculations needed for softener calibration. Once a softener is properly calibrated, the hardness of the source water should be tested periodically and the softener should be recalibrated as needed in response to changes in hardness.

While calibration can reduce salt usage in existing water softeners, upgrading to a more efficient system can yield further reduction in salt use. Older softeners often are timer-based, meaning the system regenerates after a specified amount of time, even if the system has softening capacity remaining. As domestic water use varies day to day and from season to season, this variability means timer-based softeners often regenerate either too infrequently, leaving the home with only hard water for a period of time, or too often, wasting energy, water, and salt, and adding unnecessary chloride pollution to the waste stream. Timer-based systems become increasingly less efficient during periods of lower water use. Newer, more efficient water softeners are demand-based, which means they regenerate after a specified amount of water has passed through the system. This results in the recharge cycle running on an as-needed basis. Because demand-based systems operate more efficiently than timer-based systems, they can reduce the use of salt, water, and energy.

An additional way to reduce water softener salt use is to operate a bypass valve. A bypass, blending, or mixing valve allows a portion of the unsoftened source water to bypass the water softener system entirely. This hard water is blended with the softened water to produce a finished water with a specified amount of hardness. The bypass valve can be operated to produce a blend that has a level of hardness that is acceptable to the homeowner while reducing the amount of salt used.

Lastly, the amount of chloride produced by demand-based water softeners can be reduced by decreasing the amount of water used within the home. This can be achieved by implementing water conservation practices and by using low water use appliances such as high-efficiency washing machines and dishwashers, low-flow showerheads and toilets, and faucet aerators. These devices can reduce the required water softening by decreasing the amount of water used by the household. This in turn can reduce the amount of salt used and chloride produced in the demand-based softener.⁵

Are there alternate water softening technologies that do not produce chloride?

While ion exchange water softeners represent the vast majority of private water softening in the Region, there are alternate technologies that can treat water for hardness.

- Portable exchange water softeners can be an alternative to conventional ion exchange water softeners. A portable exchange water softener is a self-contained tank that softens water using ion exchange technology similar to traditional water softeners, however once the resin softening capacity is exhausted, the tank is removed to a service provider facility to be regenerated. Because the regeneration is done at a central facility, the service provider can contain and treat the waste brine, preventing it from being discharged directly to the environment.
- Reverse osmosis systems can remove hardness by passing the water under pressure through a membrane, which can soften water without generating chloride. However, reverse osmosis can be energy intensive and waste as much as 20 percent of the inflow water, which makes it an unsuitable technology for whole house water softening.

⁵ *Timer-based water softeners would need to be upgraded to a demand-based water softener in order to achieve a reduction in salt use with the decreased water use.*

- Nanofiltration is a membrane filtration technology similar to reverse osmosis, however its operating pressure is lower. This results in lower operating costs and less water wasted, which makes it a viable alternative to conventional ion exchange systems for whole house water softening.
- Capacitive deionization is a newer softening technology that utilizes electrodes to remove ions from the water, where negative electrodes remove positive ions and positive electrodes capture negative ions.

Reverse osmosis, nanofiltration, and capacitive deionization do not produce any chloride. While these technologies can offer a chloride reduction benefit, at the time of writing they are not widely used within the Region for whole house residential water softening. Due to limited availability, it may be difficult for a homeowner to assess the cost and feasibility of each technology.

In addition to water softening technologies, an emerging group of technologies called water conditioners could be used to treat water for hardness. Water conditioners do not remove hardness from water but rather interact with the hardness to reduce the formation of scale in pipes, fixtures, and appliances. As such, water conditioners are not true water softeners because they do not remove hardness from the water. None of these technologies produce chloride in their waste stream. Water conditioning technologies to reduce scale buildup include:

- Template assisted crystallization water conditioners induce the formation of microcrystals composed of calcium and magnesium to effectively bind up the hardness-causing ions. These microscopic crystals do not cause buildup of scale.
- Magnetic treatment utilizes magnetic fields to cause the hardness ions to form minute clusters, which reduce scale buildup.
- Electrically induced precipitation applies an electric field to precipitate out the hardness as soft scale, which can be flushed away with the movement of water through the system.

The clusters or crystals created in all of these emerging technologies can remove existing scale throughout the plumbing system, which can provide the benefit of improved performance, reduced energy use, and reduced cost of water heater operation as well as restore flow capacity in pipes, fixtures, and appliances.

Finished water containing these clusters or crystals is safe to drink and can even be a beneficial source of calcium and magnesium.

Table 8.4 provides a summary of the various considerations of each drinking water treatment technology presented. At the time of writing, all of these alternative and emerging technologies were relatively new and need more research and development to become more widely used and potentially replace traditional ion exchange water softeners at the whole household or commercial scale.

Can iron filters remove hardness and be a substitute for water softeners?

While iron filters do not remove hardness and thus cannot be a substitute for water softeners, they can help reduce water softener salt use in locations where there is a high level of iron in the source water. Iron can reduce the performance of water softeners by attaching to the exchange resin. Softener regeneration cycles are not effective at removing iron from the resin. This can reduce the hardness removal capacity of the softener, potentially leading to an increase in salt use. Treating the water with an iron filter prior to entering the water softener can prevent iron buildup in the softener and maintain the efficiency of the softener, reducing salt use and chloride production.

Do water softeners harm septic systems?

While scientific opinion is divided on whether the use of water softeners is harmful to septic system components, recent findings suggest that maintaining the efficiency of a water softener may mitigate potential impacts that the water softening process can have on septic systems. Homeowners can take measures to reduce the amount of chloride entering the septic system by implementing chloride reduction practices discussed previously in this Chapter. Beyond potentially maintaining the health of the septic system, reducing household chloride production can decrease the amount of chloride pollution to groundwater and native soils as well as potentially save money due to less salt and energy used.

8.6 AGRICULTURE

Much of the rural portions of the study area for the Chloride Impact Study are dominated by production agriculture fields or livestock sites. While chloride loading from agricultural sources represent only around 5 percent of the annual loading from sources in Southeastern Wisconsin, it has a disproportionate impact in rural areas, which experience less winter road and parking lot deicing. The primary sources of chloride from agriculture include chloride in synthetic fertilizer (potassium chloride), chloride fed to livestock and excreted as manure, and background chloride content in groundwater used as irrigation water on

agricultural fields. The following discussion will evaluate methods for reducing chloride exports from agricultural sources.

How do applications of fertilizer, manure, and irrigation water to agricultural fields contribute chlorides to the environment?

Potassium is a macronutrient needed by crops to facilitate plant growth. It is typically applied to agricultural fields in the form of synthetic fertilizers commonly known as potash. Potash fertilizer is a general name given to a group of fertilizers that contain potassium (K) but is mostly produced in the form of potassium chloride (KCl).

- Potash Fertilizer: KCl represents about 95 percent of the potash used in the United States. When applied to crop fields, KCl breaks up into its ion forms, K^+ and Cl^- , the potassium ion utilized more by the plant in comparison to the chloride ion, leaving excess chloride on the field.
- Manure: Salt in the form of sodium chloride (NaCl) is commonly found in animal feed, which is then consumed and excreted in animal waste, which is applied to agricultural fields as manure. In the same manner as potash fertilizer, macronutrients in manure (nitrogen and phosphorus) are utilized by the plant more than chloride, leaving excess chloride on the field.
- Irrigation: Irrigation water is used on crop fields when precipitation does not provide the required water for plant growth. Irrigation water is typically sourced from groundwater which has a background chloride concentration. Chloride is highly mobile in water, thus when irrigation water is applied to crop fields, it contributes chlorides to the fields.

In general, chlorides are present in the typical applications to agricultural fields, usually in excess of what plants can utilize. Thus, excess chloride is left on the field to run off to surface water, and/or infiltrate into groundwater.

Are there alternative fertilizers to potassium chloride?

There are alternative synthetic, mineral, and soil amendment options to KCl. Potassium sulfate (K_2SO_4), potassium nitrate (KNO_3), and potassium thiosulfate ($K_2S_2O_3$) are alternative potash fertilizers to KCl. Each has the advantage to KCl of providing two macronutrients to plants (potassium and sulfur for K_2SO_4 and $K_2S_2O_3$, and potassium and nitrate for potassium nitrate), as opposed to KCl which only provides K as a macronutrient. The main disadvantages of these alternative potash fertilizers are that they are much more

expensive than KCl and provide less K for the same amount of fertilizer. In conversations with County conservationists within the Region, alternative potash fertilizers are not often used in the Region due to a lack of awareness and availability of these fertilizers to agricultural producers.

Potassium-magnesium sulfate (langbeinite) and potassium feldspar are minerals found in the Earth's crust that can be used as alternative mineral fertilizers. Both contain trace amounts of chlorides. The main concerns with mineral fertilizers are that they provide less K for the same amount of fertilizer as compared to synthetic fertilizers, and there is the concern that they cannot provide nutrients quickly enough to satisfy plant needs. However, there is new research that suggests the leaching rate of K^+ from potassium feldspar is faster than previously thought at the temporal and spatial scales that plant roots experience nutrient uptake.

Compost, biochar, and glauconite (greensand) are soil amendments that contribute some nutrients to the soil but are better served as ways of improving soil health year after year.

- **Compost:** Compost is created from decomposed organic matter and only has around 14 percent of the potassium content as KCl, depending on the source material. It has the advantage of containing little to no chlorides (again depending on the source material used), but markedly improves soil structure, moisture retention, and microbial activity, rather than acting as a complete replacement for fertilizers.
- **Biochar:** Biochar is a carbon-rich material formed from the thermal decomposition of organic matter (similar to the process that creates charcoal). When applied to soil, it acts as a binding agent, reducing nutrient leaching. This keeps more nutrients in the soil available for uptake by plant roots.
- **Glauconite:** Glauconite is a mineral amendment that releases nutrients slowly over time, providing a steady source rather than high dose fertilizer applications. It also releases framework minerals that can improve soil health. The concern with glauconite is that it does not release nutrients at a high enough rate for crops with high and immediate potassium demands.

Compost, biochar, and glauconite are not effective replacements for synthetic fertilizers but when used year after year, can improve soil health and nutrient retention, which in turn reduces the amount of nutrients that need to be applied by fertilizers.

If alternatives to potassium chloride are not widely used, what else can be done to reduce chloride exports from potash fertilizers?

Aside from replacing KCl with alternative chloride-free fertilizers, the most effective way to reduce chloride inputs into the environment is to minimize excess chloride ions being spread onto fields in the first place, as opposed to trying to remove chloride ions from the soil after they have been applied. Traditional best management practices (BMPs) such as buffer strips or cover crops are expected to be largely ineffective at removing chloride from the soil because chloride is a micronutrient, although they are very effective at nitrogen and phosphorus removal and soil stabilization. Instead, practices like nutrient management plans, soil testing, precision fertilizer application, and use of controlled release fertilizers are more effective in reducing the chloride impacts from potash fertilizers. Nutrient management plans, soil testing, and precision agriculture technologies work together to curate nutrient application specific to plant and field needs. Using these techniques, nutrients can be applied in a field where they are needed and when they are needed, as opposed to uniform application patterns that may over apply nutrients in some areas of the field, and under apply in others. Controlled release fertilizers use slow-release pellets to increase the exposure of nutrients to plant roots, meaning more nutrients go to the plant, rather than running off the fields. These practices reduce the amount of fertilizer that needs to be applied, which minimizes the excess chloride available to be exported into the environment.

What can be done to reduce chloride exports from manure application?

There are no dedicated methods to remove chloride from animal waste, thus, any meaningful reduction of chloride exports from manure to the environment will come from smarter manure applications. There may be methods to reduce the initial amount of chloride present in manure by optimizing the amount of salt animals eat. The primary pathway for chloride into animal waste is through salt additives in animal feed to meet sodium needs. Animal operations could optimize the amount of supplemental salt added to their feed by analyzing the composition of their feed and by testing local water supply for sodium and chloride to account for what animals already receive from their water source for daily intake estimates. By accounting for salt already in animal feed or drinking water, supplemental salt to the animal's diet can be reduced, and thus the amount of chloride present in the animal's waste would also be reduced.

The same methods mentioned for synthetic fertilizer also apply for manure. Nutrient management plans, soil testing, and precision agriculture technologies all guide more efficient manure applications. By applying manure when and where it is needed, over-application is reduced, and so is nutrient runoff. In addition to smarter application practices, manure can be incorporated into the soil during application (as opposed to

being spread on top of the soil). Incorporation into the soil reduces the chance of runoff during storm events and may increase uptake by plant roots.

8.7 INDUSTRIAL FOOD PROCESSING

Industrial food processing in the Region is another source of chloride to the environment, contributing less than one percent of the estimated annual chloride loading presented in TR-65. However, some context is required regarding the annual loading figure for industrial food processing. The analysis from TR-65 includes only 12 industrial facilities out of hundreds in Region and thus only accounted for a small portion of the total chloride contributed from industrial food processing. Therefore, it is likely that more chloride is contributed to the environment by industrial food processing than is currently estimated in TR-65. The predominant sources of chloride include dairy food processing, meat processing, and fruit/vegetable processing. Dairy food production is defined as the transformation of raw milk into products such as milk, yogurt, cheese, butter, whey, etc. Meat processing facilities perform operations such as slaughter of livestock, further processing of raw meat into products, and waste rendering. Fruit and vegetable canning facilities engage in the manufacturing of canned, pickled, and brined fruits and vegetables. The discussion below will evaluate how chlorides enter the waste stream from food processing plants, the inability of typical in-place wastewater treatment processes to remove chloride, and potential alternative chloride removal methods.

How do chlorides enter the waste stream in food processing facilities?

Salt, or sodium chloride, is widely used for industrial food processing. During dairy processing, a sodium chloride brine is used to salt the cheese. Chlorides are also added to the waste stream during water softener recharge using a salt brine solution, from cooling liquors, and any baseline concentration in source water and milk. In meat and poultry processing, high-chloride wastewater can be generated from the hide processing, kosher slaughter, curing, smoking, pickling, and marinating processes, in addition to the water softener recharge and baseline concentration sources. Salts and chlorides are added to the fruit and vegetable canning waste stream during the washing process (baseline concentration in water) and during the can filler stage, where a brine solution is added to the cans. The purpose of this brine solution is to maintain the flavor quality of the product during the canning process.

What typical wastewater treatment processes are in place at food processing facilities, and how capable are they of removing chlorides?

The typical in-place wastewater treatment processes at food processing facilities are similar to those at municipal wastewater treatment plants. At minimum, plants perform pretreatment on their wastewater to remove large debris such as feathers, bones, and large fruit/vegetable chunks before sending wastewater to a downstream public wastewater treatment plant. Some industrial facilities perform further treatment before directly discharging to surface water, sending wastewater to a downstream treatment facility, or land applying waste. Further treatment processes can include primary treatment (removal of smaller particulates), biological treatment (reduction of oxygen demand and nitrogen removal), phosphorus removal, disinfection, and solids handling (further treatment of sludge created in prior steps before land application). These processes are not specifically designed to remove chlorides and thus typically achieve little to no chloride removal from the waste stream.

What options are there for dedicated chloride removal technologies?

Options for dedicated chloride removal/disposal techniques include, but are not limited to brine evaporation ponds, deepwell injection wells, reverse osmosis, and mechanical evaporation systems. While these technologies are all options, they are not all viable in Southeastern Wisconsin. Brine evaporation ponds require a net evaporation climate to be effective, and the humid continental climate of Southeastern Wisconsin is not conducive to net evaporation. In addition, deepwell injection is prohibited in Wisconsin by State statutes. Reverse osmosis uses pressure to force water through a semi-permeable membrane, leaving contaminants behind in a reject-brine, achieving high removal efficiency. Downsides of a reverse osmosis system can include expensive installation and maintenance. Mechanical evaporation systems using forced circulation continuously circulate a high-chloride waste stream through a heat exchanger, removing clean water via steam. Mechanical evaporators can also have high installation and operation/maintenance costs, as well as the possibility of high velocity corrosion of components. Overall, for Southeastern Wisconsin, reverse osmosis and mechanical evaporation represent options for dedicated chloride removal from waste streams.

While reverse osmosis and mechanical evaporation represent the most feasible options for reducing chloride inputs from industrial food processing to the environment in Southeastern Wisconsin (in comparison to deepwell injection and evaporation ponds in), there are still limitations and drawbacks with these techniques. Even though the chloride has been removed from waste stream by the reverse osmosis or mechanical evaporation technology, proper disposal of the high-chloride reject stream remains difficult. Since the reject brine has a high chloride content, it cannot be land applied because that would lead to soil

and water contamination, as well as no net removal of chloride from the environment. Additional options for disposal of the reject brine are off-site hazardous waste transport (expensive and logistically difficult, if waste site is not in close proximity) and sending to a municipal WWTP for additional treatment. As previously discussed, traditional WWTP processes are not designed to remove chloride from the waste stream (again achieving zero net removal of chloride from the environment) and the high-chloride brine might inhibit or kill microorganisms in the activated sludge of the WWTP. Beyond the high installation and maintenance costs of reverse osmosis systems, and the component corrosion potential of mechanical evaporation systems, the issue of disposal of the removed chloride remains. The best path forward for industrial food processing facilities to reduce their chloride input to the environment is to monitor their current chloride content in their waste streams, optimize (and thus reduce) the amount of salt used in their processes, segregate their high-chloride waste streams at the source, begin to invest in dedicated chloride removal techniques, and evaluate better methods for high-chloride brine disposal such as disposal at a waste storage facility with an impervious liner.

8.8 LEGAL AND POLICY CONSIDERATIONS

An important tool for managing chloride pollution can be use of legal and policy options available to decision-makers in the Region which are discussed in detail in SEWRPC TR-67. These include limiting slip-and-fall liability, relying on direct regulatory authority such as the Clean Water Act or corresponding State regulations and municipal ordinances, disseminating relevant information to stakeholders and the public, using alternatives to chloride where feasible, leveraging new policy strategies such as water quality trading, investigating integrated watershed management across jurisdictions, and obtaining economic assistance.

How can contractors reduce salt application without increasing slip-and-fall liability?

As it relates to chloride reduction, fear of slip-and-fall liability is one of the most-cited reasons for overapplication of winter deicers, especially on private property. This concern could be partially alleviated by granting a liability waiver against damages associated with snow and ice conditions to contractors that have earned certification for deicing best management practices. An example of a current slip-and-fall liability protection program is the New Hampshire “Green SnowPro” program. This program includes initial and on-going training courses on winter maintenance best management practices, which include equipment calibration, anti-icing, brine making, pre-wetting with brine, efficient application rate changes, and effective plowing techniques. Upon completion of the course certification examination, certified contractors, as well as property owners who hire certified contractors, receive general protection against damages arising from snow and ice conditions when using best management practices taught in the

training course. Programs similar to the Green SnowPro program in New Hampshire can allow applicators to reduce their salt application rates while still maintaining safe conditions and be protected from slip-and-fall lawsuits.

Can the Clean Water Act be used to protect against chloride pollution?

The Clean Water Act (CWA) prohibits the discharge of any pollutant from a point source to waters of the United States without a permit. Wisconsin has enacted water quality standards for chloride pursuant to the CWA.⁶ Additionally, chloride limitations are included in many permits issued pursuant to the CWA, and for Wisconsin dischargers that are unable to meet these requirements, chloride variances may be granted which mandate source reduction measures. When chloride discharge levels are too high, the Wisconsin Department of Natural Resources (WDNR) may issue variances to individual facilities. The variance includes a site-specific plan and goals to reduce pollution. Another option under the CWA is the preparation of a Total Maximum Daily Load (TMDL) for chloride discharges to a particular receiving water, which is the amount of chloride a waterbody can receive and still meet the water quality standard. Under the CWA, states must develop and adopt criteria that are sufficient to protect the designated uses of waters within their borders. Those waters that do not meet the standards are classified as “impaired” and are reported to the US Environmental Protection Agency (EPA), at which point a TMDL is developed to meet the water quality criteria and necessary chloride reductions are added to discharge permits. While these measures can be successful in controlling chloride from point source dischargers, it can be more difficult to address nonpoint sources such as winter deicing materials and fertilizer application.

How can regulation reduce the amount of chloride pollution from public winter maintenance?

The primary way regulation can reduce chloride pollution from winter maintenance is to develop regulatory requirements for salt management plans (SMP) for municipalities or counties to provide requirements for materials specifications, funding framework for equipment upgrades, winter maintenance training, materials handling and disposal, and snow storage areas. Requirements of SMPs should include practices that reduce chloride pollution while maintaining roadway safety.

An SMP can stipulate the type(s) of deicing and anti-icing materials to be used. Brine or pre-wetted salt can be required to be used rather than rock salt, which can result in a reduction in chloride pollution. As part of

⁶ The acute toxicity criterion sets a daily chloride maximum concentration of 757 mg/l that is not to be exceeded more than once in a three-year period. The chronic toxicity criterion sets a four-day average of the daily maximum concentration of 395 mg/l that is not to be exceeded more than once in a three-year period.

a transition from the application of rock salt to the application of brine, a funding framework can be outlined for conversion of the fleet from salting to brining. This can include federal grants or a budget line item(s) for the initial capital investment, however the cost savings from reduced salt use may pay for the initial investment over time.

An SMP can also include training materials for equipment calibration, recommended application rates for various deicing and anti-icing material for different roadway and weather conditions, and equipment operation guidelines. Equipment can be required to be calibrated throughout the season to ensure the recommended application rates are being used. Guidance can be included for reduction of truck speed during application to less than thirty-five miles per hour, which can reduce bounce and scatter of salt into unintended areas.

Also included in an SMP can be requirements for storage and disposal of salt. The *Wisconsin Administrative Code* sets out the storage requirements for highway salt, which requires salt storage facilities to be constructed in a manner which prevents runoff into waterbodies. Storage facilities are required to have a roof that prevents precipitation from contacting road salt piles and wind from transporting salt into surface or groundwaters. An SMP can include similar requirements for county and municipal salt storage facilities. The plan can also include stipulations for disposal of excess municipal/county salt, requiring it to be returned to the salt storage facility rather than being intentionally over applied. Similarly, communities could implement a salt “take-back” or buy back program for private applicators and residents to prevent overapplication at the end of the winter or improper salt storage.

Lastly, the SMP can include guidance on designating proper areas for snow storage placement and snow fence locations. Snow piles should not be placed near receiving waters or on permeable soils that can easily transport chloride to groundwater. Rather, snow should be placed in areas where meltwater discharges into less vulnerable areas. Snow fences can be a relatively inexpensive method for keeping snow off roads and reducing salt use. Municipalities could develop programs that provide incentives to farmers and landowners to install snow fences at recommended locations.

Can municipal ordinances address proper residential winter maintenance?

Many cities have ordinances that address proper winter maintenance in residential areas. These areas mainly include public sidewalks and other public pavement areas for which private homeowners are responsible for snow and ice removal. These ordinances usually require residents to properly remove snow and ice from public sidewalks within a certain amount of time following a winter weather event. Requirements can also

be included for limiting the amount of salt used to only that which is necessary to treat the snow and ice to allow for safe passage for pedestrians. Sweeping up excess salt after the snow and ice have melted can also be required in order to reduce salt accumulation on sidewalks. A fine or penalty structure may also be included for failure to comply with the ordinance.

What are the policy options to reduce the amount of chloride produced by water softeners?

Several policy options are available to reduce chloride produced from water softening. State plumbing codes could require higher-efficiency or on-demand softeners when a water softening system is replaced or installed. Likewise, at the residential level, a municipality could evaluate the potential for a rebate program to install high-efficiency softeners or residents could be encouraged to purchase higher efficiency or on-demand softeners at the time of sale. Similarly, a municipality can offer residential water softener calibration services either free of charge or at a discounted price to homeowners.

Regulations could also be established that oversee facility operators and salt disposal. At municipal water facilities, operators could utilize blending of softened water with unsoftened water to reduce the amount of in-home water softening required. At commercial facilities with water softeners, operators could evaluate the potential for local brine reuse as a deicer instead of discharging to the wastewater treatment plant. Finally, industrial dischargers to wastewater treatment facilities could establish salt conservation practices such as cleaning up spilled salt for reuse or disposal rather than flushing it down the floor drain.

As watersheds extend beyond jurisdictional boundaries, how can adjacent communities align their water resources management policies?

Integrated watershed management is an approach to managing water resources at the watershed level that spans geopolitical and agency boundaries. This approach is intended to address the interlinked nature of water resources and requires coordination and cooperation among involved communities and entities. An integrated management approach offers the benefit of policy alignment among entities across the entire watershed rather than a patchwork of various policies and approaches. This can make management efforts more effective and yield a higher level of environmental quality. Despite its benefits, an integrated watershed management approach can have certain difficulties, chief among them being potential lack of funding and reluctance to participate. Nonetheless, an integrated approach can be useful for chloride management, particularly with respect to nonpoint sources.

Are there funding options to assist with chloride reduction projects?

National programs exist that can provide funding for various projects that could provide chloride reduction.

These programs include:

- The *Great Lakes Restoration Initiative* is a program to restore the environmental quality of Great Lakes ecosystems, which contains funding for nonpoint pollution reduction, which could include chloride.
- *Clean Water Act Funding* provides funds for a wide variety of water infrastructure projects, including nonpoint source pollution management plans, which could address nonpoint chloride pollution.
- *The Safe Drinking Water State Revolving Loan Fund* provides financial assistance to help improve drinking water resources. Projects have been funded that can reduce chloride discharges, such as new facilities that use reverse osmosis treatment for water softening, which can reduce salt use from in-home water softening.
- *WisDOT Funding* can assist in funding high-capacity brine makers and obtaining brining trucks to offset the initial investment in brine making and ease the transition from rock salt use to brining.

Planning Report No. 57

A CHLORIDE IMPACT STUDY FOR SOUTHEASTERN WISCONSIN

Chapter 8

OPTIONS TO MANAGE CHLORIDE TO THE ENVIRONMENT

TABLES

Table 8.1
Attributes of Various Winter Maintenance Materials

Chemical	Lowest Practical Working Temperature	Corrosion Risk	Environmental Risks	Cost	Primary Best Use
Chloride Salts					
Sodium Chloride (NaCl)	15°F	High	High: Chloride accumulation in surface and groundwater is toxic to aquatic life; degrades soil quality; toxic to roadside vegetation; potential to irritate pet paws.	Low	Most cost-effective deicing option for general roads, highways, parking lots.
Magnesium Chloride (MgCl ₂)	-10°F	Moderate	High: Chloride accumulation in surface and groundwater is toxic to aquatic life; degrades soil quality; toxic to roadside vegetation; potential to irritate pet paws; can contribute to metal mobility.	Medium	Used in colder weather; Usually in liquid form for on-board pre-wetting (at the spinner); High speed direct liquid application deicing blends in cold conditions.
Calcium Chloride (CaCl ₂)	-20°F	High	High: Chloride accumulation in surface and groundwater is toxic to aquatic life; degrades soil quality; toxic to roadside vegetation; potential to irritate pet paws.	High	Typically used in emergency response for deep freeze conditions; Critical intersections, hills, or curves requiring immediate traction.
Acetates					
Potassium Acetate (KAc)	-15°F	Very Low ^a	Moderate: Can lead to high Biological Oxygen Demand (BOD) in small stagnant waterbodies which may lead to temporary oxygen depletion during decomposition, which can stress or suffocate aquatic life, although this is typically less than sugar-heavy agricultural by-products; generally nontoxic.	Very High	Almost exclusively used in liquid form; Anti-icing for critical infrastructure because it is non-corrosive; Works in extremely low temperatures; Often applied by Fixed Automated Spray Technology (FAST) systems on bridge decks.
Calcium Magnesium Acetate (CMA)	20°F	Very Low ^a	Moderate: Can lead to high Biological Oxygen Demand (BOD) in small stagnant waterbodies which may lead to temporary oxygen depletion during decomposition, which can stress or suffocate aquatic life, although this is typically less than sugar-heavy agricultural by-products; generally nontoxic.	Very High	Corrosion-sensitive bridges/structures; Safer for new concrete (less than 2 years old); Zones near drinking water reservoirs or sensitive wetlands.
Sodium Acetate (NaAc)	0°F	Very Low ^a	Moderate: Can lead to high Biological Oxygen Demand (BOD) in small stagnant waterbodies which may lead to temporary oxygen depletion during decomposition, which can stress or suffocate aquatic life, although this is typically less than sugar-heavy agricultural by-products; generally nontoxic.	Very High	Fast acting; Sometimes used on high value infrastructure and parking garages.

Table continued on next page.

Table 8.1 (Continued)

Chemical	Lowest Practical Working Temperature	Corrosion Risk	Environmental Risks	Cost	Primary Best Use
Formates					
Potassium Formate (CHO ₂ K)	-20°F	Very Low ^a	Moderate/Low: Could raise BOD and cause temporary oxygen depletion in surface water during decomposition which can stress or suffocate aquatic life, although this is typically less than acetates and much less than sugar-heavy agricultural by-products; generally nontoxic.	Very High	Aggressive low-temperature deicer; Because they are biodegradable and less corrosive than chloride salts, they are appealing for use on airport runways and high-value bridge decks near sensitive waterways; Rarely used for municipal winter maintenance of streets or highways because of prohibitive cost.
Sodium Formate (CHO ₂ Na)	0° to 15°F	Very Low ^a	Moderate/Low: Could raise BOD and cause temporary oxygen depletion in surface water during decomposition which can stress or suffocate aquatic life, although this is typically less than acetates and much less than sugar-heavy agricultural by-products; generally nontoxic.	Very High	Low temperature deicer and considered fast acting. Because formates are biodegradable, have a lower BOD profile than bio-based additives or acetates, and are less corrosive than chloride salts, they are appealing for use on airport runways and high-value bridge decks near sensitive waterways; Rarely used for municipal winter maintenance of streets or highways because of prohibitive cost.
Bio-Based Additives					
Beet Juice	0°F to 5°F ^b	Inhibits Corrosion ^c	Moderate: Decomposition in waterways consumes dissolved oxygen and increases BOD which can stress or suffocate aquatic life; Products may contain phosphorus and nitrogen, leading to nutrient loading and potential algae blooms.	Medium	Typically blended with chloride products to significantly reduce corrosion on fleet equipment and infrastructure; Can lower practical working temperature of brine blend.
Corn-Based Additives	0°F to 5°F ^b	Inhibits Corrosion ^c	Moderate: Decomposition in waterways consumes dissolved oxygen and increases BOD which can stress or suffocate aquatic life; Products may contain phosphorus and nitrogen, leading to nutrient loading and potential algae blooms.	Medium	Typically blended with chloride products to significantly reduce corrosion on fleet equipment and infrastructure; Can lower practical working temperature of brine blend.
Cheese-Brine	-5°F ^b	Moderate ^d	Moderate: Decomposition in waterways consumes dissolved oxygen and increases BOD which can stress or suffocate aquatic life; Products may contain phosphorus and nitrogen, leading to nutrient loading and potential algae blooms; Product contains high chloride levels.	Very Low or Free	Typically blended with chloride products; Can lower practical working temperature of brine blend; Because the cheese brine contains sodium chloride, deicing cost savings may be realized if product is obtained for no cost.

Table continued on next page.

Table 8.1 (Continued)

Chemical	Lowest Practical Working Temperature	Corrosion Risk	Environmental Risks	Cost	Primary Best Use
Nitrogen Products					
Urea ($\text{CO}(\text{NH}_2)_2$)	20°F	Low/Moderate	High: Has the highest BOD profile of any material summarized here; Nutrient loading (ammonia and nitrate) of surface waters could lead to rapid algal blooms.	High	Historically used at airports and specialized roadway applications for its lower corrosive attributes, however use has declined dramatically due to environmental concerns.
Glycol					
Propylene Glycol ($\text{C}_3\text{H}_8\text{O}_2$)	-20°F	Very Low	High: Has a very high BOD profile which can stress or suffocate aquatic life; However it does not persist in waterways and is generally considered not to be directly toxic to vegetation and aquatic life.	Very High	Most commonly associated with aircraft deicing; Rarely used in road maintenance other than to pre-treat high-value bridges with Fixed Automated Spray Technology (FAST) systems.
Abrasives					
Sand	Effective at any temperature	Non-Corrosive	Moderate/High: Sand will accumulate in storm drainage systems (ditches, sewers, manholes) and smother habitats in riverbeds that are critical to fish and invertebrates.	Very Low (purchase) High (cleanup)	Used strictly for traction; Effective at extremely low temperatures when deicing chemicals fail; Useful for hills, sharp curves, and intersections to prevent sliding; Used on low-volume roads or gravel roads where snowpack is commonly left on the road surface.

^a Acetates and formates are generally non-corrosive to structural steel (rebar and bridge beams). However, these agents are known to cause corrosion on galvanized steel (guardrails, light poles, etc.).

^b Unlike engineered chemicals that have fixed chemical properties, bio-based additives are biological mixtures. Therefore, they do not have a single, fixed practical working temperature. Their performance depends entirely on the blend ratio that is mixed with the salt brine.

^c While on their own, these bio-based additives inhibit corrosion, they are very seldomly used alone. Typically, these are mixed with salt brine, so the mixture should not be considered non-corrosive, but rather less corrosive.

^d While cheese brine contains chlorides which can lead to corrosion, it also typically contains organic solids (whey/proteins) that can provide a mild corrosion inhibiting effect, making it slightly less corrosive than pure rock salt brine.

Source: Clear Roads, Minnesota Pollution Control Agency, and SEWRPC

Table 8.2
Recommended Road and Highway Deicing Application Rates Based on Road Temperature

Road Temperature	Pre-Wetting (lbs/lane mile)^{a, b}	Dry Rock Salt (lbs/lane mile)	Shake and Bake Liquid Component (gal/lane mile)	Shake and Bake Granular Component (lbs/lane mile)
30°F+	100-150	150-200	40+	100
25-29°F	150-200	200-250	40+	150
20-24°F	200-250	250-300	40+	150
15-19°F	250-300	300-350	40+	200
5-14°F	250-350 ^c	Not Recommended	50 ^c	200

Note: Operators should mechanically remove as much snow and ice as possible before applying deicing chemicals. It is important to note that the application rates provided in this table are a general guide that can often change as new technologies and methods emerge. In addition, recommended application rates are often adjusted based on specific detailed weather conditions. For more detailed recommended application rates, see the Clear Roads reports "Material Application Methodologies Guidebook" and "Application Rate Guidance for Salt Brine Blends for Direct Liquid Application and Ant-Icing."

^a The application weights shown here only represent the weight of the dry rock salt in pounds per lane mile.

^b Salt brine or brine blend application for pre-wetting rock salt is recommended to be 15+ gallons per ton of dry rock salt.

^c A straight sodium chloride brine should not be used for pre-wetting operations when pavement temperatures are below 15°F. Instead, a salt brine blend of 80/20 with organic agent or 90/10 with calcium chloride is recommended. Examples of organic agents used for this 80/20 brine blend include commercial products Geomelt or BeetHeet. However, other organic agents may also be appropriate.

Source: Wisconsin Salt Wise and SEWRPC

Table 8.3
Summary of Considerations for Central Softening Technologies

Consideration	Lime	Reverse Osmosis	Electrodialysis Reversal	Ion-Exchange	Distillation
Produces chloride in waste flow				X	
Feasible on smaller scales		X	X	X	X
Feasible at individual wellheads		X	X		X
Effective at removing chloride		X	X	X	X
Waste is suitable for disposal at WWTP ^a		X	X		X
May require construction of conveyance system for waste flow to WWTP		X	X		X
May require WWTP hydraulic capacity to be increased		X	X		X
Pretreatment required ^b	X	X	X		
Waste may have beneficial reuse	X			X	
Requires waste volume reduction	X			X	
Increases amount of source water pumped		X	X		
Source water quality and level of hardness impact efficiency ^c	X	X	X	X	

^a Assuming only hardness removal and no presence of any substances prohibited by the WWTP in the source water.

^b Pretreatment would be needed to achieve optimal removal efficiency if organic materials or other solids are sufficiently present in the raw source water.

^c Presence of other constituents in the source water or higher levels of hardness can either reduce efficiency or increase operation cost to achieve the desired efficiency.

Source: SEWRPC

Table 8.4
Summary of Considerations for Private Water Conditioning and Softening Technologies

Consideration	Technology							
	Traditional	Alternate			Emerging			
	Ion Exchange	Portable Exchange	Reverse Osmosis	Nanofiltration	Template Assisted Crystallization	Magnetic Treatment	Electrically Induced Precipitation	Capacitive Deionization
Produces chloride onsite	X							
Produces sodium in finished water	X	X						
Uses salt onsite	X							
Suitable for locations with brine discharge restrictions		X	X	X	X	X	X	X
Removes contaminants other than hardness ^a			X	X				X
Produces wastewater and requires a drain connection	X		X	X			X	X
Suitable for locations with water use restrictions		X			X	X		
Uses energy/requires an electrical connection	X		X	X		X	X	X
Suitable as a whole-house water softener/conditioner	X	X			X	X	X	X
Can remove existing scale					X		X	

^a Not including manganese or ferrous iron.

Source: SEWRPC

Planning Report No. 57

A CHLORIDE IMPACT STUDY FOR SOUTHEASTERN WISCONSIN

Chapter 8

OPTIONS TO MANAGE CHLORIDE TO THE ENVIRONMENT

FIGURES

Figure 8.1
Typical Road Weather Information
System (RWIS) in Wisconsin



Source: Lead Creek Technologies and WisDOT

Figure 8.2
Truck-Mounted Mobile Infrared Pavement Temperature Sensor and In-Cab Display

Sensors are typically mounted on side mirror



In-cab display



Source: City of Oak Creek Public Works Department, Town of Linn Highway Department, and SEWRPC

Figure 8.3
State-of-the-Art Cutting Edges for Public
Winter Road Maintenance

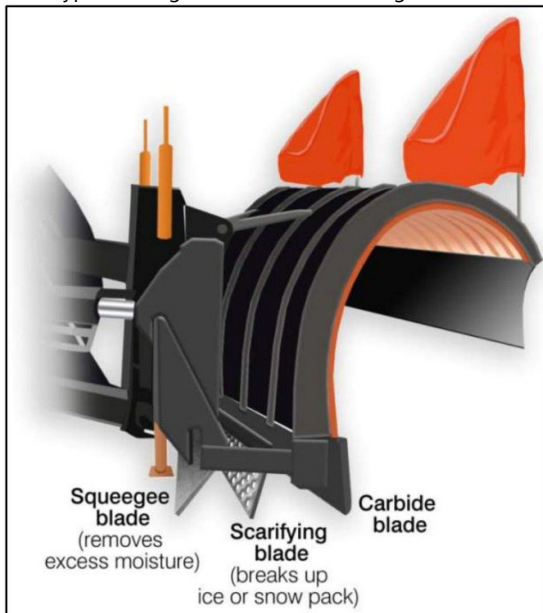
Sectional Blades on a Front-Mounted Plow



Live-Edge Blades on a Front-Mounted Plow



Prototype Drawing of a Multi-Blade Configuration



Source: Town of Linn Highway Department, Colvoy Equipment, Iowa
Department of Transportation, and Clear Roads

Figure 8.4
Common and Advanced Spinner Assemblies

Standard Centerfugal Spinner Mounted on Tailgate Spreader Standard Centerfugal Spinner with Skirt



Directional Spinner Mounted on V-Box Spreader



Zero Velocity Spreader



Source: Illinois DOT, Iowa DOT, Cliffside Body Corp, Henderson Products, Inc., and Clear Roads

Figure 8.5
Examples of Pre-Wetted Salt Spreaders



Source: City of Lake Geneva Public Works Department, City of Oak Creek Public Works Department, and Cliffside Body Corp

Figure 8.6
Anti-Icing and Direct Liquid Application
Rigs and Tankers



Source: City of Lake Geneva Public Works Department, City of Oak Creek Public Works Department, and SEWRPC

Figure 8.7
Salt Brine Makers

Shop-Built Manual-Batch Brine Maker



Fully Automated Salt Brine Making System



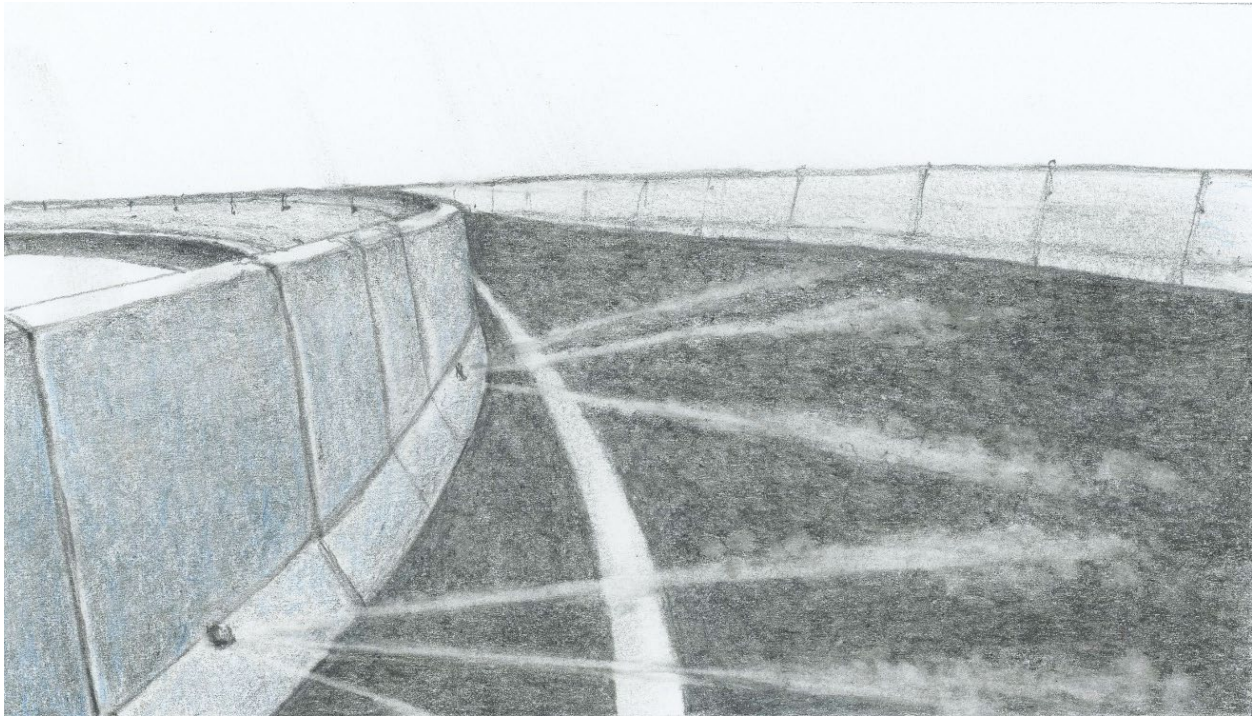
Source: Town of Linn Highway Department, City of Oak Creek Public Works Department, and Henderson Products, Inc.

Figure 8.8
In-Cab Electronic Controller System



Source: City of Lake Geneva Public Works Department

Figure 8.9
Fixed Automated Spray Technology (FAST) System for Brine Application



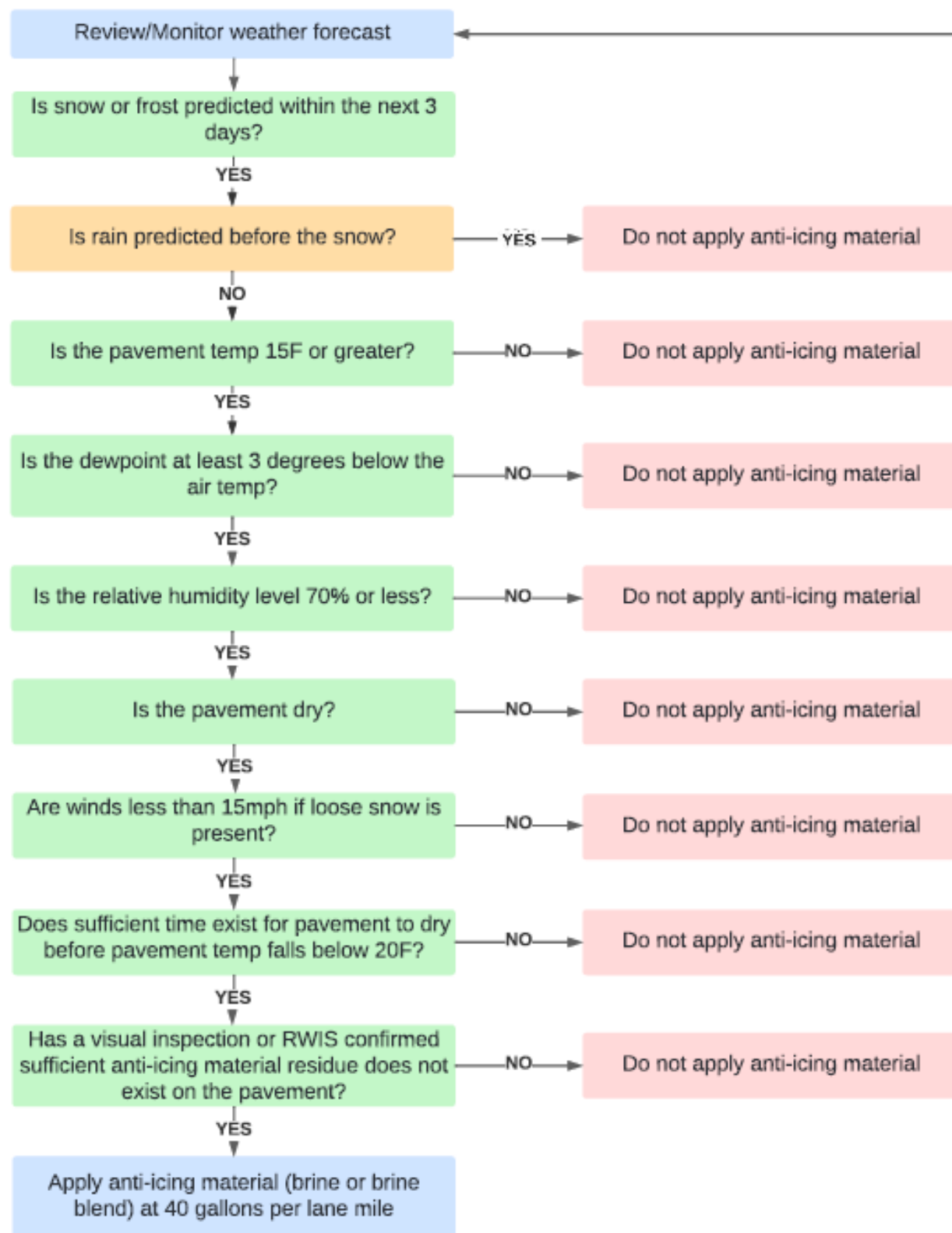
Source: SEWRPC

Figure 8.10
Anti-Icing Brine Applied in a Wet/Dry Striped Pattern



Source: Town of Linn Highway Department

Figure 8.11
Anti-Icing Application Decision Flow Chart



Source: Created by American Public Works Association and reproduced by Wisconsin Salt Wise

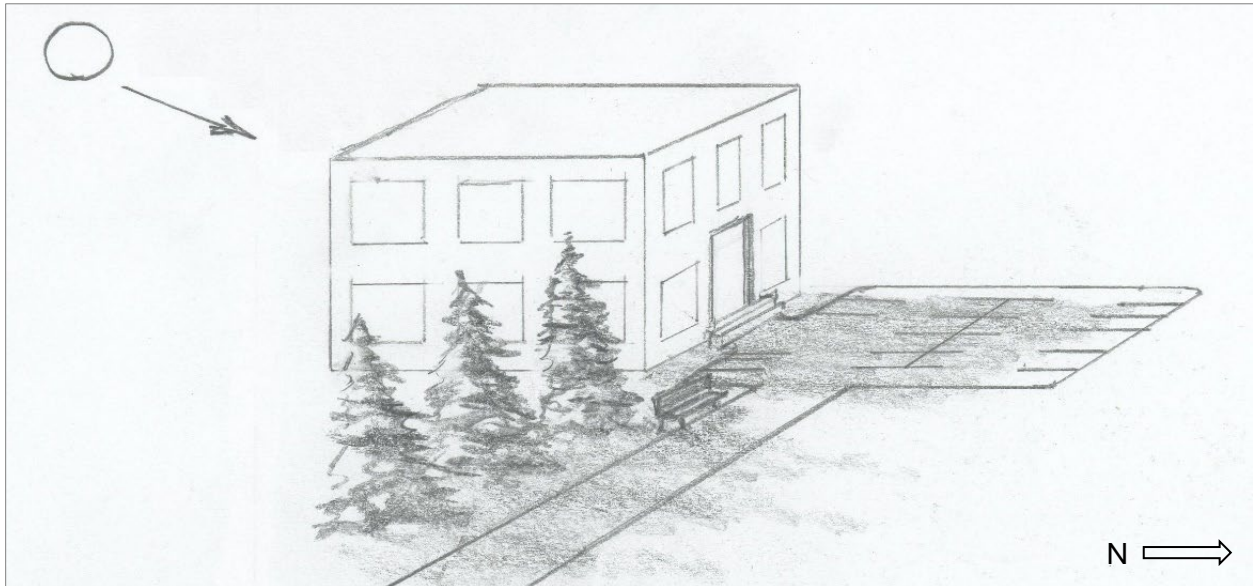
Figure 8.12
Recommended Salt Application on
Driveways and Sidewalks



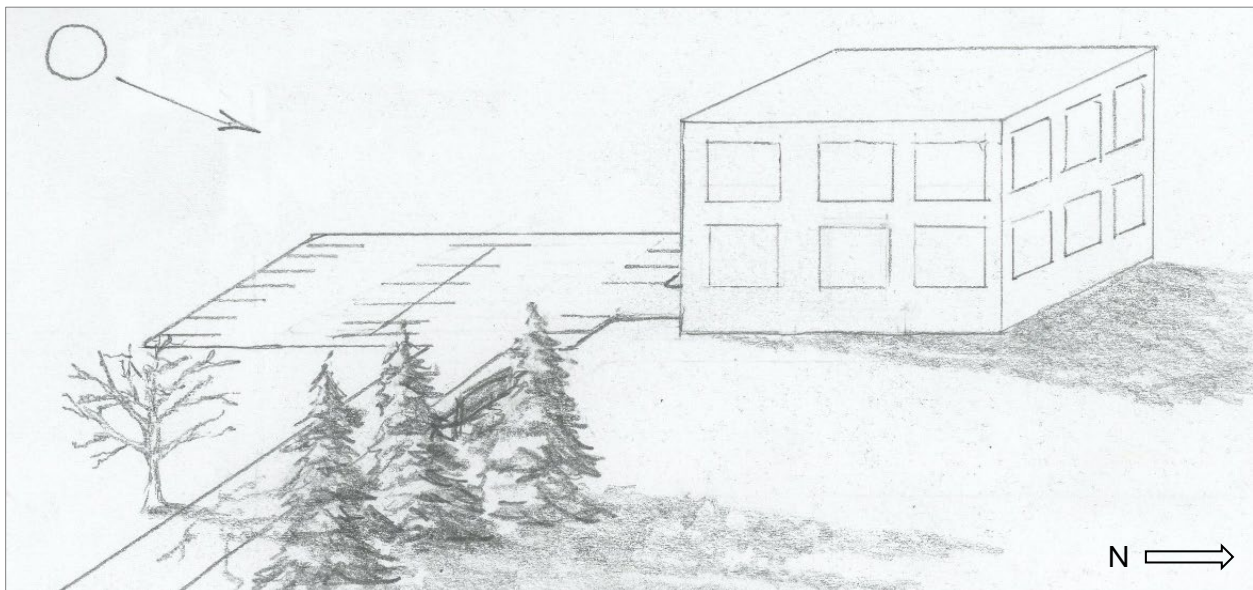
Source: City of Madison, Wisconsin

Figure 8.13
Site Layout to Maximize Melting from Sun Exposure

High Salt Design

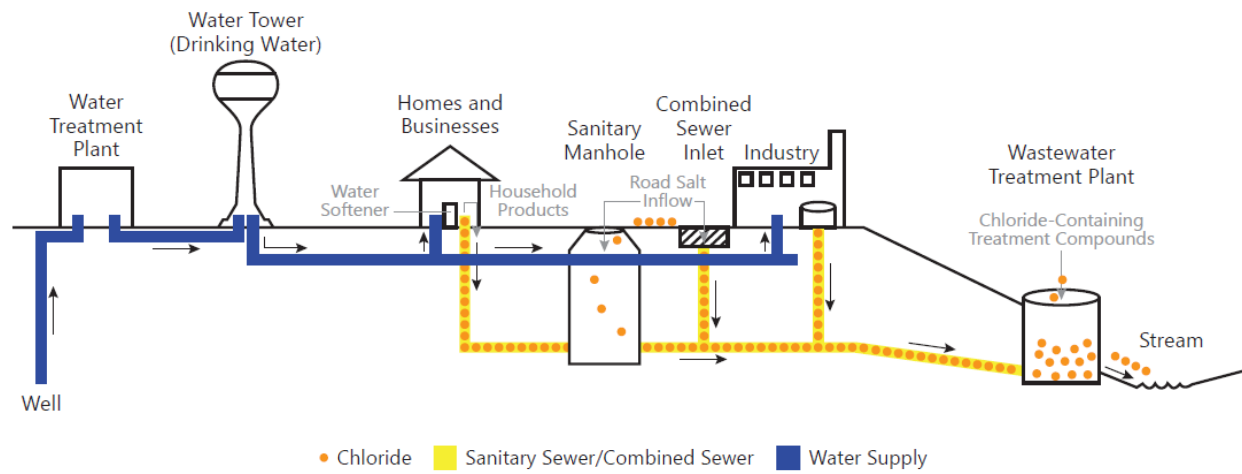


Low Salt Design



Source: SEWRPC

Figure 8.14
Chloride Sources to Wastewater Treatment Plants



Notes:

1. The chloride represented in the diagram is not drawn to scale with respect to comparing the magnitude of chloride produced from one source to another.
2. The diagram represents a community with a combined sewer. For communities with separate storm and sanitary sewers, road salt inflow into the sanitary sewer system only occurs via infiltration and inflow through defects at manholes and in the pipes.
3. Background chloride concentrations may exist in the water supply and is not represented in the figure.

Source: SEWRPC

Figure 8.15
Ion Exchange Water Softener Use and Regeneration Processes



Source: SEWRPC