10.0 – SALT USE ON PRIVATE ROADS, PARKING LOTS AND WALKWAYS

This is one in a series of Syntheses of Best Practices related to the effective management of road salt in winter maintenance operations. This Synthesis is provided as advice for preparing Salt Management Plans. The Synthesis is not intended to be used prescriptively but is to be used in concert with the legislation, manuals, directives and procedures of relevant jurisdictions and individual organizations. Syntheses of Best Practices have been produced on:

1. Salt Management Plans
2. Training
3. Road, Bridge and Facility Design
4. Drainage
5. Pavements and Salt Management
6. Vegetation Management
7. Design and Operation of Maintenance Yards
8. Snow Storage and Disposal
9. Winter Maintenance Equipment and Technologies
10. Salt Use on Private Roads, Parking Lots and Walkways
11. Successes in Road Salt Management: Case Studies

For more detailed information, please refer to TAC's Salt Management Guide - 2013.

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Environment Canada **Environnement Canada**

CONTENTS

INTRODUCTION

Over 5 million tonnes of road salts are used in Canada annually to control snow and ice on roads, parking lots and sidewalks. Considerable effort and resources are expended each winter to clear snow and ice to keep these areas safe and passable. While in many cases salt use is necessary to ensure public safety, an Environment Canada scientific assessment found that high releases of road salts are harming the environment, and has recommended that the environmental risks associated with road salts be managed.

Environment Canada's objective is to limit salt use to the absolute minimum required to maintain safety through the promotion and adoption of best management practices such as described in this document.

This document has been developed as a resource to help site owners and manager and salt users learn about best salt management practices that can be used in snow and ice control operations so that safety can be maintained and salt use can be reduced.

Experience has shown that equivalent or safer conditions can be achieved with limited salt through the use of proper winter maintenance practices. This guide provides information on common practices and important principles of salt use that should be understood by site owners/managers and contractors. This will help ensure that salt is used effectively and efficiently. The topics covered by this document include practices related to:

- Planning your attack
- Site drainage management
- Mechanical removal
- Materials (solid and liquid)
- Application rates
- Decision-making tools
- Equipment and calibration
- Record keeping
- Material storage and handling
- Snow storage and disposal
- Salt responsible contracts
- Training

Nothing in this document should be interpreted as promoting salt reduction measures over safety. A Glossary of Terms used in this document is also provided. The words in the text that are contained in the glossary are highlighted.

Better salt management practices not only benefit the environment, but can also result in cost savings to salt users. Numerous studies[1] show that salt use reductions can be achieved through better salt management practices discussed in this document.

SAFETY CAN BE ACHIEVED WITH LESS SALT

Winter maintenance efforts are solely directed at creating safer winter conditions for people visiting, living or working at sites or using travel ways such as roads, parking lots, sidewalks and pathways.

The amount of de-icing chemical used is often a "judgement call" based on an opinion of how much is enough to prevent accidents and associated injury and lawsuits. This "judgement call" is executed by a range of people. It may be the winter maintenance supervisors with many years of experience and training or the new equipment operators in the field for their first winter. Clearly, all people involved in the "salt call" require the appropriate training and awareness in order to make the right call.

While it is important to use the right amount of snow and ice control materials for given conditions, the fear of lawsuits can lead to excessive salt use "to be on the safe side".

There is clear evidence that safe conditions and often safer conditions can be achieved with limited salt by:

- Being proactive with snow and ice control (it requires much less salt to prevent the snow/pavement bond or ice than to break the bond or melt the ice after it has formed).
- Recognising that salt is used in conjunction with mechanical removal.
- Using variable applications rates (you do not need the same amount of salt to treat a frost or light

[1] See Environment Canada Road Salts Case Studies at http://www.ec.gc.ca/sels-salts/default.asp?lang=En&n=CBE1C6ED-1

snowfall as you do for heavy snow and colder temperatures).

- Using liquid de-icers, either by themselves or in combination with rock salt (application rates can be reduced when using liquid enhance materials).
- Taking into consideration traffic action which augments the action of the de-icer.

Insurance companies are also recognizing that proactive winter maintenance practices can improve safety and may entitle organisations employing best practices to discounted premium rates.

The techniques discussed in the document are important in managing winter maintenance risk.

ENVIRONMENTAL / INFRASTRUCTURE EFFECTS OF SALT

Excessive use of road salts can harm the environment and infrastructure. Road salts are corrosive and may cause deterioration of roadway surfaces, concrete structures, vehicles and other indoor and outdoor surfaces. Salt impacted runoff and spray can damage or kill nearby grass, trees, crops or other vegetation.

Many municipalities are noticing elevated sodium and chloride levels in their drinking water. In Ontario, road salt has been identified as one of the threats to drinking water under the Clean Water Act.

Dissolved salt in snowmelt also drains to water systems where elevated chloride concentrations can be harmful to fish and other aquatic life.

Because of concerns about the large quantities of chlorides being released to the environment and the resultant environmental impacts, road salts underwent a comprehensive five-year scientific assessment[2] under the Canadian Environmental Protection Act, 1999. The study concluded that high releases of road salts can cause adverse impacts on the environment and that these impacts need to be managed.

Efforts are underway nationally to reduce these negative effects through improved salt management.

[2] Road Salts Priority Substances List Assessment Report, December 2001 (http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/psl2-lsp2/road_salt_sels_voirie/index-eng.php)

BENEFITS OF PROACTIVE WINTER MAINTENANCE AND SALT MANAGEMENT

Well managed snow and ice control practices, which include effective salt management, have a number of benefits for site owners, managers, users and contractors. These include:

- Creating safer conditions by using proactive strategies and therefore less risk to workers and the public and less risk of law suits;
- Lowering winter maintenance costs for materials, equipment and labour;
- Reducing corrosion damage to structures (buildings, sidewalks, parking garages, utilities etc.) because less salt is used;
- Reducing salt tracked indoors, thus reducing damage to carpets and floors, and therefore clean-up costs;
- Minimizing salt damage to vegetation surrounding roads, parking lots and walkways, resulting in lower restoration costs;
- Improving environmental aesthetics and lowering salt-related environmental damage and risk; and
- Overall, providing more efficient and effective service.

PRINCIPLES OF SALT USE

It is important to understand the science behind snow and ice control and the chemicals that are used. The benefits of proactive winter maintenance practices, including salt reduction, depends on understanding and effectively applying various principles This section briefly discusses the key principles. More detailed discussions can be found in the Salt Management Guide and the other Syntheses of Best Practices.

When Will Slippery Conditions Occur?

There are two key ingredients for the formation of ice-related slippery conditions - moisture and pavement temperatures below the freeze point of the moisture (usually 0 °C)[3].

[3] The freeze point of water is lowered below 0 °C by adding a freeze point depressant such as salt.

Moisture comes in several forms including: precipitation (rain or snow), dew and onsite drainage.

A lot of the icing conditions occur as a result of poorly managed drainage. Where water from roof drainage, off site or melting snow flows onto paved surfaces where it can freeze. The resulting ice creates an ongoing risk of slips and falls and consequently a high demand for salt.

Dew will form on a surface (e.g. pavement) when the surface temperature is at the dew point temperature. If the pavement temperature is below freezing at the same time, frost will form.

Studies have shown that pavement temperatures are frequently warmer than air temperatures, particularly during the day. This means that there are many times when the pavement temperatures will be above freezing even when air temperatures are well below freezing. It is important therefore to know the pavement temperatures when deciding on proper snow and ice control tactics. Pavement temperatures can be measured using infrared thermometers.

Tracking weather conditions is also essential to planning snow and ice control tactics. Local weather forecasts can help to anticipate whether or not snow is likely to accumulate to the point that slippery conditions will occur. The speed that the storm is moving is an important consideration. Fast moving storms are harder for weather forecasters to predict and there is a greater potential for the forecast to be wrong with respect to timing and accumulation. Slower moving storms on the other hand are easier to predict with respect to timing and accumulations. Radar images are readily available on the Internet and can help decision-makers to better understand the timing of a storm.

Why Do We Use Salt?

Salt is applied to prevent ice from forming and to facilitate mechanical snow removal.

Generally the goal is not to melt all the snow that will accumulate. In the case of a large snowfall this would require an enormous amount of salt.

When ice forms or snow becomes packed onto a frozen pavement surface, it will bind to the surface making it very difficult to remove. As traffic increases, this snow pack can turn to ice. Salt is applied to prevent or break the formation of the ice-to-pavement bond to allow it to be removed mechanically (i.e. plowed or shovelled off).

How Does Salt Work?

Salt is a freeze point depressant. This means that when salt is dissolved in water it lowers the temperature at which the resultant solution will freeze. As the concentration of salt in the solution increases the freeze point decreases. This is illustrated in the Phase Diagram shown in Figure 1.

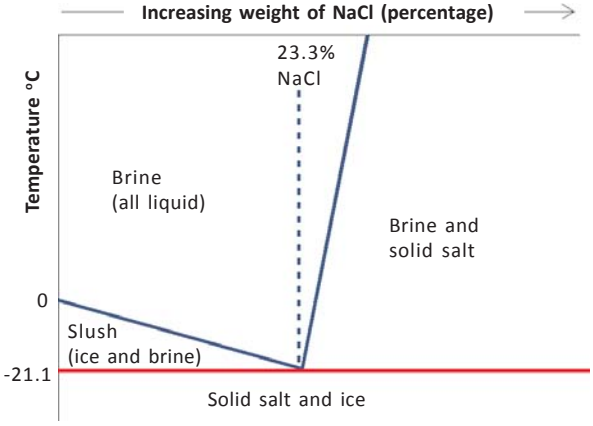

Figure 1 - Generalize Phase Diagram of Salt (NaCl) and Water

For Sodium Chloride (NaCl) the temperature at which a solution of salt and water will freeze decreases as the concentration increases until the concentration reaches 23.3%. This lowest point in a Phase Diagram is known as the Eutectic Point. A sodium chloride solution at this concentration will not freeze until the temperature drops below –21 °C.

As a solution is cooled, the water component of the solution begins to freeze. Since ice can hold very little salt, the salt that is present is confined to the remaining liquid phase, which becomes more concentrated and tends to be at the ice/pavement interface. This is represented by the area below the curve and to the left of the Eutectic Point. At this point, there is a mixture of ice/snow and concentrated brine, which appears as slush on the road. As the concentration of the remain-

ing liquid phase increases, its freezing point is lowered. The salt solution remains in equilibrium until the temperature is lowered to the point at which the solubility limit is reached and the salt precipitates out of solution. The result is a mixture of recrystallized salt, water and brine. This is represented on the Phase Diagram by the area below the curve and to the right of the Eutectic Point.

There are similar phase diagrams for all freeze point depressants. When we place dry salt onto a paved surface, we want the salt to dissolve and form a solution of salt and water, which is called brine. It is this brine that in fact melts the frost, snow or ice. Remember, our goal is to create a layer of brine at the pavement surface to prevent the snow pack or ice from bonding to the pavement so it can be mechanically removed. Different melting agents have different eutectic and working temperatures. The selection of materials has been helped by a recent study documented in NCHRP Report 577 entitled "Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts". This report provides guidance on selection of a material based on an evaluation of their cost, performance, and impacts on the environment and infrastructure. The project also produced a purchase specification, a quality assurance monitoring plan and a computer-based material decision tool that is available free of charge at http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=883.

The tool allows the user to weight the selection criteria based on local priorities and conditions. The most significant factors considered when selecting snow and ice control materials were determined to be cost, performance, effects on the environment, and effects on infrastructure.

The tool helps in assessing the relative ranking of different materials given the evaluation criteria and weighting assigned by the user.

Residual salt (fine salt left on the pavement when the surface dries after a storm or when liquid anti-icing dries) on pavement will go into solution more quickly when it comes into contact with water or snow thus preventing frost or the snow/pavement bond. This is the principle behind anti-icing.

One must be careful of refreeze when working with any freeze point depressant such as salt. As more snow and ice melts, more water goes into the solution and the concentration of salt in the resultant mixture decreases. This dilution lowers the salt concentrations and raises the temperature at which the solution will freeze. Referring back to the phase diagram for NaCl, a 15% brine solution will freeze at –10° C. If snow melts and dilutes the brine concentration by half, then the resultant 7.5% brine will freeze at around –5 °C. This is one reason why it is important to remove as much snow from the pavement surface as possible before adding salt. Similarly, if the pavement temperature drops below the freeze point of the brine, ice will form.

Contractors and owners need to ensure that the people making salt use decisions understand how salt works.

Melting agents are discussed later in this Guide under "Materials".

Use of Liquids

It takes time for large solid salt grains to go into solution once they have been placed onto the pavement – particularly at lower pavement temperatures. It is very difficult to create a high concentration of brine in this way. This is one reason why sodium chloride is usually not used below –10° C. Two ways snowfighters are addressing this problem is by spreading straight liquid salt (brine) directly onto the pavement (liquid anti-icing) or adding brine to the solid salt (pre-wetting and pre-treating) to help the salt dissolve more quickly.

HOW MUCH SALT IS ENOUGH?

Although there is a lot of experience with documenting application rates for roads, this is not the case for parking lots and walkways. At the time of writing this document there is a study being carried out at the University of Waterloo to help answer the question of how much salt is enough for parking lots. The results will not be available for at least a year.

There are many factors that affect the answer to the question "How Much Is Enough?".

A major factor is the amount of frost, snow or ice that needs to be removed. In the case of frost, relatively little salt is required to melt the frost or prevent it from forming in the first place. Different snow and pavement temperature conditions will dictate different application rates.

A Guideline published by the DuPage River Salt Creek Watersheds[4] sets out the following rates:

PARKING LOT SPREADING RATES		
Pavement Temperature Range	Pounds / 1000 Ft^2	Kg / 100 m^2
Greater than – 1 °C	3	1.5
– 4 °C to – 1 °C	5	2.4
– 7 °C to – 4 °C	6	2.9
– 9 °C to – 7 °C	7	3.4
– 15 °C to – 9 °C	8	3.9

Although this source talks about using salt down to -15 °C, it is generally considered to be ineffective below -10 °C.

Whatever the right rates are, snowfighting organizations should employ multiple rates to deal with the variety of conditions they will encounter.

When deciding on the rate one should consider the following:

- Moist snow will activate salt more quickly than dry snow since there is more moisture available to begin the brine-making process.
- Warmer pavement temperatures will activate salt more quickly than colder temperatures since there is more heat available to activate the brine-making process.
- More salt is needed at colder temperatures because it is activated more slowly.
- Fine salt will activate more quickly since it has greater surface area and therefore will dissolve faster. A gradation that has fine salt and courser salt will activate more quickly and have longer staying power.
- Roads that have traffic to mix the salt and snow will clear more quickly than parking lots, sidewalks and paths where traffic action is more limited.
- Property owners and contractors should determine and agree on the application rates for different conditions.

BEST PRACTICES

There are several factors affecting effective application of snow and ice control materials. One should consider the 4 R's of snow and ice control.

- **Right Material** - The right material will depend upon the conditions being treated. In situations where the pavement temperature is extremely cold, chemicals with lower working temperatures or sand/salt mixtures may be warranted.
- **Right Amount** – The right amount of material is dependent upon the type of condition being treated, the amount of residual chemical on the pavement surface, the expected pavement temperature and the amount of precipitation that is expected.
- **Right Place** – Precise placement of materials is important to keeping it in the right place to do the job rather than wasted to the environment. Proper material placement requires the right equipment and skilled operators.
- **Right Time** – The timing of salt placement is important to minimizing waste and maximizing chemical effectiveness. There are times when the pavement temperature is, and is expected to remain above freezing and therefore may not warrant salt application. Proactive anti-icing is key to achieving safer conditions quickly with less salt.

The following subsections discuss tactics, material, equipment and decision-making tools to help achieve the 4 R's of snow and ice control.

Planning Your Attack

The sequence by which snow and ice control techniques are applied will affect the amount of salt used. The following discusses some operational considerations to be taken into account:

- Weather forecasts and radar images should be monitored to determine when frost, freezing rain and snow could be expected in order to predict the need to treat an area.

[4] www.drscw.org

- The process by which dew and frost form on pavements must be understood.
- Both the owner and contractor should understand the size and the characteristics of the site. Both should estimate and agree on how much chemical will be required for each application. A lower application rate, acceptable for frost events or spot applications, should also be determined. Benchmarking should be done separately for both mechanical spreading and hand spreading. This means identifying how much slat would be needed at different pre-determined application rates for each area serviced. Once the benchmark amounts are determined, they can be periodically compared to actual usage and refined with experience.
- Trends in pavement temperatures should be monitored using infrared thermometers and compared with the dew point temperature to determine if frost-forming conditions will potentially exist.
- Trends in pavement temperatures also should be monitored to assess when pavement temperatures are above freezing and freeze point depressants are not required, and when pavement temperatures are below the effective working temperature of the chemical being used.
- The presence of residual chemical on the pavement surface should be monitored to determine if additional application of a freeze point depressant is required. If there is sufficient residual to handle the anticipated event then no salt or a light application may be appropriate.
- Freeze point depressants like salt should be applied in advance of, or at the start of a storm to prevent the formation of a bond.
- Snow should be plowed from the treatment area prior to the application of a freeze point depressant to minimize the amount of material needed, and the potential for dilution and refreeze.
- Freeze point depressants should be applied after plowing only when pavement temperatures are below freezing and the remaining snow/ice that could not be removed by plowing presents a hazard.
- Only enough material should be applied to do the job.
- Owners can reduce salt use and risk by closing low traffic, under used or high-risk areas during storm events.

Site Drainage Management

Poor site drainage is the situation that cause the highest risk for slips and falls and that can be reduced or eliminated. Areas prone to icing because of poor drainage require a high level of effort, attention and salt use to fight and on-going icing battle. It is better to eliminate the problem structurally, before winter.

It is instructive to tour a site on or after a rainy day to get the best understanding of where icing conditions will occur. During these tours identify and document (including pictures) the following:

- Locations where roof drainage falls directly onto or outlets from downspouts onto paved areas. Fix these by installing roof gutters and directing downspouts away from paved areas.
- Puddles due to irregular pavement that will freeze in the winter. Fix these locations by improving the crossfall of the pavement during off-season.
- Overland site drainage that flows onto paved areas. Fix these locations by installing interceptor ditches or regarding.
- Poorly located and installed utility access chambers can create a depression that holds water. These should be located away from travel ways and should be designed and installed to avoid ponding.

Meltwater from stockpiles snow is the second greatest source of water causing icing problems and high salt use. This issue can be addressed by:

- Designing parking lots so that catchbasins are located near snow storage areas.
- In snowfighting operations, placing snow on the low side of paved areas so that meltwater drains away from the pavement.
- Plowing snow to the back side of curbs so that meltwater is directed away from the pavement.

Ponded water can also be removed by power brooms or leaf blowers before it has had a chance to freeze.

Mechanical Removal

Accumulated snow and ice or slush can be controlled mechanically by removing it with plows mounted on trucks, motor graders or loaders. Snow blowers and power brooms are also used in some areas. Mechanical removal of ice and snow is preferable to melting it all.

Parking lots and sidewalks should be plowed / shovelled to remove as much snow as possible before a melting agent is applied. This minimizes the amount of melter needed to achieve final bare pavement conditions.

There is a variety of equipment available. See the section on Equipment and Calibration in this document.

Materials

Snow and ice control materials fall into two main categories:

1. Freeze point depressants – used to melt frost, snow and ice and to prevent or break the bond between the ice and the pavement; and
2. Abrasives – used to improve traction on potentially slippery surfaces.

In the section on "How Salt Works" we learned that it is the brine that is created from dissolving a freeze point depressant in water that melts the snow and ice or prevents its formation.

A variety of freeze point depressants are available. These include road salts (i.e. sodium chloride, calcium chloride, magnesium chloride and potassium chloride), acetates (i.e. calcium magnesium acetate, potassium acetate, sodium acetate) and engineered products composed of agricultural products and one or more of the previously listed materials.

These melting agents can either be solid or liquid. They will also have different working temperatures, and may have some additional characteristics that affect when, where and how they are used.

Each melting agent has different working temperatures and eutectic temperatures. The following table provides these temperatures for standard melting agents.

Name	Formula	Lowest Working Temp	Eutectic Temperature & Concentration
Sodium chloride (rock salt, halite)	NaCl	-10 °C	- 21 °C (23.3%)
Calcium chloride	$CaCl_2$	-29 °C	-51 °C (30%)
Magnesium chloride	$MgCl_2$	-15 °C	-33.6 °C (21.6%)
Potassium chloride	KCl	-7 °C	-11 °C (20%)
Calcium magnesium acetate (CMA)($CaCO_3$)	Calcium carbonate Magnesium carbonate ($MgCO_3$) Acetic acid (CH_3COOH)	-9 °C	-27 °C (32.5%)
Potassium acetate	CH_3COOK	-26 °C	-60 °C (49%)

Each material also has different costs and environmental implications associated with it. Some alternatives are less harmful to the environment and/or less corrosive to vehicles and infrastructure. The suppliers of these products should be consulted for specific information.

Applying solid salt has the advantage of ensuring that there is a supply of salt to go into solution as more moisture is added through melting of snow or ice. One disadvantage is that it takes time for solid melting agents to form brine, particularly at lower pavement temperatures. In the real world, it is unlikely that the brine will reach a sufficiently high concentration to provide the lowest freeze point depression. Consequently it is important to consider the effective working temperature of the melting agent.

By applying liquid rather than solid salt, it is possible to speed up the melting action. Liquid anti-icing involves applying a liquid de-icing agent directly to the pavement. This is usually done onto dry pavement in advance of a winter event in order to minimize dilution

that can occur when applied to wet pavement. This technique uses considerably less salt than traditional use of rock salt.

The liquid eventually dries on the pavement leaving a chemical residual that is ready to go to work once it comes into contact with moisture – either from a frosting or a snow event. In most cases the frost or snow/pavement bond never forms.

Applying a concentrated liquid anti-icing product has the advantage of providing instant melting capabilities, which can reduce slippery conditions more quickly. As well, because the concentration is at its optimum level, the effective working concentration is immediately achieved.

One caution about liquid anti-icing is that it does not have a ready supply of solid salt to replenish the brine solution as it gets diluted by moisture. This can lead to refreeze. It is therefore important to use this technique in the right conditions.

A disadvantage is that there is not a continual supply of solid chemical present to maintain the concentration. Therefore, the brine will dilute with increased moisture making it susceptible to refreeze.

Liquid anti-icing can be applied to dry pavement in advance of a storm or frost and will be present to begin melting when the frosting condition or snow arrives. However, it is **not** recommended in advance of freezing rain or sleet. Within minutes, the precipitation will dilute the anti-icing liquid to a point it is no longer effective.

In the case of pre-wetting and pre-treating salt with a liquid, the melting action of the rock salt is kick started and works more quickly. Again less salt is needed because of this more rapid action.

Pre-wetting salt involves the application of a concentrated liquid anti-icing product to solid salt either in the chute or at the spinner of the spreader. The liquid increases the speed with which the salt begins to work while ensuring that there is solid salt present to slow the rate of dilution and the potential for refreeze. It is common practice among road authorities to reduce the dry salt rate when pre-wetting. The amount of reduction is related to the amount and type of liquid being added. It is common to achieve a 20% reduction or more with high levels of pre-wetting.

Pre-treating stockpiles is a technique being used by many snowfighters. This technique involves mixing a liquid into the stockpiled solid material (e.g. abrasive or salt) to help the solid stick to the pavement surface and accelerate the melting process. Pre-treating has the advantage over pre-wetting of not requiring the same level of investment in infrastructure (i.e. chemical storage tanks) and equipment (i.e. on-board tanks and pumps). It provides an excellent way for any contractor to obtain the benefits of liquid enhanced solid de-icers without having to change their equipment. As with pre-wetting, the application rate can be reduced when using pre-treated salt.

Abrasives (e.g. sand, gravel, chips) are usually applied where a freeze point depressant is not desirable, either because the cost of a freeze point depressant is not warranted, or the pavement temperature is too cold for the product to work. Abrasives are applied when rapid traction is needed such as on ice or snow pack. These abrasives will usually be mixed with a small amount of salt to prevent the material from freezing in the storage pile or the spreader. The amount of salt should not exceed 3-5% by volume – enough to keep the pile from freezing provided the mixture is uniform. Whether mixing indoors or outdoors, a pug mill or some other mechanical method should be used to achieve a homogeneous mix. This achieves a better mix and avoids the need to "sweeten" the mix throughout the winter.

Application Rates

In an earlier section of this document we discussed the question of **How Much Salt Is Enough**. Work continues on answering this important question.

It is important however that snowfighters know how much they are actually putting down and relate actual performance to this amount and site conditions. It is also important to understand that rates should be adjusted for the conditions based on pavement temperature and precipitation type and amount.

Many snowfighters have 3 or more rates in their toolbox.

At relatively warm pavement temperatures and with frost or light snow less melting agent is needed to create safe conditions. At colder temperatures and/or with heavier snow falls, more melting agent will be

needed. As well, when there is residual chemical on the pavement less needs to be applied.

Organizations should therefore have clearly defined and well understood application rates that can be adjusted to suit the conditions that will be encountered.

Decision-support

Snowfighters are operating in a dynamic environment and are called upon to make decisions often with limited information and/or changing conditions. The following provides some guidance on tools that are available to assist in making snow and ice control decisions:

- Localized weather forecasts are essential to provide information on the nature, timing and duration of winter storms.
- Weather forecasts can provide information on precipitation, wind, relative humidity and dew point, however, pavement temperatures must be known.
- Pavement temperature trends can be determined using infrared thermometers[5]
- Value-added forecasts that provide more refined location specific details can be purchased from a weather service.
- Some weather providers can also supply pavement condition forecasts if they have access to pavement temperatures.
- Internet-based radar images can provide information on where a storm is in relationship to the area being serviced. Decision-makers can determine when a storm is likely to arrive or end.

Knowing site-specific information will also help in making timely decisions. Before the start of a snowfighting season information should be gathered on each site being maintained. This information should include:

- The size of each treatment area (parking lot, sidewalk, pathway etc.). This will help in determining how much melting agent will be required given different application rates.
- Special service areas (e.g. handicapped parking, loading docks, emergency access, fire hydrants) that may need unique treatment strategies and their treatment plan.
- Problem areas such as areas prone to icing because of poor drainage or snowdrifting.
- Snow storage sites that will ensure that meltwater drains away from paved areas.
- Shaded areas that will be prone to icing first or melting last.

Equipment & Calibration

Placement of the right amount of material in the right place requires proper equipment. To minimize salt use, as much snow as possible should be mechanically removed. Proper snow removal significantly reduces the amount of chemical needed to keep an area ice-free. It is important to choose plows designed to leave as little snow as possible behind after plowing.

Solid materials are applied using vehicle-mounted, walk-behind or handheld spreaders.

Continuous uncontrolled spreading can be wasteful. Spreaders that can be set to meter out the right amount of material for the conditions and that can be turned on and off from the truck cab help the operator to place only the right amount of material that is needed.

Liquid anti-icing products are applied with tankers, spray vehicles and portable sprayers.

The following considerations should be taken into account with respect to equipment:

- The owner/manager and contractor should ensure that sufficient equipment and staff are available to properly plow snow and apply material. It is not a best practice to quickly "burn off snow" with chemicals to avoid more time consuming plowing. Response time will also dictate the amount of equipment needed.
- Ensure that plowing equipment can reach all areas required and that the blade is appropriate and in

[5] Note: experience with some infrared thermometers has shown that the time needed for the sensor to adjust and give accurate readings (acclimatization time) increases significantly with colder temperatures (reportedly up to 5 hours when temperatures are at or below -17°C).

good shape to remove the maximum amount of snow and ice.

- Spreaders should allow the operator to target material application so that materials are confined to the treatment area and not lost to adjacent areas.
- Operators should be able to control the spreader so that the amount of material being applied can be increased, decreased or stopped when appropriate.
- Combination plows and spreaders are efficient for removing snow and spreading materials at the same time.
- Drop spreaders rather than broadcast spreaders should be used on walkways to increase the amount of material retained on the walkway to work. This will also help to limit salt damage to adjacent vegetated areas and buildings.
- Broadcast spreaders should be used on parking lots to provide for rapid coverage since traffic cannot be relied on to distribute the salt.
- All spreaders must be calibrated to ensure that desired spread rates are achieved and that the amount of material being placed can be documented. The spreader should be calibrated using the manufactures' instructions or by spreading a known amount of salt on a known area.
- Each spreader unit should be thoroughly inspected and the mechanical spreader checked to ensure the spreading rate is correct.
- Pre-wetting kits (saddle tanks, pumps and spray nozzles) should be added to salt spreaders to improve the reaction time of the salt.
- On-board pre-wetting units should be designed such that a plumbing failure will not result in release of the entire contents of the tanks.
- Dry salt should be replaced with pre-treated salt to improve performance.
- Spray trucks can be used to apply liquid anti-icing to walkways (using a hose and wand) and roads and parking areas (using a truck-mounted spray bar).
- The wide-spread availability of GPS technology and handheld computing devices has revolutionized data gathering and record keeping. Inexpensive applications are being produced to bring information to the truck and to make it easier to document snow and ice control activities.

Additional information on equipment can be obtained from TAC's Syntheses of Best Practices Road Salt Management – 9.0 - Winter Maintenance Equipment and Technologies.

Record-keeping

Good, thorough documentation is critical to the successful implementation of best practices, good salt management and managing your liability exposure. Documentation is not limited to just collecting statistical information such as time spent and the amount of material used. It also includes documenting service expectations, describing how the expectations are to be met and having site maps available.

Documentation begins with preparing for the winter season. It should include:

- equipment calibration records
- equipment maintenance records
- employee training records, and
- contractual agreement for each site.

Daily logs should document the following for each site.

- location
- date and time of treatment
- weather conditions (e.g. type of precipitation, air temperature) and pavement conditions (e.g. extent of snow cover, pavement temperature trends), and
- snow removal activities (e.g. plowing, shovelling, blowing, sweeping etc).
- Type and quantity of material placed.
- Snow hauling activities (e.g. amount removed, disposal location).
- Observed risk areas that could not be treated and why they could not be treated.

Material Storage and Handling

Studies have shown that improper storage and handling of salt and sand/salt mixtures are major sources of salt releases to the environment. The following best

practices apply to storage of solid materials (i.e. salt and sand/salt mixtures) and liquids.

- All sand and sand/salt mixtures[6] should be covered to prevent salt from being washed or blown from the pile. Permanent structures are preferred over tarps.
- All salt and sand/salt mixtures should be stored on pads of impermeable asphalt or concrete.
- Site drainage should be directed away from the stored materials to keep the stockpiles as dry as possible. This will prevent salt contamination of site drainage.
- Drainage that is contaminated with salt should be directed to a sewage treatment plant (subject to municipal approval), collected and used for brine production or sent for proper disposal.
- Solid bagged materials should be stored securely and indoors if possible.
- Areas where spreaders are loaded should be paved with impermeable asphalt or concrete.
- Annual inspection and repairs of storage facilities should be carried out prior to the start of each season. On-going inspection of storage structures and tanks should be carried out during the season. The integrity of the structure floor and the apron in front of the salt storage facility should also be inspected for repairs. Cracks in the apron reduces the ability to push spilt salt back into the dome and allows significant infiltration into the ground.
- Spreaders should not be overloaded such that material spills off the vehicle.
- Salt spilled at the storage yard should be collected and returned to the storage facility.
- Spreaders should only be washed at a location where the washwater is properly managed.
- Liquid storage tanks should be designed such that a plumbing failure will not result in release of the contents.
- Liquid storage tanks should be protected from impact from vehicles moving about the yard and be located such that spilled material can be contained and retrieved in the event of a tank or piping failure. Secondary containment should be provided around large liquid storage tanks.
- Some liquids need to be agitated/circulated to prevent separation and settling. The liquid suppliers should be consulted for proper storage procedures.
- Sediment that collects in the bottom of mixing and storage tanks must be cleaned out periodically. The sediments may be mixed with abrasive piles.

Additional information can be obtained from TAC's Syntheses of Best Practices Road Salt Management – 7.0 - Design and Operation of Maintenance Yards.

Snow Storage and Handling

In many cases, plowed snow is stored on remote or unused parts of parking lots or pushed to the edge of the pavement with no adverse effects.

However, in some cases snow must be removed from the site and transported to a disposal site. Snow that has been cleared from parking lots may contain previously applied salt and/or sand. Studies have shown that much of the salt that is contained in plowed snow will discharge from the pile early in the melt process. When this snow needs to be removed and transported to centralized disposal sites, the remaining contaminants are concentrated and then released to the environment when the snow melts. Any debris in the snow will accumulate at the snow disposal site and will need to be cleaned-up in the spring and sent for proper disposal.

Disposal sites that are not properly located and designed can have significant adverse effects on the environment. The following practices should be considered when storing and disposing of snow:

- Owners should ensure that site plans provide for sufficient snow storage to eliminate the need to transport snow off-site.
- Snow should be stored on the low side of paved areas so that melt water drains away from the pavement.
- Snow storage sites should be located such that meltwater that may contain salt is not directed towards salt vulnerable areas.

[6] Studies have shown that up to 50% of the salt in sand/salt mixtures can wash from uncovered stockpiles.

- Melt water should be directed to sediment ponds or sanitary sewers where permitted by the local municipal sewer use by-law.
- Snow should be stored on-site in paved areas where the melt water will not drain into the parking area or form puddles that cause slippery conditions that require extra salting operations to maintain safety.
- Snow should be stored in areas of the parking lot where puddles frequently form to deter vehicles and pedestrians from using these areas.
- Snow should not block drains.
- Salt should never be used to promote rapid melting of stockpiled snow.
- Snow should be stored in areas where the sun will promote rapid melting;
- Snow that is removed from a facility and transported for disposal should be taken to a properly designed snow disposal site. Property owners and contractors should determine the disposal locations prior to the winter.
- Although salt should never be used to promote rapid melting of stockpiled snow, mechanical agitation and spreading can be considered if it would allow the melt water to enter surface waters at a point in time when impacts would be the least (e.g., during high stream flows).
- Snow disposal sites should be designed in accordance with the TAC's Syntheses of Best Practices Road Salt Management – 8.0 - Snow Storage and Disposal Sites.

Salt Responsible Contracts

In addition to the weather, the amount of salt used by a snow and ice management contractor is determined by the terms of his or her contract with the property owner. In some circumstances, the property owner retains control over when ice melting agents are to be applied and in what amounts. In other cases, the owner authorizes the contractor to apply specified ice melting agents at his or her discretion to manage the risk of hazardous conditions.

Property owners will often seek to have the contractor assume all risks associated with any slips and falls. The contractor therefore has a strong incentive to use a lot of salt, especially if the contract compensates the contractor for all the salt he uses, regardless of the amount. This approach can lead to excessive salt use as the contractor looks to avoid claims.

A preferred contract structure uses fixed price for service. In these types of contracts, the contractor is paid a fixed amount for the season or for each visit to the site.

One worry that the two parties have with fixed price contracts is that it is impossible to predict the severity of the winter. The contractor is concerned that the winter will be worse than he anticipated when preparing his bid price and that he will lose money – possibly going bankrupt. On the other hand the property owner worries that the winter will be lighter than normal and he will pay for services that were not provided.

It is important that both parties enter into the process with the intent of achieving a fair contract for both. This may require off-sets to address the unusual winters. Longer term contracts also help to balance out the winters.

In addition, the following should be considered when developing snow and ice control contracts:

- Contracts should be developed to encourage mechanical removal thereby reducing the amount of salt needed to maintain safe and passable conditions.
- The size of service areas and application rates should be agreed upon.
- Response times and levels of service should be agreed on and documented.
- Property owners and contractors should detail the extent to which the contractor will report on the amount of salt used in order to aid the ongoing improvement in practices.
- Property owners and contractors should consider the use of less harmful ice melting products as an alternative to road salts.
- Contracts should avoid unfair "hold harmless clauses" that make the contractor liable for risks that are beyond his control.

Training

The snowfighting business is changing. New equipment, ice melters and techniques are available and their use to ensure safety and reduce environmental damage is expected. The successful adoption of these new practices requires changes in the way the snowfighting business is carried out. Success also requires acceptance of new approaches by property owners and managers.

Training of property owners, managers, supervisors and operators will help to demonstrate the purpose and value of new procedures and ensures that personnel are competent to carry out their duties.

The Synthesis of Best Practices on Salt Management – 2.0 - Training sets out the learning goals for a training program as well as adult learning principles for people developing a snowfighter training as part of their snow and ice control program.

CONCLUSION

Salt is an important tool in maintaining safe conditions on paved travel ways. However, studies have shown that excessive use of salt can have adverse effects on the environment and infrastructure. Property owners/managers and contractors are expected to use best management practices to ensure that safe conditions are being maintained without compromising the local environment.

GLOSSARY OF TERMS	
Abrasive	A natural material such as sand, gravel and chips; or manufactured material that is placed on a slippery surface to improve traction for walking and driving.
Anti-icing	A proactive snow and ice control practice whereby a pavement surface is treated before a bond can form between frost, snow or ice and the pavement.
Bond	A strong connection that forms between a snowpack and the pavement making mechanical removal difficult. The application of a freeze point depressant to the pavement helps break this bond (see deicing) or prevent the formation of the bond (see anti-icing).
Brine	A solution of water and salt.
$CaCl_2$	Calcium Chloride
Deicing	A reactive snow and ice control strategy of applying a freeze point depressant on top of snow or ice during or after a storm to break an ice/pavement bond that has already formed. It is generally accepted that solid forms of freeze point depressants work better then liquid forms with this strategy.
Dew	Moisture that forms on a surface when water vapour in the air condenses.
Dew Point	The temperature at which water vapour in the air condenses and forms water droplets.
Effective Working Temperature	The lowest temperature that is considered to be appropriate for the use of a freeze point depressant that provides a sufficient likelihood that refreeze will not occur.
Endothermic	A freeze point depressant that requires heat to change from solid to a liquid. The heat is taken from its surroundings lowering the temperature slightly in its vicinity. Sodium Chloride (road salt) is an example of an endothermic freeze point depressant.
Exothermic	A freeze point depressant is exothermic if it gives off heat when it forms a liquid solution. The heat is transferred to its surroundings raising the temperature slightly in its vicinity. Magnesium Chloride and Calcium Chloride are examples of exothermic freeze point depressants.
Engineered Product	A product that is manufactured under controlled conditions to ensure consistent characteristics, quality and performance.
Eutectic Point	The lowest freeze point that can be achieved for a given solution of water and a freeze point depressant. This is the bottom of the “V”-shaped curve on a phase diagram.
Freeze Point	The temperature at which a liquid will change to a solid.
Freeze Point	A material (e.g. salt) that will lower the freeze point of a solution. Used for snow and ice control to either prevent or break the ice/pavement bond that forms on driving and walking surfaces.
Frost	Ice crystals that form when dew condenses on a surface that is below freezing.

GLOSSARY OF TERMS	
Ground Speed Oriented Electronic Depressant	Electronic devices used to control the amount of material that is applied using a truck/ tractor mounted mechanical spreader. The amount of material being applied is automatically adjusted according to the ground speed of the vehicle. This allows for a known, consistent amount of material to be applied regardless of the speed of the vehicle.
Infrared Thermometer (IRT)	A device used to quickly measure pavement temperatures and trends. Comes in both hand held and vehicle mounted (with digital readout in the cab) versions.
Liquid Anti-icing	Liquid anti-icing is a proactive method of snow and ice control in which a concentrated liquid freeze point depressant is sprayed directly on the pavement surface.
MgCl2	Magnesium Chloride
NaCl	Sodium Chloride
Pavement Temperature	The temperature of the surface of a paved area (e.g. parking lots, roads, sidewalks, stairs). The area may be paved with materials such as concrete, asphalt or paving stones.
Phase	The state of a material (i.e. solid, liquid or gas).
Phase Change	A transition from one state to another. For example a change from a solid to a liquid such as melting ice, or solid sodium chloride forming brine.
Phase Diagram	A diagram that relates the freeze point of a solution to the concentration of the solution. It illustrates the phases of a material that exist in a mixture at various temperatures.
Pre-treatment	A technique whereby materials are mixed at the time it is stockpiled. For example a liquid may be added to solid salt as it is stockpiled to enhance its performance when it is placed on a paved surface.
Pre-wetting	A technique whereby a concentrated liquid freeze point depressant is sprayed onto solid salt or sand at the time it is placed onto the pavement surface.
Pugmill	A mechanical mixer
Reaction Time	The time taken for a freeze point depressant to enter into solution and begin melting frost, snow or ice.
Refreeze	The freezing of a solution containing a freeze point depressant resulting from the pavement temperature dropping below the freeze point, or the concentration of the freeze point depressant being diluted resulting in the freeze point rising.
Residual Chemical	Dry freeze point depressant remaining on the pavement surface after all the moisture has evaporated. This residual will dissolve when new moisture is added either as dew, rain or snow. This residual provides some anti-icing capabilities.
Road Salt	Chloride-based freeze point depressants including Sodium Chloride, Calcium Chloride, Magnesium Chloride and Potassium Chloride.

GLOSSARY OF TERMS	
Road Salt Management Plans	A detailed plan of how salt users propose to improve the management of their use of road alt through the introduction of best salt management practices. These plans take into consideration all activities potentially resulting in the release of road salts into the environment, including storage, application of salts on roads and disposal of snow containing road salts.
Saddle Tanks	Small containers (usually plastic) that are attached to spreader truck to transport liquid anti-icing materials for pre-wetting or anti-icing operations.
Salt Vulnerable Areas	Salt vulnerable areas are areas of a receiving environment that may be particularly sensitive to road salts. Additional salt management measures may be required in these areas to ensure environmental protection. Guidance on the identification of vulnerable areas can be found in Annex B of the Code of Practice for the Environmental Management of Road Salts (see Resources).
Sand/Salt Mixtures	Common sand that has been mixed with a freeze point depressant to prevent the sand from freezing while it is being stored. A minimum mix of 3-5% salt by volume is usually sufficient to prevent freezing.
Secondary Containment	Measures to prevent the release of stored liquids in the event of a failure of the primary containment tank. This is usually either a secondary wall around the primary tank (i.e. double walled containers) or an impermeable floor and dyke constructed around the storage tank(s).
TAC	Transportation Association of Canada (www.tac-atc.ca).
Treated	The placement of aggregate or a freeze point depressant to pavement surfaces.

RESOURCES

British Columbia

- Road Salt and Winter Maintenance for British Columbia Municipalities - Best Management Practices to Protect Water Quality Web-site: http://www.env.gov.bc.ca/wat/wq/bmps/roadsalt.html

Environment Canada

- Conducted five-year environmental assessment on road salts and worked with stakeholder working groups to develop the Road Salts Code of Practice and these Best Management Practices for Private Roads, Parking Lots and Sidewalks. Web-site: www.ec.gc.ca/nopp/roadsalt/ Telephone: (819) 997-1640
- Code of Practice for the Environmental Management of Road Salts Web-site: http://www.ec.gc.ca/nopp/roadsalt/cop/en/rs_main.htm
- Road Salts Priority Substances List Assessment Report, December 2001 Web-site: http://www.ec.gc.ca/substances/ese/eng/psap/final/roadsalts.cfm

Landscape Ontario

- Association of landscapers and winter maintenance contractors in Ontario. Web-site: http://www.horttrades.com
- Standard Form Snow Maintenance Contract Web-site: www.horttrades.com/displaynews.php?n=169&categoryID=8

Pacific Northwest Snowfighters Association

- Evaluates and establishes specifications for products used in winter maintenance based on safety, environmental effects, infrastructure protection, cost-effectiveness and performance. Web-site: www.wsdot.wa.gov/partners/pns/

Riversides Stewardship Alliance

- Municipal Low Salt Diet Program works with private parking lot owners and operators in the Greater Toronto Area to raise awareness about the environmental impacts of road salts. Web-site: http://www.riversides.org/websitefiles/riversides_road_salts_report_final.pdf

Salt Institute

- The Salt Institute has an extensive library of information and training materials related to the storage, use and management of road salts. Web-site: www.saltinstitute.org

Snow and Ice Management Association Inc. (SIMA)

- Organization providing a network and resources to the snow and ice industry. Web-site: www.sima.org

Snow Business Magazine Online

- Publication of the Snow and Ice Management Association. Web-site: www.snowbusinessonline.com

Transportation Association of Canada

- National association of federal, provincial and territorial transportation departments, municipalities, private-sector firms with an interest in road and urban transportation issues, academic institutions and other associations. Web-site: www.tac-atc.ca Telephone: (613) 736-1350
- TAC Salt Management Guide, 1999
- Syntheses of Best Practices - Road Salt Management

University of Wisconsin-Madison

- The University of Wisconsin-Madison has developed Best Management Practices for the use of road salts on their campus. Web-site: http://www.ehs.wisc.edu/documents/engit-envcomp-saltusepolicy1999.pdf
- Salt Reduction Status Report Web-site: http://www2.fpm.wisc.edu/campusecology/landscape/salt.htm