1.0 – SALT MANAGEMENT PLANS

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
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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.

INTRODUCTION

Canadians spend over $1 billion annually on winter maintenance to keep roads, walkways and parking lots safe and passable. Deicing is a key part of winter maintenance operations. Road salts (particularly sodium chloride) are the preferred deicing/anti-icing chemicals for maintaining winter safety because of their cost, effectiveness and ease of handling. Road salt (particularly calcium chloride) is also used to control dust on gravel roads and construction sites during dry weather. Excessive use of salt can have environmental impacts. Recognizing their responsibility to the environment, road authorities across Canada have been taking positive actions towards implementing salt best management practices. The Transportation Association of Canada has published a Salt Management Guide and a series of Syntheses of Best Practices to assist organizations as they find ways to more effectively manage their salt use and provide the public with the safe and efficient transportation systems they expect, while minimizing effects on the environment.

The amount of salt used is a function of local service level policies and budgets, the transportation system, snowfighting strategies and technique and weather conditions. Because of the variability of conditions across Canada, salt management initiatives need to be developed and implemented locally by each organization. Transportation organizations should be responsible for developing their own salt management plans. The framework presented here has been developed to support organizations in their pursuit of

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best management practices and the preparation of salt management plans. The framework follows an environment management system (EMS) approach.

A successful Salt Management Plan is based on the following principles:

- It is grounded in policy with guiding principles – set and endorsed at the highest level in the organization.
- It is activity based, with each activity being assessed at the outset against clearly established standards and/or objectives to determine how they can be carried out with minimal environmental impact.
- Deficiencies in current operations are identified and corrective action established and implemented.
- Required actions are documented in policies and procedures and communicated throughout the organization – including contractors hired to deliver snow and ice control.
- Activities are recorded, monitored, audited and reported periodically to assess progress and identify areas for further improvement.
- Gaps between actions and desired outcomes are identified and corrective actions are developed and implemented, with necessary modifications being made to policies and procedures and appropriate training.
- The cycle begins again and continues on an ongoing basis in the spirit of continual improvement.

Figure 1 illustrates the process.

OBJECTIVE OF A SALT MANAGEMENT PLAN

An agency's salt management plan provides the vehicle through which the organization commits to implementing salt best management practices as it fulfills its obligation to provide safe, efficient and cost-effective transportation systems. The Plan should contain best management practices to protect the environment from the negative impacts of road salts. The Plan should include all areas where road salt is used such as roads, sidewalks, parking lots and pathways. The Plan should apply to all winter maintenance personnel – both staff and hired resources/contractors.

COMMITMENT & POLICY

To be effective, the senior management of an agency must commit to developing, implementing and updating its salt management plan. A senior manager who is responsible and accountable for the implementation of the agency's salt management plan should be appointed. Organizations should establish a clear road salt management policy endorsed at the highest level of the organization.

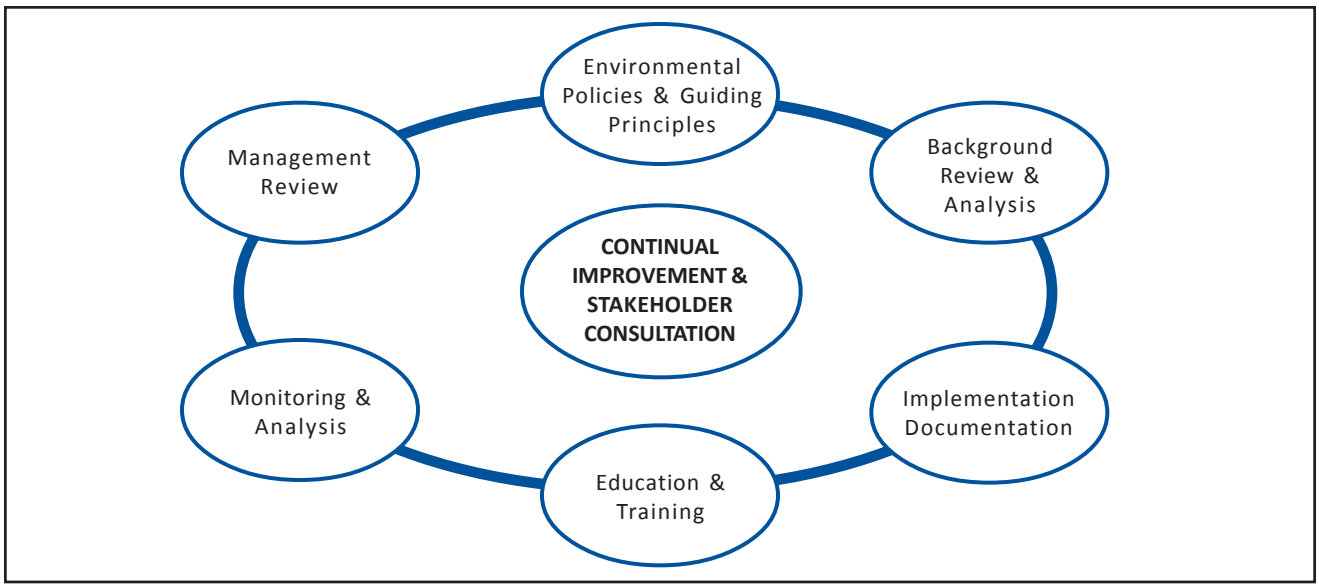

Figure 1 – Salt Management Process

GUIDING PRINCIPLES

The salt management plan should be grounded in the following principles:

a. Safety – In recognition of the importance of effective winter maintenance to the safety of system users and maintenance crews, the development and implementation of the salt management plan will make safety the overriding priority.

b. Environmental protection – In recognition of the adverse effects that excessive use of road salt can have on the environment, the salt management plan will strive to minimize the amount of road salt entering the environment.

c. Continual improvement – Different organization within Canada are at different stages of implementation of salt best management practices (salt BMPs). The cost of moving towards salt BMPs can be high, and changes must be phased in over time. Therefore the salt management plan must recognize that change will be incremental and ongoing.

d. Fiscal responsibility – The phase-in period for the salt management plan will need to be within the financial capabilities of each organization.

e. Efficient transportation systems – In recognition of the importance of efficient transportation to Canada's economy and quality of life, development and implementation of the salt management plan will take into account the effects on transportation efficiency.

f. Accountability – Each organization must be responsible and accountable for developing and implementing its salt management plan.

g. Measurable Progress – Indicators must be developed to ensure that progress on implementing the salt management plans can be tracked and reviewed.

h. Organization-based – The plans must be developed and implemented by each organization rather than be centrally driven.

i. Communication – A communication plan must be developed for communicating internally and externally with key stakeholders.

j. Knowledgeable and Skilled Workforce – The plans must include regular, comprehensive and effective training for managers, supervisors and operators.

FRAMEWORK FOR A SALT MANAGEMENT PLAN

Each organization should develop and implement its own salt management plan incorporating the guiding principles set out in this framework. The plan should be results-oriented and contain the following elements.

1. Salt Management Policy and Objectives

The organization should adopt a salt management policy that commits the organization to measurable improvements in its salt management practices.

The cornerstone of an effective plan is a clear salt management policy enforced by senior management and communicated to the organization.

2. Situational Analysis

An inventory of current practices must be established to form a benchmark against which progress can be measured. It should contain consistent elements to allow the transportation community to measure and track progress towards the goal of managing the amount of road salt being placed into the environment on a national basis. The following elements may be considered in an overall situational analysis:

MATERIAL TYPE, SOURCE AND QUALITY

- Type, amount, sources and quality of snow and ice control materials used (all types including solids, liquids and abrasive mixes)
- The quality of snow and ice control materials can influence their effectiveness. Organizations should have quality specification addressing moisture content, gradation and acceptable impurity levels. It is also important to understand the supply chain for all materials including delivery reliability. Where supply problems may occur, contingency plans should be in place.

SPREADING

- Current application rate for each type of material and pavement condition
- Percentage of fleet with pre-wetting
- Percentage of fleet with liquid only applications
- Percentage of fleet with ground-speed electronic spreader controls
- Use of alternative freeze point depressants
- Number of road weather information systems (RWIS) installations
- Number of other surface temperature measuring devices (hand-held or vehicle mounted)
- Use of dedicated pavement and/or atmospheric forecasting

SALT VULNERABLE AREAS:

- Locations of salt vulnerable areas
- Description of winter maintenance practices in the vicinity of salt vulnerable areas (e.g. alternate treatment)

SAND AND SALT STORAGE SITES:

- Number and capacity of storage sites
- Percentage of salt and sand/salt stored under cover on impermeable pads
- Percentage of facilities with indoor loading
- Percentage of sites with management of salt impacted drainage and vehicle wash water
- Levels of environmental indicators (e.g. chloride levels)
- Percentage of salt in winter sand
- Existence of a good housekeeping policy, and adherence to the policy

SNOW DISPOSAL SITES:

- Number and capacity of snow disposal sites (permanent and/or temporary)
- Levels of environmental indicators (e.g. chloride levels)
- Percentage of disposal sites with water management systems
- Conformance with existing environmental standards for snow disposal sites
- Existence of a good housekeeping policy and adherence to the policy

TRAINING:

- Percentage and frequency of staff receiving training in best salt management practices broken down into categories. (e.g. managers, supervisors and operators) and the topics covered

RESEARCH AND TESTING:

- In the interest of continual improvement, organizations should have a program to identify, test, adapt and adopt new approaches.

3. Documentation

Examples of Possible Salt Vulnerable Areas

- Groundwater recharge areas
- Areas with exposed or shallow water tables with medium to high permeability soils
- Sources of drinking water
- Salt-sensitive vegetative communities
- Salt-sensitive wetlands
- Small ponds & lakes
- Rivers with low flows
- Salt-sensitive agricultural areas
- Salt-sensitive habitats for species at risk

Each organization should have documented policies, procedures and guidelines in the following areas:

- Level of service for each facility/roadway segment
- Salt and sand application rates
- Managed sand and salt storage
- Good housekeeping practices for maintenance yards consistent with TAC's Design and Operation of Road Maintenance Yards Synthesis of Best Practices
- Equipment calibration & re-calibration
- Training
- Snow disposal

- Incorporation of salt management consideration into facility design and construction
- Salt vulnerable areas

The documentation should be aimed at introducing best salt management practices with both in-house and out-sourced operations.

TAC's Salt Management Guide and Syntheses of Best Practices can be used to supplement in-house procedures and other available documentation on best management practices.

4. Proposed Approaches

Salt management plans should have clear tasks, schedules with milestones, budget considerations and assigned responsibilities for implementing salt best management practices. The plans should deal with four areas of concern – general salt use, salt use in salt vulnerable areas, material storage and snow storage and disposal.

The plan can be developed by comparing current practices to best management practices and documenting the gaps. The salt management plan should then focus on closing these gaps. The plan should include pre-season, in-season and post-season actions to be taken to reduce the adverse impacts of road salts. It should also include consideration of equipment, labour, materials and the local climate.

Although not all salt management techniques are applicable to all regions of Canada, the salt management plan should consider strategies for introducing best practices in the four areas of concern.

Where specific technologies are inappropriate, the fact that they were considered and determined to be inappropriate should be explained in the plan. The plans should be results-oriented and measurable with proper commitment of funding and personnel to ensure successful implementation.

The other TAC Syntheses of Best Practices will assist road authorities in assessing these practices.

5. Training

Human behaviour is predicated upon attitudes based on knowledge and experience. Changes in approach require changes in behaviour. A successfully managed salt strategy requires changes in procedures, practices and equipment. Success also requires acceptance of the new approaches by managers, supervisors and operators. Each salt management plan should therefore include a comprehensive education program that demonstrates the value of new procedures and ensures that personnel are competent in delivering the new program. The Training Synthesis of Best Practice provides guidance on developing a salt-management training program.

The public must also be educated on proposed initiatives and on their role in adjusting driver and pedestrian behaviour to environmental conditions. Each organization should have a program for informing the public of winter maintenance practices.

6. Monitoring

Progress on implementation of the salt management plan can only be confirmed by tracking specific indicators and comparing these to the baseline that was benchmarked at the outset of the program.

Each salt management plan should assign responsibility for monitoring and reporting on implementation of the plan. These results should be reported annually to the senior executive responsible for the salt management plan.

The monitoring and record keeping system should document and assess the indicators identified in the situational analysis. Where there are new issues or activities being implemented as part of the salt management plan, new monitoring initiatives may be required. Any changes from the baseline established in the situational analysis need to be analyzed to assess the degree of progress being made. The analysis should also take into account the type of winter experienced to ensure that realistic conclusions are being drawn. For example, an increase in salt use may be due to an unusually severe winter rather than the failure of a plan. Similarly, a reduction in salt use may be due to a milder than normal winter rather than the successful implementation of a plan. Therefore the analysis must be sufficiently in-depth to account for these variances.

Where there are known releases to the environment being monitored (e.g. stormwater outfalls, water intakes, water treatment plants, monitoring wells,

material storage sites or snow disposal sites), then these data should be included in the annual progress report.

7. Management Review

Salt management plans must be dynamic to remain relevant. Too often plans sit on shelves and organizations fail to change. Each year, senior management within each organization should review the results of the previous year's salt management actions to confirm that the plan is achieving the desired results and to adjust the next year's salt management plan to respond to shortcomings and new opportunities. Policies and procedures should be updated prior to the next snow and ice control season and communicated to management and operational personnel.

This review should be integrated into the budgetary process to permit timely acquisitions of new equipment and to identify other funding needs.

Progress on implementation of the salt management plan should be communicated to senior management, local politicians, staff and the public.

CONCLUSION

Effective road salt management requires dedication to adopting, implementing and refining best management practices. This is not an easy task. It will require a long–term vision, senior management support, dedicated resources, adequate and regular training, perseverance, continual innovation and improvement, and an ability to deal with changing organizational culture and attitudes. It cannot be rushed. Public safety must be maintained as best management practices are implemented. Personnel at all levels of the organization will need to be trained and educated so that maximum benefits are realized.

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2.0 – TRAINING

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INTRODUCTION

Human behaviour is predicated upon attitudes, which in turn are based on knowledge and experience. A successful salt management strategy requires changes in procedures, practices and equipment. Success also requires acceptance of the new approaches by managers, supervisors and operators. Any changes in approach will require changes in behaviour. Each organization should therefore include a comprehensive training program that demonstrates the purpose and value of new procedures and ensures that personnel are prepared and competent to carry out their duties.

The purpose of this Synthesis of Best Practices is to provide the reader with information that will assist in assessing, developing and implementing a successful salt management training program.

It is important that managers understand:

1. What should be included in a salt management training program (i.e. the learning goals), and
2. The concepts of adult learning and what methods of training are the most successful in maximizing learning.

This synthesis deals specifically with salt management training and presents both the learning goals and information on adult learning. Although the learning goals are specific to road salt management, the adult learning principles apply to all types of training. Salt management training is part of an organization's overall training program, which includes safety.

RELATIONSHIP TO SALT MANAGEMENT

Training is important to effective salt management because changing salt management practices requires learning new ideas, technology and skills. Equally important is the need to change perceptions about salt use and often to change the value system, which supports the local work ethic.

SALT MANAGEMENT TRAINING

The following presents a standard set of salt management learning goals, followed by a thorough discussion of adult learning principles.

Salt Management Learning Goals

Table 1 presents the salt management learning goals that should be covered in any salt management training program.

Although everyone involved in snow and ice control should have some knowledge of all of the learning goals, the program administrator will need to determine the level of detail that is presented to the managers, supervisors and operators.

It is not likely that all staff will need the same level of training. The amount of training and the level of detail of training that is required by specific personnel will vary. For example, managers may not need to know how to calibrate a spreader or to operate a plow in order to carry out their responsibilities. They should however understand the importance of an effective calibration program and what equipment is needed to optimize salt use.

Operators that do not make salt application decisions may not have to understand much about the decision-support systems.

However, they need to understand salt application policies, the chemistry and application of salt, the environmental issues, good housekeeping practices at maintenance yards, record keeping, equipment operation and relevant decision-support information.

Workers at snow disposal sites that do not operate spreaders will need to be trained in snow disposal site operating procedures, the chemistry of salt, environmental issues and relevant equipment operations, but may not need a detailed understanding of decision-support systems for snow and ice-control.

Table 1 is a tool to help design a training curriculum. It is intended to focus on the basic learning goals. Some organizations may need to undertake additional advanced or specialized training on such topics as material selection; calibration, operation and repair of equipment etc.

Each organization will need to determine the level of detail to which each person is trained in each subject area. The differences in organizational size, weather conditions, available resources, technology, duties and responsibilities will all factor into determining what each organization teaches its staff.

TABLE 1: LEARNING GOALS

SALT MANAGEMENT POLICY
Understand the definition and importance of Level of Service and that the goal is to achieve the prescribed level of service.
Understand the organization's Operating Policies and their application to winter operations.
Understand the organization's Salt Management Policy.
PRINCIPLES OF ICE FORMATION
Understand slippery pavement conditions are a result of water being lowered below its freezing point on the pavement surface.
Understand the sources of moisture on the pavement include dew, rain, snow and drainage.
Understand dew point and what conditions will lead to dew forming on the pavement surface. Also understand what conditions will lead to frost and black ice forming on the pavement surface.
Understand the importance of pavement temperature in making snow and ice control decisions.
Understand why bridges freeze first.
Understand that shaded and low areas can be colder and therefore freeze.
SCIENCE OF FREEZE POINT DEPRESSANTS
Understand the concept of a freeze point depressant.
Understand that chemicals are used to prevent or break the bond between snow and ice and the pavement.
Know the chemical composition of rock salt, and other chemicals used by your organization.
Understand that brine rather than the solid chemical melts the snow and ice.
Understand the phase diagram for the chemicals that are used in your organization.
Understand the criteria for the selection of de-icing chemicals.
Understand the relationship between chemical concentrations and freeze point.
Understand that dry chemicals and pre-wet chemicals take time to work.
Understand the testing requirements and risks associated with the introduction of new snow and ice control chemicals.
Understand the principle of refreeze.
MATERIAL USE
Understand the role of traffic and crossfall of the pavement in forming and distributing brine.
Understand when to windrow and when to spin a pre-wetted solid.
Understand how to treat special areas such as bridges and culverts, super-elevations, intersections, hills (crests, sags, inclines), bus stops, high wind conditions.
Understand that chemical should not be applied to dry pavement where drifting snow is not sticking unless it is necessary as part of storm response strategy.
Understand when to use and not use specific chemicals, taking into account pavement temperatures, forecasts, time of day, humidity, traffic volumes etc.).

TABLE 1: LEARNING GOALS (cont'd)

BRINE PRODUCTION AND USE
Understand the procedure for making snow and ice control liquids from solid chemicals.
Understand the importance of quality control and chemical concentration.
PRE-WETTING/PRE-TREATMENT
Understand the benefits of pre-wetting/pre-treating chemicals and abrasives.
Understand the difference between proactive anti-icing and reactive de-icing.
Understand how dry materials are pre-wetted.
Understand that salt and sand can bounce or be blown off the pavement and this product loss can be reduced by pre-wetting/pre-treating.
DIRECT LIQUID APPLICATION (DLA)
Understand the concepts of direct liquid application.
Understand the benefits of a proactive anti-icing approach.
Understand how to fill spreaders with liquid chemicals.
Understand the health, safety and environmental precautions needed for handling liquid chemicals.
Understand how to measure brine concentrations.
PLOWING
Understand that timing of plowing operations so that chemicals are not plowed off the pavement prematurely.
Understand the importance of timely plowing.
Understand how to efficiently plow each beat/route/site.
ROAD SALT AND THE ENVIRONMENT
Understand that chlorides are mobile in the environment.
Understand that high salt levels can harm public drinking water supplies.
Understand that road salt may attract some wildlife to the pavement, potentially increasing the hazard of animal/vehicle collisions.
Understand that high salt levels can harm adjacent vegetation and agricultural crops.
Understand that high salt levels can harm animals including fish living in streams, wetlands and lakes.
Understand that it is desirable to only use enough chemical to achieve the prescribed level of service.
STORAGE FACILITIES
Understand that all salt and sand/salt blends should be covered and stored on an impermeable pad to minimize salt loss.
Understand that salt spillage is wasteful and can be wasteful and harmful to the environment.
Understand how to handle salt to prevent the wasteful release of salt to the environment.
Understand that timely facility maintenance and repairs are necessary to control salt loss.
Understand the salt cleanup procedures that must be followed.

TABLE 1: LEARNING GOALS (cont'd)

SNOW DISPOSAL
Understand how to manage the snow pile to facilitate melting.
Understand the measures to be used to control nuisance effects (noise, dust, litter).
Understand how to monitor and record chloride, metal, pH, TPH and suspended solids in meltwater discharges.
Understand how the snow disposal system has to be managed to be cost-effective and to reduce environmental and social impacts.
RECORD KEEPING
Understand the importance of timely and accurate records.
Understand the importance of good records for mounting a due diligence defence in the event of a lawsuit.
Understand how to complete your organization's activity/ storm reports.
Understand the importance of recording actions and inactions and the rationale for each.
Understand the importance of knowing your beat/route/site and what it takes to properly maintain it to the prescribed LOS.
SPREADERS
Understand the concept of putting out the right material, in the right amount, at the right time, in the right place and leaving it there long enough to do the job.
Understand how the electronic controller and gate settings on each spreader must be set to achieve the specified application rates.
Understand how to calibrate each spreader to ensure that the right amount of material is being spread.
DRIFT CONTROL
Understand the role and effective placement of snow drift control devices (structural snow fences, snow ridging, agricultural stubble, living snow fences).
WEATHER FORECASTS
Understand the kinds and sources of weather information.
Understand how to read a weather forecast.
Understand what can affect local weather conditions and why weather might vary from one location to another.
Understand lake effect snowfalls where relevant.
Understand that wind chill does not significantly affect absolute pavement temperatures but does affect the rate of cooling.
Understand the concept of Dew Point and Frost Point.
WIND
Understand that a wind of 15 km/hr is needed to drift snow.
Understand how wind changes can signal an approaching or passing storm.

TABLE 1: LEARNING GOALS (cont'd)

WEATHER TRACKING AND DECISION-MAKING
Understand how to monitor weather conditions and anticipate changes.
Understand how to read a radar image and use the information in decision-making.
Understand how weather forecasts can be used in making snow and ice control decisions.
PAVEMENT TEMPERATURES
Understand the importance of considering pavement temperatures when planning and executing operations.
Understand the concept of heat balance and how it can affect pavement temperatures.
Understand how to read a pavement condition forecast.
Understand how pavement condition forecasts and real time information can be used in making snow and ice control decisions
RWIS AND IRTS
Understand the components and purpose of RWIS installations.
Understand how to read and interpret RWIS data.
Understand how to properly mount a truck-mounted IRT so as to avoid erroneous readings.
Understand that IRT's are for measuring temperature trends not exact temperatures.
Understand why odd readings might be obtained (e.g. interference, out of calibration, acclimatization, buried utilities, shading etc).
Understand precautions about handling and using IRT's.
Understand public comments and complaints from an automated telephone weather and traveller information service number (e.g., 511)

When to Train

Organizations should carry out an annual training program for all of their staff to ensure that the appropriate learning goals are taught, reinforced and tested. This should be scheduled for each fall, close enough to the onset of the snow and ice control season to include seasonal and contracted personnel. Throughout the winter season, the level of comprehension of the learning goals and compliance with expected behaviour should be monitored. Periodic refresher sessions should be held to correct unacceptable behaviour and reinforce expectations.

Certification

Some organizations have included testing and a minimum passing grade in their training programs. In the absence of any industry certification standards this type of internal agency certification may be advantageous to those organizations wanting to provide an assurance of minimum competency levels. Any in-house certification should be reviewed with the agency's risk management advisors and labour relations advisors prior to being initiated.

Adult Learning Theory

Managing the learning environment is critical to the success of the knowledge transfer. Being able to recognize the impediments to learning and mitigating their impacts will positively impact the outcome of any training session.

Teaching adult learners new concepts or technologies requires a different approach to teaching than it does for children. The study of how adults learn takes into consideration that adults bring to the learning process their own experience and 'frame of reference' from which they relate and gauge the value of all new things.

Whereas children have little life experience to rely on to challenge new concepts, adults expect to be able to test new concepts against what they already know. Children are dependent on others and adults are largely self- directed. Children expect to have questions answered by outside sources in contrast to adults who expect to be able to answer at least part of their questions from their own experience.

Adult learners gather useful information into their experience bank to which all future learning events will be compared and to which a new concept will be put into context with the other data in their experience bank.

When designing training programs the trainer has to incorporate these concepts of adult learning theory into the lesson plan to successfully provide the knowledge transfer.

Adult Learning Concepts

Although most people learn in the same way, several concepts that take the maturity of the learner into consideration should be recognized:

- Adults are problem-centred rather than content-centred.
- Adults live in a "here and now" world and must perceive the need to learn.
- Adults need to know "What's-In-It-For-Me" (WIIFM).
- Adults are concerned with immediate problems.
- Everyone learns more through active participation.
- Everyone retains more when all senses are used in learning.
- Everyone's perceptions vary so material should be presented in different ways.
- Everyone learns from doing the tasks.
- Everyone needs to integrate new concepts immediately.
- Everyone learns from testing so evaluation should be a mutual activity between learner and trainer.
- Everyone needs to be given feedback on how they are doing throughout the process.

Adult Retention Rates

It is also important when designing a lesson plan to use those teaching methods that generate the highest rates of retention in adult learners. In general terms adults retain:

- 10% of what they read
- 20% of what they hear

- 30% of what they see
- 50% of what they see and hear
- 70% of what they talk over with others
- 80% of what they use and do in real life, and
- 95% of what they teach someone else to do.

Instruction methods should include a combination of verbal and visual aids, group discussion and practical application. Learners who participate in a teaching process where the lesson plan is designed to use these components will experience the greatest rates of retention.

Components of Instruction

The trainer's role in providing the training extends beyond introducing new material and testing for the knowledge transfer. The training session has many elements that the trainer can be expected to manage throughout the session. The elements include the following:

- gain control and attention
- inform learners of expected outcomes
- review known related material
- present new material
- reinforce new learning
- probe for learning transfer
- test for retention
- provide feedback & appraise performance, and
- compare against expected outcomes.

Needs Assessment

Training needs vary among employees. New staff will need the full training program. However determining where the knowledge deficiencies exist for others in the organization is much more complex. There is no one method to collect the information. One approach would be to design a test and have the operators complete it to the best of their abilities. However the analysis of the test may not necessarily reveal the true state of their knowledge. The results could be affected by the individual's comfort level with being examined and the true needs deficiencies can be skewed. The testing might reveal some individuals who know the theoretical, but have a 'practical' deficiency.

One solution is to try to gather information from many sources. It may be possible to collect data from work management software, if available, that can provide reports by individual operators. There may be merit in interviewing the operators and asking them where they think they need additional training. It is also possible to have the supervisor rate each individual's knowledge based on their observed level of performance as a comparison to stated expectations. Each of these will aid in identifying the deficiencies.

There is a caveat to this approach to training however. Certainly it is more efficient to train only those who need to be trained. However, in many work environments, training is viewed as a break from the day-to-day tasks. If only the knowledge deficient is given the time off to be trained, then the operators who know the work will not get the same break. This may result in de-motivating operators who feel they are being penalized for being proficient.

The solution is to train everyone equally or, where possible, involve the proficient in training the deficient.

Training Design

Planning a training session involves three key components:

- Establishing learning objectives
- Identifying the learning components you want to cover
- Assembling methods and activities into a lesson plan

Learning Objectives

These are the instruction objectives that the trainer will want the learner to know, feel or be able to do at the end of the lesson. It describes the intended outcome of instruction in observable and measurable terms. It describes what the learner will be doing when they are demonstrating achievement of the task. Or more simply put it will answer the questions: Where are we going? How are we going to get there? How will we know when we are there?

The lesson plan will, produce new knowledge, produce new attitudes or produce new skills. Understanding what the learning goals are designed to achieve is critical to lesson planning for adult learners.

Much of what we hope to achieve in salt management training is a change in attitude and habits. It is more than just a process of imparting knowledge. The attitude and behaviour of the individual worker is what we need to change. The physical skills are not significantly different from the skills that currently exist so the concentration will be in teaching new attitudes and new knowledge. For example: understanding that there are situations where using more salt will not necessarily make the conditions better.

Learning Components

These are lists of what items will be covered during the training session. The trainer should take into consideration the arrangement of the learning tasks so that the process builds in a logical sequence. Typically the tasks should be arranged from the known to the unknown, the simple to the complex, the concrete to the abstract and the general to the specific. For example: understand the function of brine prior to learning about pre-wetting.

Lesson Plan

This is a plan of the specific elements and components of the session arranged to maintain interest and solicit participation from the learners. This is where the trainer will select the teaching methods to maximize retention. Adult learners retain more of what they do than what they are told and they retain the most when they can use it in real life. For example: a lesson on spreader controls in the cab of the truck where the operator can get tactile feedback will have a greater knowledge transfer than if the same lesson where in a classroom setting.

Training Methods

Consideration should be given to the timing of the training. Since skills used in salt management are specific to winter the training is best provided before or during the winter season. In most operations there is a window of opportunity at the end of the summer maintenance season and the beginning of the winter maintenance season. Training for salt management can occur at the same time as the annual winter preparation work is scheduled. There also may be time available at the end of the winter maintenance season, just prior to the start of summer work, to review the effectiveness of the salt management initiatives and training and get feedback from staff on what to improve upon next year.

Class management combined with module-based delivery can be used to design an efficient learning setting as well. One example is to provide for each training module to be delivered in different areas where learners move from area to area on a rotational basis. Each module is designed to be snappy enough to prevent boredom and the information is presented to a smaller group. Time can be designed into the rotation to permit learners some one-on-one time with trainers.

Training opportunities should not be limited to formal classroom settings. Trainers should be aware of the workplace schedules, inclement weather policies, shift changes and shift downtime for example and take advantage of these windows of opportunity to present training modules.

Depending on the regular duties of the staff there are also opportunities to provide training in informal tailgate sessions or in post storm debriefing sessions.

Train the Trainer

Depending on the size and available resources of the organization there are advantages in designating and training a staff member(s) to provide the salt management training.

Before appointing a staff member to become a trainer for the purposes of salt management, care should be taken to ensure that the individual has the necessary characteristics to be an effective trainer. Beyond knowing the subject matter an effective trainer will have the following characteristics and may be the person in your organization that people currently go to for advice.

- Is accessible for questions.
- Knows how to give feedback - always positive and never uses sarcasm or ridicule.
- Holds respect for his colleagues and is respected by them.
- Can summarise ideas in a clear and precise way.
- Listens to the opinions of other and seeks their recommendations.

- Facilitates ideas and the sharing of new concepts or work methods.
- Is current on new methods and procedures.

Smaller organizations can also develop joint projects with neighbouring organizations to introduce economies of scale into the delivery of the training. It may also be possible to have one individual trained to cover off more than one agency.

It may be practical to contract with outside trainers to provide this service. Sometimes organizations need the "outside expert" to introduce and gain acceptance of new concepts.

There are Train-the-Trainer programs offered by various organizations that can be used to develop in-house training.

Testing for Retention

In developing the testing program it is advisable to have each organization determine their workplace specific standard of testing and performance. The philosophy of the testing should include not just verification of the knowledge transfer but to provide a medium to assess the quality of the instruction and the analysis of the results. This will permit the trainers to modify the curriculum or identify subjects that require more training in specific areas.

The testing should be fair and adaptive so that nothing is too easy or too hard for the test writers. The test design must be representative of the subject covered and the same test should be administered for each staff member (subject to literacy or language barriers).

Evaluation

We know that it is preferable to have the adult learners involved with the evaluation process as an aid to their learning and knowledge retention. While this may be achievable in some parts of the learning components it is not possible for the entire lesson plan.

The key to designing the evaluation for the training session lies in the description of the learning objectives. If the learning objectives are well defined then what is measurable is also defined.

The trainer will have to be aware of the competency level of the learners in designing methods of evaluation. There may be a requirement to offer oral tests to those whose writing skills prevent accurate assessment of their skills.

The trainer should take advantage of any opportunity to have immediate and automatic feedback on whether the learner's actions are consistent with the learning goals. The more immediate the feedback, the more likely the learner will begin to self evaluate. They will begin to correct themselves once they recognize the gap between the stated objectives and their knowledge.

Transfer of Training

It is estimated that 40% of skills learned in training are lost immediately, 25% remains after six months and only 15% remains after one year. The trainer can increase the level of retention by incorporating as many of the following strategies as possible into the lesson:

- Use realistic examples of how skills can be used.
- Give learners real life context for the application of concepts rather than presenting theory without a practical association.
- Use rich analogies.
- Include practice of skills.
- Use clear and effective visual aids.
- Consider pre-training assignments.
- Keep skills and concepts close to the work generally done by participants in the normal jobs.
- Use post-training follow-ups.
- Encourage sharing of anecdotal experiences through discussion sessions.

This reinforces the need for refresher training. Trainers should make available easy access to reference materials to permit the learners to refresh their knowledge in a comfortable, non-threatening way. Again, periodic tailgate sessions help to reinforce the learning goals.

Situational Learning

In order for training to be effective the trainer must recognize that individuals or groups of individuals are going to differ with respect to their ability to learn,

their level of comfort and their familiarity with the learning process. Each of us brings our own frame of reference, bias and pre-conceptions to the classroom.

In some instances the learners will be very experienced in assimilating knowledge and others will have had little experience in classroom learning situations. A lesson plan designed to transfer knowledge to a room full of supervisors will not likely be very effective in a room full of equipment operators. Although the content may be similar, the transfer methods, the learning concepts, the duration and timing of the delivery will have to be modified specifically to suit the audience.

Resistance to Learning

Workplace Culture

The natural culture in the workplace may represent a challenge to the trainer and should be factored into the design of the training session. While each workplace will be different, some workplaces will have very co-operative workers eager to learn and others will have a history of reluctance to change. The attitude of the workers as a group is the issue.

In a group dynamic situation there will be informal leaders who the group relies upon to communicate and reinforce their culture.

Sometimes these informal leaders will compete for the attention of the learners and steer the group away from the established lesson plan. These leaders can be an asset or liability. It is the trainer's challenge to tap into and channel this enthusiasm to achieve the learning objectives. Where this energy cannot be used productively then the trainer must neutralise any disruptive influence these individuals have on the group.

Worker Attitude

Apart from the cultural attitudes in the workplace, each individual operator will have a perception of his/her role within the operations. Some will hold the view that acquiring knowledge of new systems or technologies is not their responsibility and they don't get paid to think about such things. They perceive their role as followers of instructions. Their 'locus of control' is 'external' and they rely on others, such as their supervisor, to provide the appropriate conditions/features for them to carry out their work.

The challenge for the trainer is to convince these individuals that there is something in it for them (WIIFM) and to try to 'internalize' their locus of control by stressing how important each individual's contribution is to the overall success of the salt management initiative. The trainer should take the approach that when the operators are on their route they have options to consider, given the road and weather conditions, which only they as operators are in a position to make. External influences are too remote to make the best decision under the circumstance and their judgment is valued as the best available given their training, experience and local knowledge.

Labour/Management Issues

Training sessions offer an opportunity for the informal leaders to discuss other issues unrelated to the training. Unresolved issues are commonly brought up during a training session because of the nature or make up of the audience in attendance. At the onset of the session it is necessary to identify the purpose of the training and explain that issues other than what is on the lesson plan will not be discussed. In situations like this there is merit in having the trainer be someone who the learners do not view as a sounding board for labour management issues. There must be other opportunities for airing grievances or concerns for this strategy to work.

Fears of the Learner

How people react to new things varies greatly by the individual. However the trainer can anticipate that a number of the learners will have some fear that the change or introduction of new methods or technology will present some personal threat. The threat will manifest itself either in a fear of job security where the workers skills will no longer be valued or if they fail to learn the new systems they will be replaced. The trainer will have to reinforce the benefits the new systems or technology offers the workers.

Workers may also have a fear of the unknown or a fear of looking foolish in public or they may bring to the classroom the baggage left over from unpleasant schooling situations in their past.

Remember, to an adult learner, it is important to get the WIIFM (what's in it for me) issue on the table right away.

Second Language/Literacy Skills

Not everyone has the same communication skills. Some of the learners will have a first language other than English or French and some will be challenged to understand any written communication. It will be important for the trainer to identify those learners who have these learning impediments and modify the training and evaluation to accommodate their needs.

When dealing with these learners the trainers should try not to bring undue attention to them in a classroom setting. It is advisable to ask their supervisors prior to the training if there are learners with these challenges.

Changing Worker Value Systems

For many operators, who have been involved in winter control operations for more than the last few years, the standard of a job well done has been to see how much salt they can put down during their shift. Their value system said "More is Better" or "When In Doubt - Put It Out". Then along comes an initiative to optimize the amount of salt being used and the value system is changed to "Just the Right Amount and No More".

Changing an individual's or a workplace value system is not going to be achieved easily or with a simple directive from management. Although it is necessary to provide training, information, and the technical and environmental rationale for making the change, the worker still has to rethink his personal description of a job well done. His accomplishment targets have to be reset and to do this requires ongoing positive support and reinforcement. Once the initial training is given and the knowledge of the learner evaluated there should be secondary initiatives to reinforce the change in the value system.

Positive Messaging

The success of the training is the level of knowledge retention in the learner. Putting the key learning points in front of the learners in the workplace can enhance the level of retention and the rate of change in values. The key message of using the right material in the right amount in the right place at the right time can be promoted in the workplace. For example the application rates or spreader control settings can be posted in an area where the learners congregate such as lunchrooms or staging areas. Similarly, reminder signs with this information can be displayed in the truck cabs adjacent to the vehicle controls.

Statistical data can be used to provide regular feedback. If work management software systems are available in the workplace then year-to-year or year-to-date comparison information of salt use or salt costs can be posted or distributed so the operators can see what impact they have on the financial side of the operations.

The salt optimization message can be reinforced through the knowledge of its impact on the environment. Even though the potential impact to humans is low and may not be a major concern in the workplace, there may be sensitivity to the salt impact on the environment. The impact of salt on aquatic life forms and the potential impacts to the food chain is a message that is likely to be taken seriously.

Informal post-storm sessions can help to reinforce the training especially if the there is an opportunity for the internal champions to relate their experience with the equipment, the conditions and the decisions they made based on what they encountered.

Continuous Learning

Researchers estimate that training provides 20% of the critical skills required to do a job and the remaining 80% is learned on the job. So regardless of the effectiveness of the lesson plan most of the learning will take place on the job outside the classroom setting or any other setting.

It becomes critical to the effectiveness of the overall operations to nurture a workplace where operators are encouraged to share information, experiment with new concepts and challenge old ideas. Management has to be alert to the discussions in the works yard to be able to assess if the attitudes are leading to the desired behaviours. If the behaviour has not changed additional or follow up re-training is required.

The need for annual training/re-training sessions is reinforced by this fact as well. The trainer can take

advantage of the knowledge and skills of some of the best operators to help in training the rookies both in the classroom and in the cab where knowledge transfer has the highest retention rates.

Training Information Resources

There are a variety of excellent training resources available through the following sources:

- Transportation Association of Canada
- Salt Institute
- AASHTO
- Provincial Road Associations
- Private Sector Training Providers
- Colleges and Universities
- APWA/CPWA, and
- Smart About Salt Council.

Trainers should assemble a bank of local case studies, local photos and examples to reinforce learning goals.

SALT VULNERABLE AREAS

Operators need to understand the salt management practices that they are expected to use to minimize salt impacts. Training programs are important to ensuring that salt is effectively managed everywhere, including in salt vulnerable areas.

MONITORING

For training, organizations should monitor the extent to which staff is performing with respect to expected learning goals. This should be done on an ongoing basis through observations of staff behaviour. Any deficiencies in behaviour should be identified and a plan developed to re-train in the appropriate areas.

RECORD KEEPING

Up-to-date files should be maintained of the training provided to each member of staff. It is advisable to include any certification and course description in the file to maintain a record of the worker's competency. The records should include the date, time, duration and subject of the training, as well as the source of the training and trainers. Records should be maintained in such a way as to allow summaries to be prepared on the percentage of staff at each level that is trained in salt management.

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3.0 – ROAD, BRIDGE AND FACILITY DESIGN

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.

INTRODUCTION

Once a roadway, bridge, building or other facility is designed and constructed, it is in place for a very long time, during which it must be maintained. Proper facility design can reduce the need for (and cost of) snow and ice control, a major component of operating budgets throughout Canada. Effective incorporation of quality construction materials and techniques, effective drainage, adequate snow storage, sufficient cross-fall, accommodation for effective plowing and snow storage, etc., will help to facilitate effective snow and ice control and salt management.

The primary purpose of this Synthesis of Best Practices is to increase the designer's awareness of the importance of considering operations from the outset. That includes the techniques, materials, configurations and design parameters to reduce the amount of snow and ice accumulation and to manage the impacts of salt on the infrastructure and the environment. This Synthesis of Best Practices presents basic principles to consider in design. For more detailed information, see TAC's *Salt Management Guide* - 2013.

CONTENTS

RELATIONSHIP TO SALT MANAGEMENT

Ice forms on pavement when freezing temperatures and water occur in combination on the traveled surface.

Salt is used to prevent the formation of, or break the snow/pavement bond and to remove ice that has formed.

Facility designers cannot do much about precipitation but can be instrumental in maximizing solar heating of pavement and managing onsite drainage and drifting snow so as to reduce the risk of ice formation and the need for salting.

Throughout all phases of facility development (location, planning, preliminary design and detailed design) designers have the opportunity to make decisions regarding the location, configuration and design details of the facility, which will affect, throughout the life of the facility, the potential for snow and ice accumulation.

If a roadway, building, parking lot or sidewalk has a lower potential for snow and ice accumulation, then the winter maintenance demands will be correspondingly lower and, therefore, the actual application of salt over a given period of time is likely to be lower. Design can also affect the ease of maintenance.

Research and case studies have confirmed that there is a direct relationship between certain design parameters, snow and ice accumulation and the ability to provide cost-effective winter maintenance. It is therefore suggested that, as a guiding principle, designers should consider maintenance requirements when determining the location, concept designs, preliminary designs and final designs for infrastructure.

It is possible that the incorporation of features to minimize snow and ice buildup into a design will add to the capital cost. It is also clear, however, that from a broader life-cycle view such initiatives are likely to increase safety and reduce maintenance costs throughout the life of such a facility. These trade-offs should be considered as an integral part of location planning, preliminary design and detailed design. Valuing design initiatives must be done on a life-cycle basis (including operations and maintenance costs). Therefore, it is essential that maintenance personnel be involved in design discussions.

SALT MANAGEMENT PRACTICES

Designers can influence the amount of maintenance effort and salt used in three key ways:

1. Maximizing solar heating potential
2. Minimizing the amount of water flowing onto, across or ponding on paved surfaces
3. Minimizing the potential for snow to blow onto paved surfaces.

Each of these is discussed below.

Maximizing Solar Heating

We have all experienced the warmth of the sun on a cold winter's day. The sun can increase pavement temperatures by 10 degrees Celsius or more. Even on cold days this solar heating can raise pavement temperatures above freezing and either melt snow and ice or prevent moisture from freezing.

Maximizing solar heating potential involves exposing pavement to the sun and reducing shade. In the case of building design, this can be accomplished by orienting building so that paved areas are on the sunny side of the building as much as possible.

Shaded areas will be colder than sunny areas. Therefore shading should be reduced where possible. Pavement shading can be reduced by removing obstacles that will block the sun on the south side.

When planning earth or rock cuts, road authorities usually remove equally from both sides of the road. There are many reasons for this. However, where there is flexibility, it makes sense to maximize the removal on the side that will allow solar heating. Removals also need to provide for snow storage when plowing so that the melt water does not flow back onto the pavement.

Both summer and winter cooling and heating can be affected by the type of vegetation planted adjacent to roadways and parking lots. Deciduous trees will provide shade in the summer and allow the sun through in the winter.

When planning vegetation removals and grade alterations, the effects on snow drifting and snow storage must also be considered.

Drainage Management

Proper roadway and parking lot design incorporates sufficient cross-fall to distribute saline brine across the surface which minimizes salt use.

Much of the salt used on parking lots, sidewalks and roadways is to address ice formed with water from poor drainage.

Many buildings are poorly designed and allow roof drainage to drop or discharge onto paved travel areas. This perpetual icing requires ongoing salt application to manage the risk.

Designers need to pay special attention to intercepting building and site drainage and directing it away from paved surfaces.

It is informative to view a site on a rainy day to understand how poorly designed facilities can affect drainage. The areas of poor drainage are clearly evident. These areas are prone to icing in cold weather and therefore are high risk areas for slips and falls and consequently become high salt use area. Effective drainage management can therefore reduce salt use over the life of the facility.

Drainage from melting snow pushed to the high side of paved areas is a particular problem. Parking lot designers often place catch basins such that water from snow piled around the perimeter needs to flow across travelled areas to reach these outlets. This water will freeze into sheets of ice if the pavement is below freezing.

The problem can be addressed by better grading of the lots and placing interceptor drains closer to the edge of the pavement.

Snow storage must be taken into account when designing roadways and preparing site plans. Ideally snow storage locations should be identified and designed so there is sufficient snow storage capacity and drainage is away from paved surfaces. In the case of roadways, sufficient shoulder area is required to ensure that snow can be plowed off the travelled surface and stored for the duration of the winter. In urban areas this may not be practical and therefore snow will need to be picked up and transported to snow disposal sites.

FUNDAMENTALS OF SNOW DRIFTING

In some locations a significant amount of the snow that needs to be removed from roadways, parking lots and sidewalks is deposited through drifting. Therefore effective drift control can reduce snow and ice control efforts including salt use. Designers can have a significant effect on whether or not a site will have drifting problems.

Operationally, drifting can be controlled through the erection of drift control devices such as snow fence (structural and living) and snow ridges and the strategic placement of buildings.

Understanding the cause of snow drift accumulations and designing to minimize the causes can reduce the severity of an icing problem, thus lowering the salt requirement.

Snow drifting will occur when a driftable source of snow exists in an open area upwind of a site and when the local wind speed (measured approximately 1 m above ground) exceeds the threshold speed of 15 km/h. Threshold speed is defined as the limiting speed below

which the wind will not lift and transport snow particles. Once these conditions exist the wind will transport the snow in a thin layer close to the ground. As long as there are no obstructions to slow the wind, the snow will blow across the pavement and will not accumulate.

These snow particles will continue to be transported until they sublimate (change directly from solid to vapour state) or until wind speed slows to below the threshold speed and particles settle on the ground. If the wind speed increases, the turbulence caused by the friction at the ground surface causes a mixing action that increases the thickness of the blowing snow layer and usually causes reduced visibility. Reduced wind speed areas will be caused by obstructions to the wind such as changes in grade, vegetation, plowed snow banks, safety barriers, bridge abutments, buildings etc. (See Figures 1-4)

The reduced wind speed zones around these obstructions will accumulate snow that will affect the facility if the obstructions are close enough to the pavement.

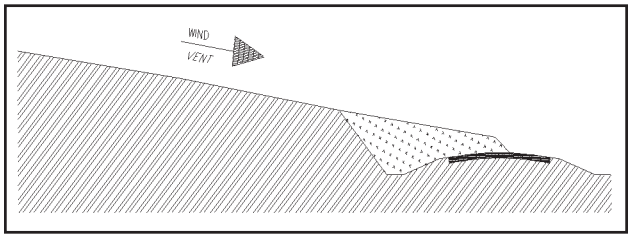

Figure 1 – Snow accumulation problem caused by change in grade

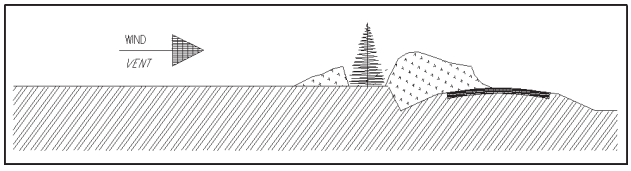

Figure 2 – Snow accumulation problem caused by trees

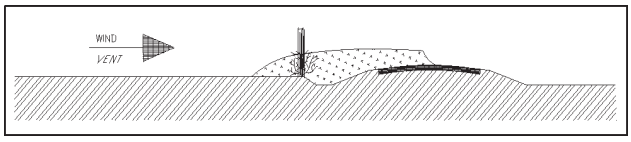

Figure 3 – Snow accumulation problem caused by fencerow obstruction

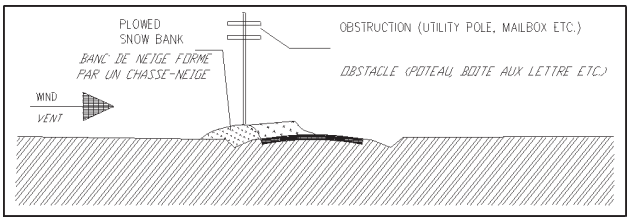

Figure 4 – Snow accumulation problem caused by utility pole obstruction

In some cases if the snow can blow across a paved area and high traffic volumes also occur, the vehicles will pack snow onto the surface and cause icing conditions. Equally if salt is applied to a surface in areas of low traffic volumes, the salt can form moisture and cause the snow to stick to the surface where it would otherwise blow across the pavement. This concept of not salting should not be implemented without careful consideration. A written plan should be in place that specifies when salting should and should not occur. Some jurisdictions may decide that not salting is inconsistent with their maintenance philosophies.

FACTORS TO CONSIDER IN ROADWAY AND BRIDGE PLANNING AND DESIGN

Below is a list of key factors to consider in the planning and design of roadway and bridge facilities in order to minimize the likelihood of snow and ice buildup. These concepts can also be used to identify solutions to snow accumulation problems on existing roadways. For more details the reader is referred to TAC's Road Salt Management Guide - 2013. In addition, on more complex projects the designer is advised to use the services of a specialist in the area of snow and ice control.

Meteorological Data

- The following meteorological data should be obtained as background information:
  - average daily and annual snowfall
  - prevailing wind directions and speeds
  - storm directions and the amount of snowfall typical to a winter storm
  - mean monthly temperatures and expected winter extremes
  - number of freeze/thaw cycles

- Facility maintenance staff is often familiar with local conditions and are a source of useful "hands on" information.

Surrounding Terrain

- The terrain surrounding a site will affect the amount of snow that can blow towards a facility.
- In establishing the location of a new facility bear in mind that the upwind terrain is key. The distance from the facility to any major upwind features (e.g., a ridge, a heavy tree line, a building line, etc.) is referred to as the "fetch". The bigger the fetch, the larger the snowdrift potential and the larger the potential problem at the facility.
- The surface of the upwind fetch area is also a major consideration. A "smooth" area such as frozen water or short grass will not trap snow and hence will not assist in reducing drifting conditions. Rougher terrain, such as ploughed fields, crop stubble, long grass, shrubs or particularly mature trees with dense winter branch structure will trap snowfall and may reduce the potential drifting conditions at the facility.

Interchanges/Buildings

- Complex wind flows are associated with interchanges and buildings and usually it is necessary to conduct a model study to fully assess conditions.
- From the point of view of snow accumulation, at interchanges, the roadway with a higher level of service (LOS) should cross over the roadway with lower LOS as prevailing winds would blow snow off the major roadway.
- Open style abutments should be considered over closed abutments to reduce snow accumulation, although the higher cost of open style abutments and their typically rural nature may dictate the use of closed abutments in many instances.

Pavement Shading / Exposure to Sun

- In areas of high tree cover, consider the winter altitude and azimuth (bearing, measured clockwise from true north) of the sun, and the potential shadow effects of the tree cover which will affect the potential for ice melting on the pavement surface. Trees should be cleared back far enough to maximize the heating effect of the sun. Similar considerations should be given to site conditions where vertical walls are part of the facility design. In this case, the vertical wall should be replaced with a sloped embankment if possible. To the extent possible, buildings should be oriented so that paved areas are not shaded.

Elevated Road on Fill Section

- With divided roadways and a median width which will allow the establishment of independent grades for the two directions of travel, it is desirable to set the elevation of the upwind lanes lower than those of the downwind lanes, or at least, at the same elevation as the downwind lanes.

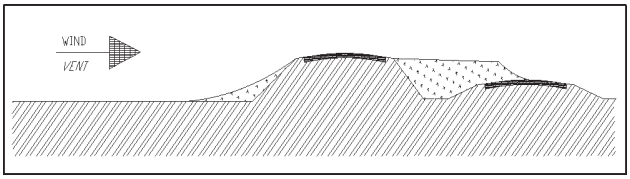

Figure 5 – Elevated roadway causes snow accumulation on adjacent lanes

Preferably the top of pavement should be approximately 1 m above typical snow depths in the area.

If possible eliminate the need for safety barriers, and therefore, the obstruction that causes snow drifting with slope flattening of fill side slopes. For minimum side slope without guide rail (in the range of 3:1 to 4:1), refer to TAC's *Geometric Design Guide for Canadian Roads*. Ideally, side slope should be flattened to 7:1 for effective snow accumulation.

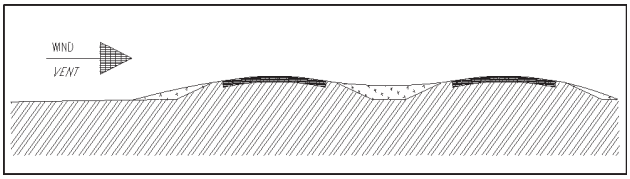

Figure 6 – Travelled surfaces at same elevation minimize snow accumulation on roadway

Generally, a road's cross-section totally on fill without significant terrain features upwind is more likely to blow clear of snow than any other design configuration.

Wide Ditches

Wide ditches provide storage for plowed snow which otherwise would be piled along the edge of the roadway and would promote more snow accumulations. Refer to TAC's Road Salt Management Guide - 2012 for further details on calculating volume of drifting snow.

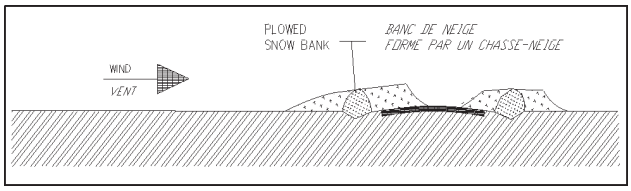

Figure 7 – Lack of storage causes plowed snow banks along road

Use of Guide Rails

Box beam / cable guide rails have the least obstruction and in theory, accumulate the least amount of drifted snow but in practice, plows push snow against box beam / flex beam to create a solid barrier, therefore, for the purposes of snowdrifting / accumulation, assume all barriers are solid.

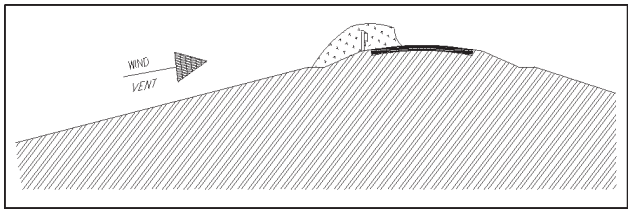

Figure 8 – Safety barrier causes snow accumulations along road

- Solid Jersey barrier is easiest to plow against.
- Tall solid barrier has increased drifting area and increased shaded area.
- Reduce the need for barrier at side of roadway through slope flattening.

Berms for Snow Accumulation

- Locate berms upwind of the roadway, setback 7 times the berm height.
- To obtain the maximum snow collection capacity, maximize the berm height and ensure berm slopes are as steep as practical.
- One tall berm is more efficient at accumulating snow than a number of rows of shorter berms.
- To maximize the effectiveness of tree plantings, locate coniferous trees on a berm. However, the setback should be 15 times the combined height of the berm and the mature tree.

Backslope

- Flatten upwind backslope (ideally 7:1 or flatter) to minimize drifted accumulations on pavements.

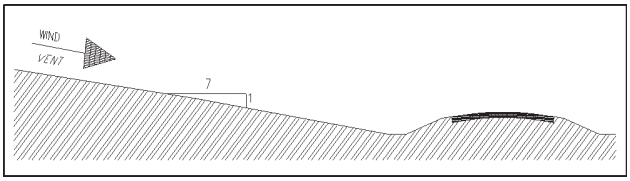

Figure 9 – Flatten backslopes

- With roadways in cut sections, consider a wider cut on the upwind side than on the downwind side, ideally meeting the 7:1 minimum gradient discussed above. If the roadway cut is a source of material for other sections of the roadway, consider taking the majority of the material from the upwind side of the cut.

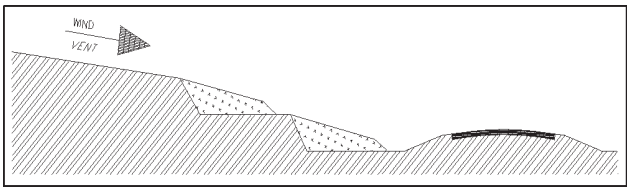

Figure 10 – Use wide cut to store drifted snow

Obstruction Close to Facility

- As shown in Figures 2, 3 and 4 obstructions that can cause snow accumulation problems are as follows:
  - trees too close
  - mail boxes
  - utility poles
  - guide rails
  - plowed snow banks
  - fence rows
- Consideration should be given to eliminating / minimizing these obstructions if they are causing snow accumulation problems.

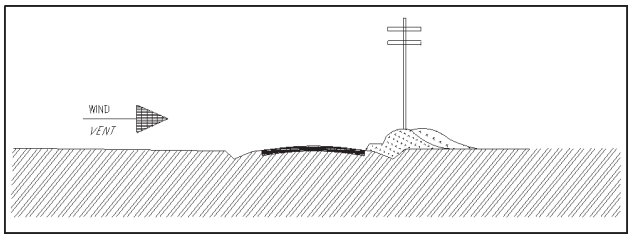

Figure 11 – Locate obstruction on downwind side of road

- Where possible locate obstruction on downwind side of facility.
- As a general rule of thumb a 50% solid obstruction (snow fencing, vegetation) should be placed a distance of 15 times its height from the facility/ right of way, on level ground. A solid obstruction (buildings, double vegetation) should be placed 10 times its height on level ground.
- Noise walls do not typically present a problem with snow accumulation as they usually are located in residential areas that limit snow movement towards the wall and the roadway, however, snow drifting at end details should be considered.

Vegetation Management

- With appropriate landscape design, many snow drifting problems could be solved or lessened. Similarly, improper design or placement of vegetation can aggravate a snow accumulation problem (particularly at interchanges).

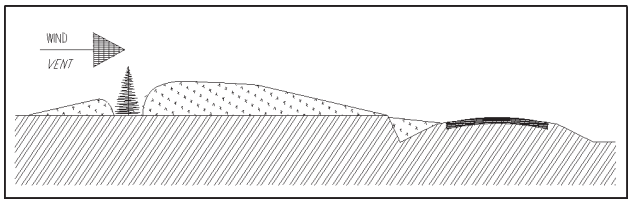

Figure 12 – Properly located trees will reduce snow accumulation on road

- Before vegetation is removed for the construction of new facility (or for existing facility expansion) designers should evaluate existing site conditions in order to determine whether or not existing vegetation could prevent a snow related problem or could cause a future snow related problem. Preserving existing vegetation is more economical and time efficient than planting new vegetation. This approach also allows existing vegetation to be incorporated into new landscape plans.
- The objective of upwind snow fences (non-living or living) is to encourage a snow drift immediately downwind of the fence or vegetation with the result that little snow is left to drift onto the facility/roadway.

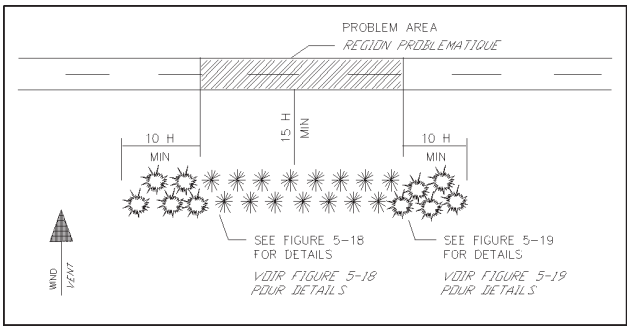

Figure 13 – Details of typical landscape layout

- Upwind vegetation planting can have a similar effect to snow fences providing the configuration and location is appropriate and the planting is not close to the roadway.
- Plants with dense branch structure will hold snow to approximately one half its height. Trees and woody plants are better as they do not tend to bend as much under the weight of the snow.
- Corn stalks left in agricultural fields on the upwind side can slow wind speed and reduce drifting and blowing snow. Five or six rows of corn with a similar setback to that shown in Figure 13 will be effective in reducing snowdrifts.
- Uncut grass in the ROW is better than cut grass as it keeps snow from blowing with the exception of grass directly adjacent to the roadway, which ideally should be cut short to avoid drifts that would extend onto the roadway.
- If there is sufficient land area available, at least 60 metres, a snowbreak forest is a viable option. However, a much more economical solution for new facilities is to retain existing forest. This saves the time required for newly planted vegetation to reach their required height. Snowbreak forests also provide substantial benefits to wildlife and may be managed for timber production.
- As many facilities are too small to accommodate the setback required for living snow fences, cornrow fences, snowbreak forests or even structural snow fences; it may be necessary to enter into land use agreements with private landowners.

- See also the Vegetation Management Synthesis of Best Practices.

Urban Considerations

- In an existing urban environment, little can be practically done to reduce snow accumulation, as roadway rights-of-way are constrained and adjacent lands typically built-up; accumulated snow is removed as per the municipalities' snow removal program.
- Many traffic-calming measures, such as speed bumps, curb bulbs or chokers, raised crosswalks and platform intersections can create difficulties for snow removal equipment and can affect drainage and maintenance efficiency, and as such, their use should be carefully considered.
- Channelization in the form of raised medians and islands can also create difficulties for snow removal equipment.
- Many roadside fixtures (mailboxes, bus shelters, parking meters, light standards, etc.) can hinder snow removal.
- Snow storage in an urban environment is often a challenge and consideration should be given to providing larger cul-de-sacs, bicycle paths and wider curb lanes (especially across bridges) for temporary snow storage. Developments should also factor snow storage and melt water drainage into their designs.
- Care should be taken to avoid snow storage in locations viewed as "pedestrian areas" (i.e. kill strips) to avoid potential liability in slip-and-fall claims.
- Meltwater should always be directed away from paved area where it could freeze, creating slip-and-fall risk.
- Consideration should be given to plow path in road design (corner radii, cul-de-sac radii, turning roadways, etc.).
- The type of sidewalk (e.g. curb line) and width of the boulevard may define whether a grader and/or a speed plow are used.

Rural Considerations

- Raised medians and islands can create difficulties for snow removal equipment.
- In a rural environment, the roadway right-of-way tends to be less constrained and cluttered than in an urban environment, providing more temporary and permanent snow storage locations.

Drainage

- Good facility drainage will lead to reduced ice accumulation, and as such, reduced salt usage (this includes intersecting roadways and accesses as well as the main roadway, parking lots and sidewalks).
- Set maximum and minimum grade to help maintain an even distribution of salt, and to allow melted ice/snow to drain to catch basin.
- Optimize salt usage by using lower superelevation rates (to help maintain even distribution of salt).
- Use crowned roadways, and good crossfalls (2%-3%).
- Mark all culvert ends to make them easier to locate for cleaning and thawing activities.
- Design parking lots with catch basins located near the perimeter so melt water from snow storage areas does not have to flow a long way across paved surfaces where it could freeze and require excessive salting.
- Ensure that building drainage does not cause icing of travel ways and walkways.
- Drainage is discussed in further detail in the Drainage and Stormwater Management Synthesis of Best Practices.

Sub-base Considerations

- Underground springs can affect pavement conditions and should be taken into account.
- Frost prone areas may cause heaving of the pavement surface and can be treated with insulation. However this can affect the thermal properties of the paved surface.

Automated Spray Systems

Areas that experience a high number of frosting or black ice events each winter season have traditionally required a significant amount of labour and road salt to manage properly. Short icing events, some lasting only

minutes near sunrise, require a proactive approach, as the application window is small. Missing even a few events can be hazardous.

Maintaining material on the road to deal with frosting events can be difficult and expensive on roads with higher traffic volumes. Applying the material just prior to an anticipated event is ideal. Automated liquid anti-icing spray systems have been developed to help organizations better manage their icing problems.

- High level, long span bridges over water or river valleys are especially susceptible to frequent and sudden icing conditions. The combination of humid air and the fast cooling bridge deck will produce a significant number of frosting and black ice events. The sudden change from a warmer, ice free, at grade road surface to a colder, icy, bridge deck leaves little transition time for drivers to react to the hazardous road condition.
- Elevated highway ramps, curved sections of roads with downgrades and intersection approaches at the bottom of hills are also areas where icy conditions can be difficult to manage.
- Fully automated chemical delivery systems have been developed that use sensors embedded in the roadway and mounted on towers, site mounted computer hardware and software and nozzles embedded in the roadway or the parapet wall, to automatically apply liquid anti-icing chemical to the road surface just prior to a forecasted icing event.
- Automated systems can be designed and installed as a component of a new bridge or road section or retrofitted during a bridge rehabilitation or roadway upgrade. Incorporating automated systems during the initial design and construction is considered more economical than retrofitting a system after construction.
- Automated systems help organizations meet the 4 R's of Salt Management by placing the right material, in the right amount, in the right place and at the right time.
- Where the temperature ranges allow, chloride based liquid anti-icing chemicals can be used. Systems on bridges over water tend to use non-chloride based liquid anti-icing chemicals to reduce corrosion of the bridge deck and chloride impact on the water system below.
- Because the liquid storage tanks and piping are usually unheated, chemicals with very low freezing points (e.g. magnesium chloride, potassium acetate) tend to be preferred.
- The tower sensors or RWIS component of automated systems can be used as part of a regional RWIS network.

PAVEMENT OVERLAYS

Pavement overlays have been developed to serve the same function as automated spray systems. The overlay holds deicing chemicals like a sponge and deliver them to the surface to deal with frost and icing events. The principle behind them is that a residual of chemical that has been applied to the pavement is retained within the pavement and then automatically released when snow and ice conditions develop much as the automated spray system would be activated when frost or snow/ice conditions are present.

FACTORS TO CONSIDER IN REDUCING HARMFUL EFFECTS OF SALT ON STRUCTURES

The use of salt is an integral component of most winter maintenance programs and is necessary to maintain proper operating standards. While the purpose of this Synthesis of Best Practices is to present ways of ultimately reducing salt usage, it is accepted that salt will be applied at appropriate levels to bridges, parking garages, walkways etc. to maintain operating standards. The adverse effects of road salt on infrastructure, however, are well documented. In recent years, many practices and materials have been adopted by various jurisdictions with the objective of reducing the adverse effects of de-icing salts. This section summarizes what can be done to minimize the impacts of road salts.

In those areas where salt will be applied to maintain operating standards, it is prudent for the designer to stipulate construction methods and materials that will provide durable structures.

The designer should consider the most appropriate structural form or type, the appropriate choice of materials, advantageous construction techniques and the effective control of drainage, all in an effort to minimize the potential for accelerated deterioration caused by road salts.

Factors to be considered in the design of durable structures can be divided into three major groups; Structural Considerations; Material Considerations and Drainage Considerations.

Structural Considerations

Structural considerations refer to the structural systems that are chosen to minimize impacts of road salt such as:

- The presence of expansion joints is regarded as a principal cause of premature deterioration of structural elements. Salt brine eventually breaks through joints, resulting in compound deterioration. The use of expansion joints can be minimized through the use of longer expansion lengths and in the case of bridges, the use of integral and semi-integral abutment bridges. Additionally, for bridge rehabilitation projects, bridge expansion joints often can be eliminated by the use of flexible concrete hinges to make a concrete deck continuous over a series of simple spans.
- During the fabrication process, the flanges of steel plate girders can "curl" towards the web, creating an area where moisture can collect. In roads over road crossings, salt spray can accumulate in these areas. The use of steel I-girder sections on road over road crossings should therefore be minimized, in favour of concrete or steel box girders.

Material Considerations

Material considerations refer to standard construction materials and methods that are used to prevent the premature corrosion of steel components by providing a barrier to salt brine infiltration, or by use of materials that do not corrode. These considerations may include:

- The assurance of a durable concrete by adherence to standard codes of practice for concrete design (e.g. use of air-entrained concrete), taking into consideration exposure conditions.
- The use of High Performance concrete.
- The use of corrosion inhibitors in the concrete mix design.
- The use of durable, barrier type waterproofing systems.
- The use of stainless steel reinforcing.
- Adherence to standards and codes of practice with respect to detailing, concrete cover and other practices designed to enhance structure life.
- The use of non-metallic materials for non-structural components such as drain pipes and reinforcing steel supports.
- The use of coating systems (galvanizing, epoxy coating, metallizing) for embedded or exposed accessories such as handrail, utility poles, deck drains, expansion joints, door frames, etc.
- The use of Advanced Composite materials. These materials are generally non-metallic and hence not subject to corrosion.
- The use of concrete surface sealants to prevent or decrease the rate of salt brine penetration.

The above can be considered individually or jointly as part of an overall system to enhance durability.

In addition to the appropriate choice of materials, details must be used to minimize as much as possible the exposure of structural components to salt brine. For example, weathering steel is used extensively throughout North America for bridge girders. These steels form an oxide layer that reduces the rate of corrosion, eliminating the need to paint the girders, reducing maintenance costs. If, however, the steel is allowed to continuously come in contact with salt solution, the rate of corrosion accelerates, thereby eliminating the benefit of weathering steel. Also, the use of asphalt without waterproofing should be discouraged. Asphalt can trap the salt solution, and does not permit the natural "flushing" of the deck. Bridge decks with an asphalt riding surface without waterproofing will exhibit an accelerated rate of deterioration.

Drainage Considerations

It has been demonstrated that moisture, in combination with road salts, is a key element in the onset of corrosion. Providing adequate drainage is essential to a durable structure. Factors to consider include:

- Adequate longitudinal gradient to provide surface run-off. Inadequate gradients can result in ponding leading to accelerated deterioration and a icing hazard.

- Elimination of deck joints and deck drains. These elements are invariably the first to fail in a bridge deck. When failure occurs, other bridge components are exposed to salt brine; resulting in premature deterioration.
- Use of details to keep moisture away from vulnerable components (i.e. raised bearing pedestals, drip grooves, asphalt tunes, etc.). It must be assumed that during the life of the structure, most components will come in contact with salt brine, either from direct application to the structure, or from salt spray from below the structure. The use of details that will minimize the exposure of structural components to salt, or prevent spread of salt brine, will extend the structure's life. Additionally, a maintenance program that includes the flushing of areas prone to debris and salt brine accumulation (bearing seats, bearings, expansion joints, deck drains) is beneficial in extending the service life of a structure. Such flushing operations should include a pre-flush sweeping program and measures to contain and dispose of impacted water.
- Adequate drainage of bearing seats. Bearing seats should be sloped to facilitate drainage and prevent ponding of salt brine adjacent to bearings.

SALT VULNERABLE AREAS

Most major new road improvements will go through an environmental assessment process that generates and evaluates alternatives on the basis of their environmental impacts. When generating alternatives, transportation planners should take into account the location of salt vulnerable areas and avoid them to the extent possible. Where avoidance is not possible, route location and roadway design should endeavor to minimize the potential for salt runoff and spray to cause adverse environmental effects. This could include effective stormwater management (see the Drainage and Stormwater Management Synthesis of Best Practices), use of pavements that minimize spray (see the Pavements and Salt Management Synthesis of Best Practices) and the selection of alignments on the downwind side of salt vulnerable areas.

The planning and design of industrial, residential, commercial and institutional facilities should protect salt vulnerable areas, where possible, and everywhere incorporate salt management strategies to reduce or eliminate the potential adverse effects of salt impacted drainage on vulnerable areas.

MONITORING

Facility owners should monitor their roadways/sites and identify areas that are prone to drifting and icing problems. This will allow for a proactive approach to drift control and resolving shading problems. Maintenance-related design issues should be brought to the attention of the designers so that problems can be corrected in future designs.

RECORD KEEPING

There are no special salt-related records that need to be kept with respect to facility design although it would be advisable to document any specific actions taken to reduce salt impacts during design. This may help in obtaining approvals in sensitive areas.

TRAINING

There is a definite need to incorporate winter maintenance considerations into facility planning and design. Many high salt use areas can be avoided through proper location and design. Road and bridge designers and architects should be given training in winter maintenance so that they can anticipate potential winter maintenance problems arising from specific designs and take corrective measures during the design process. Staff involved in erecting drift control structures should be trained in proper placement and maintenance of these structures.

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4.0 – DRAINAGE

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.

INTRODUCTION

Salt-laden runoff can have adverse effects on the natural environment. The nature and extent of these effects are site specific, and may be temporary or can persist for long periods of time. In some areas, the concentration of chloride in the groundwater and stream baseflow may reach levels sufficient to impair the potability of groundwater or alter aquatic habitat. This Synthesis of Best Practices establishes Guiding Principles to aid in the design of drainage works for existing or new roadways and parking lots, and provides a framework to identify the specific practices that can be implemented to minimize potential effects of salt on the surrounding environment.

This Chapter of the Synthesis of Best Practices does not specifically address the effects of salt-laden runoff and salt spray on vegetation. The Synthesis of Best Practices for Vegetation Management provides information on that aspect of snow and ice control chemicals. It also does not deal with other contaminants in pavement runoff.

RELATIONSHIP TO SALT MANAGEMENT

Most of the salt that is placed on a pavement during snow and ice control operations eventually runs off with the pavement drainage. This drainage enters the

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environment through three primary pathways. The first is through overland drainage or stormsewer systems, ultimately discharging to nearby surface water. The second is infiltration into the ground, potentially entering groundwater. The third is through spray caused by traffic and wind, potentially affecting adjacent vegetation and agricultural crops. If any of these pathways introduce high salt concentrations to salt vulnerable areas, then adverse effects may occur. Proper drainage planning and design can reduce the potential effects on salt vulnerable areas by isolating the drainage from vulnerable areas.

This Synthesis of Best Practices, when used in combination with other policies and guidelines for drainage design, will assist in the responsible selection of drainage management measures. Regardless of the policy framework, the following guiding principles exist for creating an overall management plan that also minimizes salt related effects:

1. Safety is the priority. Drainage design must ensure that pavement runoff is efficiently and safely removed from the travel surface.
2. Drainage design must consider, comprehensively, all drainage related impacts in the formulation of a responsible and effective management strategy.
3. The most significant, potential, long-term impact of salt-laden runoff is impairment of domestic groundwater supply.
4. Drainage design must endeavor to protect the natural environment.
5. Drainage design must be practical and must not impose undue maintenance requirements.

SALT MANAGEMENT PRACTICES

The main purpose of any pavement drainage system is to convey runoff safely downstream to either a natural or man-made drainage system. Management measures should be implemented to ensure that this is done with minimal impact to the infiltration characteristics, water quality, erosion potential, and flood risk of the receiving drainage system. At the onset of any drainage design, sufficient information should be collected to characterize the existing drainage system surrounding and downstream of the paved area.

IMPACT IDENTIFICATION

A detailed surface water assessment should be completed to identify all potential effects to natural features as a result of the paved area. The requirements of the assessment will be defined by the policy framework in the area where the drainage design is being completed. As a minimum, the assessment should include a review of the effects of salt-laden surface water on potable water taken from groundwater sources, sensitive aquatic habitat, agricultural lands, wetlands and wildlife.

Each of these features is described below. Guidelines have been provided to establish the relative importance of each feature as defined by low, medium or high potential for impact. Specific site characteristics may require that other features be considered as well. The impact potential identified for all significant features will assist in the selection of suitable mitigative measures.

Ground Water

The suitability of groundwater for potable use and irrigation can be significantly impaired by the infiltration of salt from pavement runoff. To determine the potential for impact from salt-laden runoff on groundwater, the following questions must be addressed:

- Are there domestic wells near the roadway or parking lot?
- If there are wells, do they draw from a sensitive aquifer (e.g., small, shallow aquifer)?
- Are the surficial unconsolidated materials permeable (e.g., sandy soil)?
- Are there any snow management facilities upstream (i.e. snow disposal sites, snowmelt ponds)?
- The degree of potential impact on groundwater can be determined based on the responses to these questions:
- High: The answer is ‘yes’ to all or first three questions.

- Medium: The answer is 'yes' to the first question and 'yes' to either the second, third or fourth question.
- Low: All other cases.

Aquatic Habitat

Salt-laden runoff may impact aquatic habitat in two ways: sudden pulses of chlorides during spring runoff, and continuous levels of chloride present in the groundwater discharging to the receiving stream. Although both types of effects are a concern, sudden pulses are the greater concern in considering "how much is too much". The following guideline can be used to assess the potential impact:

- High: The receiving watercourse has a permanent baseflow, and the catchment area of the road or parking lot represents more than 10 percent of the catchment area of the stream.
- Medium: The receiving watercourse has a permanent baseflow, and the catchment area of the road represents less than 10 percent of the catchment area of the stream.
- Low: All other cases (i.e. receiving watercourses with no permanent baseflow).

Agricultural Land

Salt-laden runoff can impact crops in cases where there is the potential for water to pond on agricultural lands. This situation can arise where there is poor positive drainage or an outlet has been blocked by ice or debris. Guidelines for assessing potential effects are as follows:

- High: Agricultural land is adjacent to the road or parking lot, and drainage has a high likelihood of ponding or blockage.
- Medium: Agricultural land is adjacent to the road or parking lot, and drainage has a low to moderate potential for ponding or blockage.
- Low: Agricultural land is either outside the road or parking lot runoff influence zone, or there is no agricultural land adjacent.

Wetlands

Swamps, peat bogs, marshes and other types of wetlands can be impacted where runoff is directed to adjacent natural vegetation features. In these cases the runoff may enter the wetland as sheet flow or via a roadside ditch. With very high and prolonged chloride loading, there is the possibility that changes in local plant composition may occur, with the possibility of a reduction in the overall value and diversity of the wetland. Small, perched wetlands that intercept the shallow water table or that are primarily surface water dependant may be most susceptible to chloride loading effects due to their small size and a reduced dilution potential. Large wetlands with extensive catchment areas and high dilution potential are likely more tolerant of chloride loading. Potential effects may be classified as follows for wetlands located adjacent to the roadway:

- High: No clear flow path evident through the wetland and/or small perched roadside wetlands present (<5 ha in size).
- Medium: Poorly defined channel evident through the wetland and/or moderate sized wetland with better dilution potential (5 -20 ha in size).
- Low: Clearly defined channel evident through the wetland and/or large wetland with good dilution potential (>20 ha in size).

Wildlife

Ponded runoff can serve as a salt source for wildlife. The attraction of the wildlife to the saltwater can be a safety hazard. Potential effects may be classified as follows:

- High: located in an area where large mammals (such as elk, big horned sheep, white-tailed deer and moose) are present and where ponding adjacent to the pavement is a current problem or has a high potential based on design limitations and topography.
- Medium: located as above, but ponding is not a current problem or has only a moderate potential based on design limitations and topography.
- Low: located as above, but there is no existing or future ponding problem or large mammals are limited or absent in the area.

Impact Identification Summary

The potential effects of salt on each of the categories can be summarized in a table similar to the following example. This table represents a starting point for identifying appropriate drainage management practices that can be used to minimize the effects of salt on the adjacent environment:

Impact Potential	Feature That May Be Impacted				
	Ground-water	Aquatic Habitat	Agricultural Lands	Wetlands	Ground-water
Not applicable			✓		
Low					✓
Medium				✓	
High	✓	✓			

IDENTIFICATION OF ALTERNATIVE MANAGEMENT PRACTICES

The minimization of salt related effects should be one objective of any management strategy formulated for pavement drainage systems. Unfortunately, the range of potential effects from salt-laden runoff offers considerable challenge to the designer. There are a number of practices that can aid in the management of runoff, however, each practice may mitigate some types of effects while accentuating others. For example, promoting rapid conveyance of runoff to a receiving watercourse will reduce the potential for impairment of potable groundwater while increasing potential effects on aquatic environment.

Although not a comprehensive list of measures available to the designer, nine common alternative management practices are identified below. In most cases, these practices will be required to achieve other drainage objectives. For some sites, combinations of these and/or other measures may be required to effectively minimize effects related to salt rich surface drainage.

Management Practice		Purpose
1	Sheet Flow	Runoff conveyed across grass buffer strips or embankments.
2	V-ditch	Runoff conveyed by ditch to receiving watercourse.
3	Storm Sewer	Runoff conveyed away from sensitive areas using storm sewer system (negligible infiltration potential).
4	Flat Bottom(Trapezoidal)Ditch	Runoff conveyed by ditch with flat bottom ditch.
5	Flat Bottom (Trapezoidal) Ditch with Storage	Runoff conveyed by flat bottom ditch which includes on-line storage to trap sediment and reduce velocities and runoff rates.
6	Dry Basin (Pond)	Runoff directed to stormwater management basin designed to reduce runoff rates and promote sedimentation.
7	Wet Basin (Pond)	Runoff directed to stormwater management basin designed to reduce runoff rates, promote sedimentation and enlarge biological uptake.
8	Buffer Strip and Containment Berm	Berm designed to contain runoff within buffer strip, with positive outlet provided to prevent flooding and sustained water levels.
9	SWM Infiltration Measures	Runoff directed to subsurface with the goal of full infiltration of runoff and promotion of groundwater recharge.

Local drainage policies in different parts of the country may identify additional measures that could be implemented effectively to mitigate drainage effects.

The following table illustrates the merits of each management practice in addressing the potential effects that can result from salt-laden runoff. As the table illustrates, the practices which benefit groundwater effects are typically consistent with those that benefit agriculture, wetlands and wildlife. However, most of these practices have the potential to negatively impact aquatic resources. This table, in conjunction with the ranking summary table prepared at the end of the impact identification process, will help to determine which effects can be successfully mitigated through the use of specific drainage measures.

In most cases conflicts will not arise, and the selection of suitable management practices for minimization of salt effects will be relatively simple. The measures will typically be selected as part of the overall management strategy formulated to achieve other drainage and stormwater management objectives. In cases where objectives are conflicting, the practitioner must review each site on its own merits and set priorities such that the overall effects are minimized.

Management Practice	Characteristics	Feature That May Be Impacted				
		Ground Water	Habitat	Aquatic Lands	Wetlands	Agricultural Wildlife
Sheet Flow	Disperses runoff	×	✓	≈	≈	≈
V-Ditch	Channels runoff downstream.	✓	×	✓	✓	✓
Storm Sewer	Channels runoff with little opportunity for infiltration	✓	×	✓	✓	✓
Flat Bottom Ditch	Channels runoff. Some attenuation of flow rate. Some sediment trapping. Some potential for infiltration.	≈	×	×	✓	≈
Flat Bottom Ditch with Storage	Channels runoff Attenuates flow rate Some sediment trapping Some potential for infiltration	×	×	✓	✓	×
Dry Basin (Pond)	Attenuates flow rate Sediment trapping Potential for infiltration	×	✓	≈	≈	≈
Wet Basin (Pond)	Attenuates flow rate Sediment trapping Potential for infiltration	×	✓	≈	≈	×
Buffer Strip and Containment Berm	Contains and disperses runoff.	×	✓	≈	✓	×
SWM Infiltration Measures	All runoff directed to subsurface for full infiltration	×	≈	✓	≈	✓

Legend:

- ✓ The identified management measure may reduce the level of impact from salt-laden runoff (i.e. the level of impact potential for a feature may be decreased from high to medium, medium to low, etc.).
- × The identified management measure may increase the level of impact from salt-laden runoff (i.e. the level of impact potential for a feature may be increased from low to medium, medium to high, etc.).
- ≈ The identified management measure will have minimal effect on the level of impact potential.

DESIGN REQUIREMENTS OF PREFERRED MANAGEMENT PRACTICES

The policy framework in the area where the design is being completed will define specific design characteristics of the recommended stormwater management measures. In most cases, stormwater management objectives other than salt management will dictate the design requirements.

In addition to local policy frameworks, design information for these measures can be found in numerous technical documents relating to stormwater management.

SALT VULNERABLE AREAS

Drainage designers need to consider the environmental setting into which their drainage system will be placed. Salt vulnerable areas need to be identified and the potential for salt impacted drainage to affect these vulnerable areas must be assessed. Special design modifications to traditional stormwater management measures may be warranted to protect these salt vulnerable areas. Measures may include clay or geosynthetic liners in conveyance ditches and ponds, infiltration ponds where appropriate or use of storm sewers to transport drainage past vulnerable areas.

TRAINING

Since pavement drainage depends primarily on design and not on operations, typical salt management training programs would pay little attention to drainage issues except to teach the concept and importance of proper design.

Training for drainage designers should include design options for managing the adverse effects of snow and ice control chemicals.

MONITORING AND RECORD KEEPING

It is not practical to monitor all runoff from paved areas for chloride levels. However, responsible authorities should consider monitoring salt vulnerable areas. An actual example includes a cooperation of a local municipality and an environmental authority to add chloride monitors to their stream monitoring network. They measured the chloride concentration in the watercourses as they entered the municipality and again as they left the municipality to track fluctuations. There are many complications with such a monitoring program. These include:

- At what frequency will samples be collected?
- Will the sampling be continuous?
- Will the data be communicated back to a central location automatically?
- The sampling stations will likely need power and telephone capability for communicating the data.
- Sampling locations must be protected from vandalism, flooding and ice effects.
- If conductivity is being used as the measure, then it will need to be correlated to chloride levels.
- Data analysis will have to take into account any confounding data such as chlorides entering the environment from other sources (e.g. private uses, water softeners, landfills etc.).

Records should be kept on the chloride or conductivity levels and snow and ice control events to determine how the levels fluctuate around an event. The analyst will want to be able to draw conclusions on whether or not the applications of best salt management practices are having an effect on the chloride levels in the aquatic environment. It will be important to determine whether or not drops in chloride levels can be attributed to improved practices and not just different weather conditions.

ACKNOWLEDGEMENTS

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5.0 – PAVEMENT AND SALT MANAGEMENT

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

INTRODUCTION

This Synthesis of Best Practices has two key purposes. The first is to provide pavement designers with information on methods to mitigate the environmental and pavement impact of road salt through proper pavement design. The second is to provide maintenance staff with information on pavement-related salt management considerations. For further information on the factors identified in this Synthesis of Best Practices the designer should refer to the Road Salt Management Guide- 2013.

RELATIONSHIP TO SALT MANAGEMENT

There are pavement design factors to be taken into account that relate to the ability of pavements to withstand snow and ice control chemicals. These can have a bearing on the way in which winter maintenance is carried out, the melt performance of salt, and therefore the amount of chemical necessary to be used. The pavement designer should make every effort to provide pavement designs that serve to support the minimizing of the use of salt for deicing purposes. Consideration should be given to the following factors affecting salt usage:

- Type of pavement surface.
- Pavement thermal and material properties.
- Environment and climate.

Pavement surfaces generally consist of either concrete

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or asphalt, while pavement structures can be either concrete or asphalt, or a composite of both. Road maintainers do not report significant differences with the pavement variations, although there are subtleties that affect the way snow and ice behave on different surfaces in the winter and how they need to be maintained. The key is to understand how the various pavement types function under different winter conditions.

Because of their light colour and higher thermal mass, concrete pavements tend to heat up and cool down more slowly than asphalt pavements. This heating and cooling occurs differently at different times of the year, depending on the temperature of the underlying materials. This makes monitoring of pavement temperatures critical to making accurate snow and ice control decisions. Asphalt pavements can heat up to considerably higher temperatures during the day and, once the solar effect is gone after sunset, cool down more quickly than adjacent concrete pavements.

For snow to melt or for a solid salt to dissolve to form a solution, heat is required (i.e. endothermic reaction). While traffic tire action can provide some of the required heat, in most cases this heat is drawn from the pavement.

Concrete pavements are less pervious than asphalt and tend to shed brine more quickly than aged asphalt surfaces, and therefore can be prone to more rapid refreeze than more porous asphalt pavements. Winter conditions on concrete surfaces need to be monitored closely and may require more frequent applications of snow and ice control chemicals or more quantity based on the pavement temperature trends. The surface may also be grooved to increase drainage, improve wet weather friction and reduce noise. This grooving, however, also removes brine more quickly and may reduce the formation of residual chemical crystals on the road surface as the pavement dries. Transverse grooving does reduce splash and spray from concrete pavements. This would be beneficial near areas that are sensitive to salt spray. However, this may be offset by the increased usage of salt necessitated by the rapid surface drainage.

Because of the rigidity of concrete and the crossfall controls during construction, there are often fewer imperfections in the crossfall than with asphalt/flexible pavements that can develop rutting from in-situ compaction and other surface undulations. Therefore, with concrete surfaces there is less likelihood of "puddling" or "ponding" in the wheel tracks. This has both pros and cons. The benefit is that there is less likelihood of refreeze in the wheel track, and there can be a more consistent distribution of brine across the crossfall. On the other hand, there is less concentrated chemical retention to keep the wheel tracks from icing up.

Asphalt pavements can have different porosity depending on the construction, and this porosity can change over time as the asphalt wears and oxidizes. Open Friction Course (OFC) pavements are often used because of the improved drainage and reduced noise – they are a quieter pavement. The OFC in facilitating drainage also reduces spray. This reduced spray can be beneficial in proximity to areas that are vulnerable to salt spray.

A good crossfall on any pavement will permit the placement of chemicals on the crown or the high side of the road and allow for the slope of the pavement and traffic to distribute the chemical down the driving surface. This tends to keep the chemicals on the road longer. Higher slope percentages tend to shed the chemical "brine" more quickly; in this regard, a 2% crossfall on tangent is preferred over a 3% crossfall. Poor crossfall due to deterioration of the pavement necessitates broadcast spreading, leading to greater loss of chemicals to the ditch.

Porous concrete pavements are designed to channel water into the ground more quickly. These were designed to promote water recharge into the ground rather than encouraging surface runoff (and, often, reduce traffic noise impacts on neighbours). A concern is that this also will promote infiltration of salt impacted water that would have adverse effects in salt vulnerable groundwater areas. These pavements will also rapidly remove salt brine thus reducing the retention of deicing chemicals potentially requiring more frequent applications.

SALT MANAGEMENT PRACTICES

Road salt does not generally damage properly designed, constructed and well maintained pavements, however there is some potential for magnesium chloride to react chemically with cement paste and

affect the structural integrity of concrete over time. The corrosivity of snow and ice control chemicals can be reduced by the use of additives. The following discusses the potential effects of salt on pavements and best practices for pavement design. It also discusses some winter maintenance considerations related to the type of pavement surface.

Effects of Salt on Pavements

The typical salt-related damage to flexible and rigid pavements listed below is described in further detail in the section that follows:

- Salt can accelerate damage to some poorly designed or constructed hot-mix asphalt pavements.
- Salt can cause scaling of concrete pavements and concrete pavers.
- Salt can cause spalling of steel reinforced concrete by accelerating steel corrosion.
- The brine resulting from road salt use can damage some thin, cracked or poorly drained flexible pavements by causing differential frost heaving at the pavement edge or at unsealed cracks.
- The magnesium in magnesium chloride may react with the cement paste in concrete, weakening the pavement structure.

Pavement Design

The design and evaluation of new pavement alternatives requires the pavement designer to identify subgrade conditions, drainage mechanisms, climatic data, material properties, traffic data, pavement geometry, constructability and life-cycle costs. The designer should review the advantages, disadvantages and costs to develop an appropriate solution for each situation. If pavement materials do not have proven performance, they should be tested before construction to ensure they are durable.

The principal design considerations to reduce salt impacts on pavements include:

- Improving resistance of asphalt pavements to moisture susceptibility by:
  - Follow standard specifications for asphalt mix designs.
  - Conducting anti-stripping testing of the materials and mix designs to be used in construction.
  - Specifying suitable compaction requirements and testing procedures.
  - Ensuring that both QA and QC procedures are specified to ensure that the material produced complies with the mix design proportions and includes the necessary anti-stripping agents.
- Improving resistance of asphalt pavements to moisture susceptibility by:
  - Following standard specifications for asphalt mix designs.
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  - Specifying suitable compaction requirements and testing procedures.
  - Ensuring that both QA and QC procedures are specified to ensure that the material produced complies with the mix design proportions and includes the necessary anti-stripping agents.
- Improving resistance of rigid/concrete pavement and concrete pavers to scaling by:
  - Ensuring that durable concrete, which will resist the action of freezing and thawing and de-icing salts, is specified. The concrete should comply with CSA-A23.1.
  - Ensuring that mix designs include certification that the aggregates, cement and other materials used comply with CSA-A23.1 requirements.
  - Ensuring that the air voids system in the hardened concrete complies with CSA-A23.1 requirements.
- Improving the resistance of embedded reinforcing steel, tie bars and dowel bars to corrosion by:
  - Ensuring that the minimum concrete cover over reinforcing steel meets the requirements of CSA-A23.1. Provision of additional cover to provide some tolerance during construction is also desirable.
  - Ensuring that bridge deck joint design, particularly the shape of the longitudinal and transverse seal reservoirs, is selected to

maintain a positive seal for the longest possible time. The designer should refer to American Concrete Pavement Association's (ACPA) joint and crack sealing guide.

- Ensuring that the seals for longitudinal and transverse joints are made of durable materials.
- Ensuring that dowels and tie bars are resistant to corrosion by using epoxy coated steel or corrosion resistant steel.

- Mitigate the damage caused by brine infiltration into flexible/asphalt pavements by:
  - Designing pavements that are resistant to cracking by providing adequate pavement structure for the climate, sub-grade and traffic conditions.
  - Designing asphalt pavements with an appropriate thickness consistent with best management practices.
  - Designing partially or fully paved shoulders for roadways constructed with a rural cross-section that shed the brine away from the traffic lanes where it can cause less damage are desirable.
  - Specifying that asphalt mixes with asphalt cements are resistant to thermal and fatigue cracking. Designers should select suitable grades of asphalt cement using appropriate standards or guidelines.
  - Providing a suitable internal drainage system as part of the pavement structure to drain away any infiltration that does take place. This includes the provision of base and sub-base layers that are permeable enough to drain rapidly and designing suitable outlets to allow the water to drain away.
  - Limiting the fines content of the base granular material (passing the 75 mm sieve) to around 8 percent maximum for gravel sources and 10 percent maximum for quarried sources is desirable.
  - Where drainage is a major concern, a limit of 5 percent fines content is desirable.

Construction

Designers should provide suitable project specifications to ensure good construction practices and quality materials. Contracts should include provisions for Contractors to carry out Quality Control (QC) testing to ensure materials meet the specification requirements and provisions for owner's Quality Assurance (QA) testing to verify results.

Applying Road Salts

- Snow and ice control decision-making should be based on pavement temperatures rather than air temperatures.
- Pavement surface temperatures can fluctuate significantly depending upon the time of day, degree of cloud cover, sub-surface conditions (i.e. frost penetration, moisture presence, thermal retention properties, etc.) and type of pavement. Therefore ongoing monitoring of pavement temperatures is important to good decision-making.
- On roads, solid road salts should be windrowed on the crown or high side of the driving surface where a good crossfall and traffic will distribute the resulting brine over the road.
- Wider spread patterns are called for when spreading on deteriorated pavements where an undulating surface or poor crossfall will not ensure adequate chemical migration across over the entire road, or on parking lots and sidewalks where traffic will not adequately distribute the chemical.
- Applying liquid melting agents or pre-wetted salt can prevent or clear frost more quickly than solid salt. A straight liquid will avoid the endothermic cooling effect that solid salt can have on pavements.

SALT VULNERABLE AREAS

Though open friction course asphalt or grooved concrete pavements will shed surface brine more quickly, they can reduce salt spray and therefore may be beneficial in proximity to areas that are vulnerable to the effects of salt spray.

Porous concrete pavements can be highly detrimental to vulnerable groundwater resources due to promotion of rapid infiltration of salt impacted water and should be avoided in these areas.

MONITORING AND RECORD KEEPING

Pavement temperatures should be monitored to assist in making decisions. This can be done when mobile using hand held or truck mounted infrared thermometers. Road Weather Information Systems can provide a surface and subsurface pavement temperature at a fixed location, and can support the generation of a pavement condition forecast as well as real-time pavement condition information. The subsurface probe can also help in making seasonal load restriction decisions.

Pavement temperature trends should be recorded in daily logs, along with pavement conditions, weather conditions and winter treatment strategy.

Pavement temperature monitoring equipment should be tested at least annually to ensure that they are operating correctly. Inaccurate equipment should be recalibrated, repaired or replaced.

TRAINING

Training is described in detail in the Training Synthesis of Best Practices. The following pavement related topics should be included in a Salt Management training program.

- Understand the role of pavement crossfall in snow and ice control and when to windrow and when to broadcast chemicals.
- Understand the importance of pavement surface temperature on snow and ice control decision-making.
- Understand how to measure pavement temperature trends.
- Understand what factors can affect pavement temperatures and how knowledge of these factors can be used to predict temperature changes.
- Understand how to treat different pavement conditions during different types of weather events.

CONCLUSION

Generally, good pavement design and construction will help resist the negative effects that snow and ice control chemicals can have on pavement structure integrity.

Also, good pavement design can help improve the performance of the winter chemicals that are applied, leading to reduced usage for the same or better level of service and safety, and thus lessened environmental impact.

Road maintainers need to understand pavement temperatures and how these temperatures can vary, throughout both the day and the winter season, in order to make proper treatment decisions.

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6.0 – VEGETATION MANAGEMENT

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INTRODUCTION

De-icing salt has the potential to negatively impact vegetation (including agricultural crops). Sometimes these impacts can be quite serious. There are several measures that can be taken to help reduce these negative impacts, but short of discontinuing salt usage they cannot be entirely eliminated. Designers should try to implement as many measures as possible.

RELATIONSHIP TO SALT MANAGEMENT

Effective salt management practices can reduce the amount of salt entering the environment. Implementation of the practices discussed in the other chapters will go a long way towards reducing salt loadings to the environment. In areas where road salt must continue to be used to maintain roadway safety and assured access, road authorities should identify salt vulnerable vegetation and agricultural operations and should implement appropriate best management practices on roadways adjacent to these areas.

SALT MANAGEMENT PRACTICES

Minimizing the Impact of Salt Spray

Where road salt spray is problematic, consider whether lower application rates for road salts can deliver accept-able service levels. Where road salt continues to

CONTENTS

be an issue, there are several precautionary measures that can be taken to avoid negative impacts on vegetation as a result of de-icing salt spray accumulating on foliage and branches.

Optimizing Salt Use

The other Syntheses of Best Practices identify many methods for optimizing salt use that will help to reduce the vegetative impacts of winter operations. Some of these include:

- plan and design roadways to avoid areas where vegetation and agricultural areas are salt sensitive
- apply salt at optimal rates in a proactive manner to prevent ice from bonding with the pavement
- use liquid anti-icing or pre-wetting to reduce the amount of salt lost to the ditch due to blowing or bouncing
- use properly calibrated electronic controllers to ensure that material application rates are accurately regulated
- use pavement temperature sensors and good road weather information to ensure that salt is applied only when needed
- use effective plowing to optimize salt use
- use snow drift control techniques to minimize the amount of snow blowing onto the roadways that in turn will reduce the need for salt

Plant Species Selection

Landscape planting should try to:

- always plant salt tolerant species in areas subject to salt spray (Attachment 1 provides a list of salt tolerant species)
- plant vegetation in groups to maximize protection afforded by other vegetation

Location Selection

When selecting where to place vegetation the following should be considered:

- do not plant salt sensitive species within salt spray limits
- if salt sensitive species must be used within salt spray limits, locate the plants on sites elevated above the roadway surface to minimize salt spray coverage, or in areas physically protected from salt spray

Maintenance and Prevention

To ensure long-term survival of vegetation:

- in urban areas protect newly planted conifers by erecting burlap screens during the winter months
- in urban areas consider applying anti-desiccants and anti-transpirants (e.g. gypsum) to the tender shoots of sensitive plants
- sweep salt laden grit from turf areas as soon as possible in the spring
- shield natural areas from salt spray by planting buffers of salt tolerant species
- where feasible and cost-effective consider using snow fences (living or structural) to reduce snow accumulation on roadways or to trap salt spray and prevent it from traveling far from the roadway

Minimizing the Impacts of Salt Laden Runoff

There are several precautionary measures that can be taken to avoid negative impacts on vegetation as a result of plant roots absorbing salt from the soil and soil water.

Species Selection

Landscape planting should try to:

- use species tolerant of salt laden runoff (see Attachment 1)

Location Selection

To minimize runoff impacts:

- avoid planting sites in heavy runoff collection areas such as depressions
- landscaping should be planted on the back side of ditches to permit maintenance access and ensure that salt laden roadway runoff is not directed towards plants

Drainage Design

When designing drainage facilities:

- place shallow ditches along roadsides or swales around sensitive vegetation to divert salt runoff away from sensitive species
- incorporate salt splash barriers into median design to redirect and channel away salt spray and water runoff
- ensure that drainage designs minimize springtime ponding of salt laden water around sensitive vegetation
- use hard surface treatments in urban areas heavily impacted by roadway deicing salt

NOTE: For additional information refer to the Drainage and Stormwater Management Synthesis of Best Practices.

SALT VULNERABLE AREAS

The impact zone for salt spray is generally confined to the right-of-way of most low volume roads. However, with high volume roads this spray can extend to areas off the right-of-way, especially on the downwind side. Salt vulnerable crops and vegetation in these impacts zones can be affected. Road authorities should identify these areas, evaluate the economics of replacing salt vulnerable crops with salt tolerant alternatives and consider introducing improved salt management practices on roadways in salt vulnerable areas on a priority basis. Attachment 2 provides a listing of field and forage crops and their salt sensitivity.

MONITORING

Regular monitoring of salt spray impacts to vegetation is not routinely carried out. However, road authorities should monitor salt usage in salt vulnerable areas to ensure that only the desired amount is being used.

RECORD KEEPING

In order to show due diligence in proximity to salt vulnerable areas, road authorities should maintain records of salt usage.

TRAINING

Training programs should identify the location of salt vulnerable areas and train operators in these areas on the best practices being employed. Training may also include proper wrapping of salt vulnerable species prior to the winter, if appropriate.

ATTACHMENT 1

Anything listed as invasive by Invasive Species Canada:http://www.invasivespecies.gov/ or provincial, territorial or municipal agencies should not be planted.

Salt Tolerant Roadside Trees

Salt Tolerant

Common Horsechestnut (Aesculus hippcastanum)

- Serviceberry (*Amelanchier canadensis*)
- Maidenhair Tree (*Ginko biloba*)
- Honey Locust (*Gleditsia triacanthos*)
- Tulip Tree (*Liriodendron tulipifera*)
- Colorado Blue Spruce (*Picea pungens glauca*)
- Mugho Pine *(Pinus mugho*)
- Austrian Pine (*Pinus nigra*)
- Jack Pine (*Pinus banksiana*)
- Hop Tree (*Ptelea trifoliata*)
- White Oak (*Quercus alba*)
- Red Oak (*Quercus rubra*)
- English Oak (*Quercus robur*)
- Black Locust (*Robinia pseudoacacia*)

Moderately Salt Tolerant

- Amur Maple (*Acer ginnnala*)
- Manitoba Maple (*Acer negundo*)
- Yellow Birch (*Betula alleghaniensis*)
- Paper Birch (*Betula papyrifera*)
- White Ash (*Fraxinus americana*)
- Large-toothed Aspen (*Populus grandidentata*)
- Trembling Aspen (*Populus tremuloides*)
- Cottonwood (*Populus deltoides*)
- Black Cherry (*Prunus serotina*)
- Japanese Pagoda Tree (*Sophora japonica*)
- Eastern White Cedar (*Thuja occidentalis*)

Salt Intolerant

- Balsam Fir (*Abies balsamea*)
- Red Maple (*Acer rubrum*)
- Sugar Maple (*Acer saccharum*)
- Silver Maple (*Acer saccharinum*)
- Eastern Redbud (*Cercis canadensis*)
- Shagbark Hickory (*Carya ovata*)
- Black Walnut (*Juglans nigra*)
- Ironwood (*Ostrya virginiana*)
- Norway Spruce (*Picea abies*)
- Red Pine (*Pinus resinosa*)
- White Pine (*Pinus strobus*)
- Scot's Pine (*Pinus sylvestris*)
- London Plane Tree (*Platanus acerifolia*)
- Douglas Fir (*Pseudotsuga menziesii*)
- Basswood (*Tilia americana*)
- Littleleaf Linden (*Tilia cordata*)
- Hemlock (*Tsuga canadensis*)

Salt Tolerant in Roadside Shrubs

Salt Tolerant

- Silverberry (Elaeagnus commutata)
- Sea Buckthorn (Hyppophae rhamnoides)
- Common Ninebark (Physocarpus opulifolius)
- Choke Cherry (Prunus virginiana)
- Staghorn Sumac (Rhus typhina)
- Buffaloberry (Shepherdia canadenis)
- Snowberry (Symphoricarpus albus)
- Japanese Tree Lilac (Syringa reticulata)

Moderately Salt Tolerant

- Forsynthia (Forsynthia ovata)
- Red Cedar (Juniperus virginiana)
- Mock Orange (Philadelphus coronarius)
- Smooth Sumac (Rhus glabra)
- Elderberry (Sambucus canadensis)

Salt Intolerant

- Grey Dogwood (*Cornus racemosa*)
- Red-osier Dogwood (*Cornus stolonifera*)
- Winged Euonymous (*Euonymous alatus*)
- High-bush Cranberry (*Viburnum trilobum*)

ATTACHMENT 2

SALT SENSITIVITY OF FIELD CROPS AND FORAGE CROPS

SENSITIVE	MODERATE TOLERANCE	TOLERANT
CornSoybean White Bean Red Clover Alsike Clover	Canola Wheat Barley Oat Reed Canary Grass Meadow Fescue Intermediate Wheatgrass Crested Wheatgrass Bromegrass Alfalfa Sweet clover	Tall Wheatgrass Slender Wheatgrass

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7.0 – DESIGN AND OPERATION OF MAINTENANCE YARDS

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INTRODUCTION

A Maintenance Yard is the location from which snowfighting agencies and companies stage their maintenance operations. Yards may be small, as in the case of a contractor facility or large and complex and as in the case of some road agencies. Agency yards may be dedicated to operating a single department like Roads or shared with other operating groups such as Sewer and Water, Waste and/or Parks Maintenance. They are referred to by a variety of other names including: patrol yards, camps, garages or depots. For the purposes of this document however we will refer to these facilities, either dedicated or shared, as Maintenance Yards. It is common that road maintenance work will be carried out from several road maintenance yards located throughout the area serviced by the snowfighting agencies and companies. Often in the past, these yards were located where land was in surplus or inexpensive for them to obtain. Little site engineering was used in determining the locations of the buildings on site and the functionality of the facilities simply evolved over time to match the needs of the department. Their impact in the local environment was not a major consideration in determining location or design and construction.

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This Chapter of the Syntheses of Best Practices is intended to present the salt management and environmental considerations that should be taken into account when locating, designing, operating and maintaining maintenance yards. There are many other considerations, particularly related to safety, that are unrelated to salt management that are not addressed in this document, but that should be taken into account when designing and operating maintenance yards.

The role of a maintenance yard can vary from being the central location for maintenance operations (including administration functions) to simply serving winter operations only. The practices described in this chapter apply to both.

This Synthesis of Best Practices includes:

- planning
- site selection
- designing a functional facility
- salt storage
- site drainage
- brine production
- site operation and maintenance
- monitoring
- record keeping, and
- training.

In general, maintenance yards are constructed for multiple purposes including the delivery of winter maintenance services.

For winter operations, there is a strong need to focus on salt loss, whether in the form of airborne salt dust, brine runoff, wastewater discharge from vehicle washing and surface drainage or simple loss of road salts through improper handling practices. Lost salt will dissolve and can infiltrate into the soils below and adjacent to the site. Components of road salt entering the environment can travel great distances and affect wells, vegetation, groundwater and surface water where the groundwater emerges as springs or discharges into streams.

There are cases where road authorities have had to replace salt impacted wells and the resultant corroded appliances of affected homeowners or install filtration systems (e.g. reverse osmosis systems) to remove contaminants.

In addition, salt impacted runoff can affect vegetation and agricultural operations, on and adjacent to yards, as well as any downstream aquatic habitats where the salt impacted water collects.

Good yard design and salt handling practices are essential to preventing unnecessary salt loss and the resultant environmental impacts.

The Yard In Action

The yard layout should be designed to be efficient in all activities. Considering the cycle of handling road salts in the yard may reveal potential enhancements that can be made to improve yard efficiency and reduce salt loss. It is assumed that a new maintenance yard would include some or all of the following:

- an office, lunch, wash and utility rooms
- parking areas for staff vehicles and maintenance equipment
- a vehicle maintenance garage
- winter materials storage facilities
- winter materials handling area
- indoor vehicle washing area
- a garage and/or shed for maintenance equipment and materials
- outside material storage area (e.g. gravel, posts, etc.)
- brine production and storage areas
- brine loading areas, and
- washwater and impacted surface water recycling system for brine production.

The typical salt handling cycle flows from delivery, to stockpiling, to loading onto the spreader and then to exiting the yard. Upon return, the spreader off-loads unspent salt (preferably indoors), and the equipment is then washed to remove remaining salt residue.

Each area affected by these activities can provide an opportunity for improvement.

Typically, a delivery transport trailer end dumps or off loads the salt via a longitudinal conveyor. Preferably, the storage facility has been designed and constructed to allow the salt to be unloaded directly inside. If unloaded outside, the salt must be moved into the storage facility.

Ideally, the salt should not be "double handled." In some cases salt is blown into storage facilities using a closed pipe system to eliminate double handling. Whether mechanically piled or blown, each handling can cause particle breakdown, segregation and loss. While handling can serve to break up any chunks that may be present, this double handling is inefficient. It also allows for a greater wind-blown loss of salt and the loss of salt fines that are remaining on the outdoor surface.

Loading and overloading spreader vehicles are potential sources of spillage. Improperly sized loaders and careless loading cause excessive spillage.

Where liquid melting agents are used, spillage of liquids can occur during production, delivery and transfer to spreaders.

It is not always necessary to spread the full load of material. Operators should be instructed to spread only what is needed to achieve the prescribed level of service. Unused materials must be returned and offloaded to the storage facility.

To minimize corrosion, spreaders are washed following a storm. The washwater is likely contaminated with dirt, oil, grease and salt (chlorides).

The washwater can be directed to a storage tank and used to make brine. Where washwater is used for brine production it is important that all reclaimed water be directed through a properly designed oil and grit separator (OGS) prior to use and that only detergents or de-greasers that are suitable for an OGS be used in the washing operations. Note: Local regulatory requirements may affect the ability to use washwater for brine production.

If not reclaimed for brine production the washwater should be directed to a sanitary sewer. If no sanitary sewer is available the washwater should be directed to a properly designed storm water management pond. Such ponds usually have designs which encourage the deposition of fines and heavy particles in a fore bay area and a secondary area where the salt impacted water can be diluted with surface drainage from the non-impacted areas of the yard to lower the salt component concentrations prior to discharge into a ditch or receiving body. The water that is collected should be periodically monitored/ checked to ensure compliance with release concentration requirements.

To summarize, salt is lost to the environment in a variety of ways during the salt handling process. These include:

- spillage of solid salt during delivery, mixing of sand/ salt blends, stockpiling and loading/ overloading of spreaders being carried away in the surface drainage of the yard
- salt being dissolved from uncovered stockpiles of salt and sand/salt blends
- spillage of liquid deicing chemicals during production, delivery, transfer to spreaders or tank/ line failures
- vehicle washing, and
- blowing salt dust from exposed piles.

Guiding Principles

When planning, designing and operating a winter maintenance yard, the following guiding principles should apply.

- Locate the yard(s) at strategically efficient location consistent with local land use plans and/or regulations.
- Locate and operate storage sites to minimize impacts to the natural environment and control nuisance effects, including noise, dust, litter and visual intrusion on adjacent landowners. Carry out Salt Vulnerability Mapping of the candidate areas and select areas that are less vulnerable to salt impacted drainage water.
- Place stockpiles inside storage structures.
- Use low permeable surfaces to minimize infiltration.
- Collect and reuse or properly manage salt impacted site drainage and vehicle washwater to comply with local water quality regulations and protect surface and groundwater resources.
- Promote indoor operations where possible.
- Handle materials and clean up spilled salt to minimize salt loss to the environment.
- Collect and dispose of onsite contaminants and wastes in accordance with local waste management legislation.
- Control emissions (drainage, noise, dust, litter, fumes) to prevent off-site environmental impacts.

SALT MANAGEMENT PRACTICES

Planning

While summer activities may dictate the core staffing needs, winter route times and service levels are the determining factors in establishing the numbers of staff and equipment that must be allocated and housed at each yard. Whether consolidating or constructing at new locations, there is more to consider than simply efficiency improvements. The re-evaluation of yard needs provides an opportunity to achieve the most functional design with positive economic and environmental returns.

A general yard location is dependent upon:

- control of emissions (drainage, noise, dust, litter, fumes) to prevent off-site environmental impacts
- the needs of the organization
- optimization of route times calculated to meet a required level of service, given equipment capabilities, and
- environmental considerations.

The supervisor of winter operations may not be able to make immediate changes to the winter equipment fleet. However, over time, as the winter fleet is improved, there will be more efficient use of resources. This will help to maximize the effectiveness of salt used, and to optimize the number of maintenance yards needed.

Site Selection

Next to the proximity and access to the road network to be serviced, it is important to assess site physiography and topography when choosing a new site. Ground conditions (soils or rock) and the lay-of-the-land complement the drainage management objectives.

For example, unlike granular bases, clay bases will prevent rapid infiltration of salt laden water. Conversely, highly permeable soils almost always allow the surface water to reach the ground water table. This may not be a serious concern if there is relatively quick outlet to a tolerant watercourse or the runoff is captured, contained and managed, but uncontrolled runoff can generate considerable liability if the groundwater impacted by salt becomes a well water source.

A site that has natural surface drainage will limit the impact on groundwater. Underlying soil and rock characteristics, groundwater use and characteristics, and proximity to, and sensitivity of surface water should be understood to evaluate potential impacts from the presence of salt. For example, a site with a deep groundwater table will limit the potential for groundwater contamination from salt and hydrocarbons.

It is also important when selecting a site for a maintenance yard to understand the long-term land use plans around the potential site. If a development based on groundwater sources for its water supply is to be located down gradient from the maintenance yard then the organization could face a future liability due to salt impacts to the groundwater.

A properly conducted environmental impact assessment, emphasizing the risks associated with salt loss pathways, will help to ensure that an appropriate site is selected and that proper considerations go into facility design.

When planning and designing maintenance facilities, salt vulnerable areas must be taken into consideration and avoided to the extent possible. Where they cannot be avoided, specific measures should be included in the design to protect vulnerable areas.

Salt vulnerable areas could include:

- bodies of water with low dilution, low volume or salt sensitive species
- salt sensitive vegetation and agricultural operations
- sources of drinking water (i.e. surface water and groundwater), and
- groundwater recharge zones or shallow water table, with medium to high permeability soils.

The assessment of alternative sites should consider the potential chloride loadings to salt vulnerable areas and whether or not these loadings could have any adverse effects. Sites that have the potential to adversely affect vulnerable areas even after applying best management practices should be eliminated from further consideration.

Design

Maintenance yards are often multi-functional facilities. A maintenance yard can be an evolving design. All functions conducted at the yard must be considered in designing the most suitable layout and features for the yard. The designers should consult with the people who will work at the facility when laying out the flow of the yard. The yard should be laid out to permit vehicles involved in the salt-cycle to move efficiently and safely about the site. The design should be flexible enough to allow the yard to be expanded as service delivery areas increase, or to be retrofitted to satisfy the latest method or policy change.

A Winter Maintenance Area (WMA) is a paved area of a maintenance yard where all salt materials will be handled and vehicles will operate. Its purpose is to isolate those activities in order to contain and manage salt-impacted drainage. As such, all activities that can lead to salt-impacted drainage should be located within the WMA. Such activities include:

- sand-salt mixing
- salt deliveries
- salt loading
- material storage
- access routes
- equipment washing, and
- snow storage (i.e. salt-impacted snow cleared from the yard).

Also designers should consider the following:

- The size of the WMA should be minimized to reduce the amount of salt-impacted run-off that needs to be managed.
- Avoid inclines that would require additional salting or sanding to gain traction during winter months.
- All activities not involving salt management should be located outside of the WMA.
- The WMA should be constructed on a pad with low permeability (e.g. 100 mm of high strength asphalt underlain with a low-permeability membrane) to limit infiltration of salt-impacted drainage. A small berm or curb (e.g., 150 mm asphalt curb) should be placed around the WMA to direct drainage.
- Drainage ditches conveying salt-impacted run-off should be of low permeability (e.g., asphalt lined).
- Drainage inside the WMA should be directed to containment where it can be tested and properly managed. Containment options include storage ponds and tanks. Testing will depend on management options which may include:
  - release to the environment
  - removal by licensed waste-hauler, or
  - directing the salt-impacted run-off to an oil/grit separator and then possibly to containment for brine production.
- Containment (e.g., storage ponds and tanks) must be designed to contain the drainage. Also, consideration should be given to the consequence of containment failure and back-up options to reduce deleterious impacts. Containment must be designed to contain the drainage from the WMA using annual precipitation data and pump-out frequency. Storage pond design considerations include:
  - sloping the bottom to allow for collection of water for disposal
  - lining the bottom to prevent infiltration of brine; constructing the pond with clay, a sand base, an UV stable 30-mil liner and sand top layer
  - providing a fore-bay area to settle out heavier suspended solids
  - allowing for sufficient freeboard to handle normal precipitation events
  - providing escape routes (e.g., tires roped together) for anyone falling into the pond
  - fencing the pond for security, and
  - pond agitator may be required to prevent mosquitos from breading (nuisance and disease prevention).
- Drainage from outside of the WMA (non-salt impacted) should be directed off-site in a way that minimizes off-site impacts (for example, to a storm water management pond).

A yard which has ample size and access, and which has managed drainage is a facility which:

- is safe from which to operate
- is cost effective to use
- facilitates the management of site drainage and vehicle wash water
- protects salt vulnerable areas
- generates limited liability
- provides indoor storage for all salt and sand/salt blends, preferably large enough to allow indoor delivery and spreader loading
- notes the prevailing winter wind direction and positions the building and doors with regard to sheltering loading operations; minimizing snow drifting around doorways, and keeping precipitation out of the storage areas
- provides proper lighting to help ensure safe and accurate salt loading operations when visibility is reduced during a storm event, especially at night
- properly spaces buildings and material storage facilities (e.g. liquid storage tanks) in order to maneuver vehicles properly and safely
- properly locating the office building with a viewing window suitable for observing the loading area (to confirm numbers of trucks, sizes of loads and general yard activity)
- constructs storage facilities on low permeability pads to limit infiltration of salt laden drainage
- constructs the loading pad of asphaltic concrete or other low permeability material at the entrance of the facility
- provides for the interception and management of salt impacted drainage
- locates parking, fuelling and loading/ unloading areas as well as paved pathways to permit efficient vehicle movements and limit backing operations
- locates catch basins properly, with hook-ups to avoid directing salt-laden runoff through storm sewers into salt vulnerable watercourses, or directly into the ground through poorly sealed sumps
- identifies snow storage around the yard perimeter to lessen the impacts of salt-laden melt water (see the Snow Storage and Disposal Synthesis of Best Practices)
- locates the potable water well for the maintenance yard up-gradient to prevent it from being impacted by site operations
- installs security fencing
- installs outlets for block heaters for vehicle readiness, and
- installs berms and screening to reduce nuisance omission such as dust and noise and reduce unsightliness of outdoor storage.

Storage

Solid salt stockpiles should not be exposed to wind, rain or snow. Dissolved salt does not “disappear”, but rather enters the site drainage and creates problems off-site.

Therefore, proper storage of salt and sand/salt blends requires that they be covered to protect them from the elements. Salt and blended abrasives should be stored inside storage facilities located within the WMA.

The following should be considered when designing storage facilities:

STRUCTURAL

Structure designs range from the traditional dome, to rectangular sheds or barns, to high arch structures, to elevated silos. Storage structures can be made of different materials including wood, steel, aluminum, fiberglass or fabric.

Consideration should be given to the multiple function of storing sand with salt or other winter operations materials. Some structures provide a more efficient capacity than others depending on the intended methods of putting up the piles as well as in using the materials.

Consideration should also be given to the prevailing winter wind direction and channeling when siting and orienting the building. Where possible, position the building and doors to shelter loading operations, minimizing snow drifting around doorways and keeping precipitation out of the storage areas.

STORAGE CAPACITY

- The structure should be sized taking into account the seasonal needs, the reliability of the material source and the delivery frequency and timing possible during the winter season. The volume housed should include a contingency quantity to ensure that the supply will not run out in times of need or in the event of supply problems. This allows flexibility in the delivery of material to minimize potential environmental impacts caused by inclement weather.
- Structures should be sized so that materials are fully contained and do no extend outside the building. Likewise the capacity should not be exceeded.
- Where there is insufficient capacity to store all the materials inside the structure then tarps should be used to protect salt from the elements.

CONSIDERATIONS FOR INDOOR STOCKPILING AND SPREADER LOADING

- Indoor storage for all salt and sand/salt blends should be large enough to allow indoor delivery and spreader loading.
- Spillage during stockpiling and spreader loading is an important source of salt loss. The extent to which these activities can be carried out under cover will minimize salt loss.
- The design should accommodate the method of "putting up the pile". There should be sufficient room to minimize material handling and the associated dust.
- Note: there are special considerations when selecting the storage facility design to permit indoor activities. The two most significant ones are ventilation and roof and door clearances.

Ventilation

- Ventilation is required for vehicle exhaust and dust.
- Carbon monoxide (CO) monitors/alarm systems are required.

Roof and Door Clearances

- The door and roof structure should be high enough to allow a transport trailer to end dump inside the structure. On rectangular structures, end doors are advantageous.
- The entrance to the storage structure may have a door, curtain or a sufficient overhang to minimize precipitation entering the structure.
- Operational access and egress to the structure should be considered in entranceway layout.

BASE

- To maximize storage capacity on the smallest footprint, the trend is to enclose the base of the pile and support the structure on a concrete wall, with or without a footing. These walls need to be designed to withstand the strain of materials and loaders pushing against them. They should be free of gaps that would allow salt or salt-impacted drainage to escape. Any gaps that could permit the release of salt from the storage structure or the entrance of water into the structure should be sealed.

ROOF AND EXTERIOR

- The roof and exterior of the storage structures shall be constructed of waterproof material such that precipitation and moisture are prevented from entering the building.

LIGHTING

- Proper lighting should be provided to help ensure safe and accurate salt loading operations when visibility is reduced during a storm event, especially at night. Emergency power backup may be required so that operations can continue during periods of power outages.

FLOOR

- The floor of the structure provides both the operating surface and the barrier to infiltration of salt-impacted water into the ground. Since indoor operations will place significant stresses on the floor, the floor must be designed properly. The floors of all structures should be constructed of low permeability material such as high strength asphalt or concrete. Both asphalt and concrete

are somewhat permeable and should be sealed to minimize infiltration. Floors can also be underlain with a low-permeability membrane to limit salt loss.

ALLOWING FOR SALT/SAND BLENDING

- One possible design is to have salt at one end of the structure and blended sand at the other end with space to allow a pug mill and conveyor for creating the blend. This configuration warrants side doors to allow spreaders to drive through the structure and be loaded with different materials from either end.

COSTING

- In evaluating the costs of the various storage alternatives, of special note is the comparison of the actual, realistic in-use capacity that is expected in service, rather than simply the theoretical capacity. For example, a conical structure with a given design capacity will be greatly underutilized if the material stored is in two piles, one on either side. In addition, larger storage capacity allows agencies / companies the flexibility to buy salt during dips in market price (with the added benefit of having extra supplies in the event of back-to-back storms (there is a real "cost" to not providing adequate winter maintenance).
- Consideration of life cycle costs for repairs and intermittent refurbishing may show that a more functional yet costly facility to build is less costly in the long run because of lower operating costs.

LIQUID STORAGE FACILITIES

- Designers should consult with local environmental regulatory authorities regarding siting and containment requirements for liquid storage facilities.
- The required storage capacity will depend on the security of supply, production/delivery times and rate of use.
- Storage capacity can be reduced by using an "on demand" system.
- Where supplier-owned storage containers are used, arrangements need to be made for the delivery of full containers and removal of empties during yard operations.
- Supplier-owned storage containers should be treated the same as other brine storage containers (i.e. protected from vehicle impacts and provided with spill containment around both the storage tank and liquid transfer point where appropriate).
- Where practical, secondary containment should be provided through double walled tanks and/or containment dykes. Typically, containment capacity is 110-125% of the capacity of the largest tank.
- Crash protection should be provided to prevent vehicles from impacting the production and storage facilities.
- Sufficient water supply is often a constraint when designing a brine production facility. The designer must ensure that sufficient water capacity is available to produce brine at the required rate for the maintenance operation.
- Water supply lines may need to be heat traced to prevent them from freezing.
- The freeze point of the liquid being stored and the lowest possible winter temperatures must be taken into account when determining the need to heat the production and storage tanks and piping.
- Emergency power supplies may be needed to ensure that liquid supplies are available in the event of a power failure.
- Designers must take into account the desired fill time for spreaders when selecting pump and line sizes. Pumps and lines that are too small will prolong the time it takes to refill onboard tanks.
- Production and storage tanks must be designed with a clean-out or flushing capability to remove settled impurities.
- Some liquids may require periodic circulation to prevent settlement of impurities, additives or product separation.
- Site Drainage:
  - The site should be graded to direct drainage away from any down gradient groundwater well locations or salt vulnerable areas to a storage and/or treatment area.

- Snow plowed from the site should be directed to areas where the melt water will be directed away from groundwater wells, storage area and salt vulnerable areas.
- Salt-laden water should be collected and properly managed. The water can either be used in brine production or sent for disposal at sewage treatment facilities where permitted.

- Indoors:
  - Indoor material storage and vehicle loading is preferred. A drive-through facility is beneficial.
- Underground Storage:
  - Some highway agencies have buried the storage vessels and used the earth heat to maintain the temperature above freezing. Buried vessels have a high potential for undetected or large loss of material and costs for remediation or mitigation of contaminated soil and groundwater. It is suggested that great care be taken in the selection of this option and that local regulatory agencies and a professional engineer familiar with underground containment systems be consulted.

Operations and Maintenance

In addition to proper design, good operating practices are essential to minimizing material wastage and environmental impacts. Organizations must review all aspects of their operations (delivery, storage, handing, site drainage, brine operations, vehicle washing etc.) to determine where salt loss is occurring and to develop procedures to minimize or eliminate these losses. The following practices should be followed.

SALT HANDLING:

- Where practical to do so, spreaders should be loaded inside the storage structure. Where inside loading is not possible, other systems are needed to recover salt spills that occur during loading.
- When loading spreaders outside of the storage structure, care should be taken to minimize spillage of salt onto the loading pad and sweeping the pad of such spillage as soon as possible.
- Overloaded spreaders are prone to spilling salt during operations. Therefore, spreaders should not be loaded beyond their capacity and, where feasible, should be covered with tarps when loaded with salt or sand.
- Stockpiles frequently have portions that have become frozen. These frozen blocks need to be properly managed and should not be placed into spreaders. These blocks should be pushed into the corner of the storage facility and allowed to thaw and dry. Once they have thawed and dried, the material should be broken up and reintroduced to the pile. Where brine production is ongoing, blocks of pure salt can be put into the brine production tank.
- Deliveries of salt should be arranged such that material is placed within the covered storage facility as soon as possible upon delivery. Deliveries should be scheduled for periods of good weather.
- All deliveries should be covered when being transported to the maintenance yard.
- Spreaders should be properly calibrated and periodically checked to ensure continued calibration. They should be recalibrated following any servicing of the salt delivery system.
- Some organizations benchmark their service areas to establish the amount of material that would be placed under specified application rates. At the end of a run, the total material placed can be compared to the benchmark to see if the projected amount was put down. If there is a discrepancy then the reasons can be investigated.
- Excess salt and sand remaining in the spreader following a storm should be returned to the storage facility and deposited within or as close to the entrance of the storage facility as possible. Where materials are off-loaded outside of the storage facility, they must be placed into the storage facility as soon as possible.

VEHICLE WASHING

- Prior to washing, the spreaders should be swept to remove as much of the residual solids as possible and thereby minimize the amount of dissolved salt and solids in the wash water.
- Where possible, vehicles should be washed indoors rather than outdoors to contain the wash water.

- Where only outdoor washing is possible, it should be done where all washwater can be contained and directed through positive drainage to a water management system.
- It is preferable to direct washwater to a storage facility where it can be reclaimed and used for brine production or sent for disposal.
- If a washwater reclaim system is not available spreaders should be washed at a location where the washwater can be properly diluted, disposed or treated. When sending for disposal, careful consideration must be given to the ultimate receiver of the washwater.
- All vehicle washwater should be directed through an oil/grit separator. Note, oil/grit separators do not remove dissolved contaminates like the sodium and chloride from salt-impacted water. Where discharge is to a municipal system, salt-impacted water can exceed municipal chloride limits.

SAND/SALT MIXING

- Sand and salt mixtures should be mixed inside, or on low permeable pad located as close to the storage area as possible.
- Mixing should be done during good weather. This will reduce salt loss due to precipitation and wind, and minimize the moisture content of the sand/salt mix.
- Mixing should be done using a pug mill or some other method to achieve a homogeneous engineered blend. This reduces the amount of salt needed to prevent freezing of the pile.
- Sand should be as dry as possible, thereby reducing the amount of salt required to prevent freezing.
- After the sand and salt have been mixed, the mix should be loaded into a storage facility as soon as possible. The mixing area should then be swept and the sweepings placed into the storage facility.
- Organizations that purchase manufactured sand/salt mixes should check deliveries to validate that the percentage mix is as specified. Too high a percentage of salt is wasteful and too low a percentage may result in the pile freezing.

SALT BRINE PRODUCTION & STORAGE

Brine production units require significant water supplies. Where well water is the intended supply source there may be insufficient supply to meet brine production requirements. Therefore, water supply must be carefully planned. A designer should identify all potential water requirements, both current and future needs, and plan the water source and taking requirements accordingly as follows:

- Water wells for human consumption should be located up-gradient of the Winter Maintenance Area to prevent the well from being impacted by site operations. Wells need to be drilled and installed with due regard for protecting groundwater resources from surface contamination, preventing aquifer cross connection and maintaining the function of groundwater such as baseflow and availability for water supply.
- Depending on local requirements, a licensed well driller may be required. Necessary permits must be obtained.
- Wells providing water for brine production should be located down gradient of the Winter Maintenance Area.
- Cisterns should be used in rural settings to stockpile water. Drawing from a cistern allows the well and underground pump to be better maintained with a consistent lower draw. The cistern can also handle water deliveries during times of drought or high water use.
- Where regulations permit, consideration should be given to using washwater or salt laden drainage and stormwater for brine production. Since relatively clean water is required to ensure a proper brine solution is produced, any salt-impacted water collected for recycling should be directed through an oil/grit separator prior to being used in brine production.
- Where possible, clumps of salt or wet salt can be placed into the brine production plant rather than placing this material in the salt storage facility.
- Where salt brine storage tanks are used, these tanks should be placed above ground, and protected from potential impacts by vehicles. Secondary containment should be provided where a tank failure could result in environmental

damage. Containment may be provided by double-walled tanks and/or dyking systems. Provincial regulatory agencies should be consulted to determine the containment and handling requirements.

- Periodic inspection of tanks, pumps and pipes/hoses should be carried out and any leaks and damage should be repaired immediately.
- Brine production and storage facilities may need to be flushed periodically to remove sediments. The materials produced from this flushing activity are mostly sand and gravel and can be screened and mixed with the abrasive pile.

SOLID MATERIAL STORAGE FACILITIES

- Allow for indoor loading and unloading of winter maintenance materials.
- Allow sufficient area for material storage and include room to load and unload to reduce the need to double handle material.
- Any roof leaks, tears or damage should be temporarily repaired during winter to reduce entry of precipitation, with permanent repairs being completed prior to the next winter season. At no time should leaks be allowed to persist when materials are being stored inside.
- The floors should be inspected annually for cracks and repaired/resealed as required.
- If an agency/company lacks a building sufficiently sized for its inventory, a tarped outside storage pile would be used until sufficient space is cleared in the structure (i.e. use the inside storage first, not the outside storage). In that way, the movement of the salt inside can be done between storms, reducing the potential for environmental losses. Outside storage should be on the Winter Maintenance Area.

MONITORING

It is important to understand how much salt is being used, where it is going and the resultant environmental impacts. Monitoring will aid in the determination of the extent of the impacts and effectiveness of the mitigation measures taken. Most activities should be focused on preventing, minimizing or mitigating the impacts. Attachment 1 provides a checklist for inspecting maintenance yards. In addition monitoring may include the following:

- Baseline condition (benchmarking) of the site and surrounding area for future monitoring comparisons. For new facilities, this should be completed prior to the site being commissioned.
- The amount of material used during the year which can be reconciled at year-end.
- The use of weigh-in-motion (WIM) sensors at the entrance and exit to the site to confirm recorded amounts and track dispatches.
- WIM sensors would work well in conjunction with a loader scale sensor so the operator is in control of the load and his good judgment can be confirmed.
- Road authorities should also monitor compliance with good housekeeping policies.
- Providing for an activity code in maintenance management systems specifically for yard housekeeping to maintain a focus on this important activity and not unnecessarily burden other activities.
- Most storage facilities have salt contamination in the ground below the site and can migrate offsite. By establishing permanent monitoring wells and implementing a regular groundwater monitoring program, road salt plumes may be detected early (prior to off-site migration) allowing organizations to mitigate through improvements to road salt storage and handling procedures.

RECORD KEEPING

The performance measures that should be tracked and monitored include:

- percentage of salt and sand/salt blends stored under cover
- percentage of storage sites with collection and treatment of washwater and drainage
- inspection, housekeeping and repair records
- stockpiling records
- quality control records for brine concentrations, and
- levels of environmental indicators (e.g. chloride levels).

TRAINING

Training should focus on ensuring that those handling salt at the yard minimize the potential to waste salt and impact the environment. Prior to each winter all staff that are handling winter sand and deicing chemicals should receive training. The training program should focus on the following learning goals with respect to maintenance yards:

- understand that all salt and sand/salt blends should be covered to minimize salt loss
- understand that salt spillage is wasteful and harmful to the environment
- understand the salt-handling activities that result in wasteful releases of salt to the environment
- understand how these salt-handling activities should be carried out to prevent the wasteful release of salt to the environment
- understand the maintenance yard salt cleanup procedures that must be followed
- understand that timely yard maintenance and repairs are necessary to control salt loss, and
- understand the importance of proper record keeping and how to complete the required documentation on yard maintenance and salt use.

Training should be carried out through the following methods:

- pre-winter briefings
- observation and corrective action, and
- informal briefings during the season.

SUMMARY AND RECOMMENDATIONS

Most winter operators have an understanding of what works well in a maintenance yard setting. The practitioner's advice should be sought in planning changes to facilities or in locating and designing new ones. This consultation can also provide a complementary benefit of having the workers better understand why the facility is constructed the way it is and how it is expected to meet the needs of the winter service to be delivered. In designing a new maintenance yard or designing a major refurbishing of an existing yard, many of the above ideas are worthy of consideration. Information is also available from the Salt Institute and from storage structure suppliers for further guidance.

MAINTENANCE YARD INSPECTION CHECKLIST

Yard:	Date:	Inspector:

SOLID SALT STORAGE AND HANDLING	YES	NO
Has a review of current storage practices for salt and sand/salt blends been done?	☐	☐
Is there a defined Winter Maintenance Area (WMA)?	☐	☐
If yes, is it on a pad with low permeability (e.g. 100 mm of high strength asphalt underlain with a low-permeability membrane)?	☐	☐
If yes, is there a small berm or curb (e.g., 150 mm asphalt curb) surrounding WMA to direct drainage?	☐	☐
Is salt stored inside permanent roofed structures?	☐	☐
Is regular preventative maintenance performed on facilities?	☐	☐
Has the roof been inspected for leaks?	☐	☐
Were leaks found?	☐	☐
If found, were leaks repaired?	☐	☐
Has the floor been inspected for cracks?	☐	☐
Were cracks found?	☐	☐
If found, were cracks repaired?	☐	☐
Has the walls been inspected for leaks?	☐	☐
Were leaks found?	☐	☐
If found, were leaks repaired?	☐	☐
Is salt stored on an impermeable pad?	☐	☐
Does it have impermeable loading pads?	☐	☐
Is the site graded to ensure that water runs away from the storage structure?	☐	☐
Is salt delivered during dry weather only?	☐	☐
Are delivery trucks covered/tarped when being transported to the maintenance yard?	☐	☐
Is salt delivered directly into the storage facility?	☐	☐
Is delivered salt placed into storage immediately?	☐	☐
Is there indoor loading of spreaders?	☐	☐
Are spreaders calibrated and periodically check to ensure continued calibration?	☐	☐
Are there practices used to minimize spillage during loading?	☐	☐
Are there practices used to minimize outside salt spills?	☐	☐
Are there practices used to clean up salt spills quickly?	☐	☐
Is excess salt returned to storage?	☐	☐
Is salt-laden runoff directed to catch basins?	☐	☐
Have strategies for cleaning up existing sites and minimizing salt loss to the environment been developed and implemented?	☐	☐
Has a guide to best practices related to storage, handling and application of road salt and winter sand been developed and implemented?	☐	☐
Has training been implemented for supervisors and operators?	☐	☐

LIQUID STORAGE AND HANDLING	YES	NO
Are personnel trained in proper handling of liquids?	☐	☐
Has regulator been consulted regarding sitting and containment requirements for storage facilities?	☐	☐
Do liquid storage facilities have secondary containment?	☐	☐
Is secondary containment provided in the form of double walled tanks and/or containment dikes?	☐	☐
Is crash protection provided to prevent vehicles from impacting the production and storage facilities?	☐	☐
Are periodic inspections of tanks, pumps and pipes/hoses carried out?	☐	☐
Has consideration been given to using washwater or salt impacted drainage water for brine production?	☐	☐

BLENDED ABRASIVE HANDLING	YES	NO
Are blended abrasives stored under cover?	☐	☐
Are they delivered during dry weather?	☐	☐
Are salt and abrasives mixed indoors?	☐	☐
Does outdoor mixing only occurs during good weather?	☐	☐
Is the percentage of salt in the mixtures known?	☐	☐
Is only enough salt mixed in to keep the pile from freezing?	☐	☐
Are spreaders loaded inside?	☐	☐
Are there practices to minimize spillage when loading spreaders?	☐	☐
Are there practices to ensure spreaders are not overloaded?	☐	☐
Are spilled blended abrasives cleaned up quickly?	☐	☐
Are excess blended abrasives returned to storage?	☐	☐

LIQUID BRINE PRODUCTION FACILITIES	YES	NO
Are water wells located up-gradient of the WMA?	☐	☐
Are cisterns necessary/in place?	☐	☐

SITE DRAINAGE	YES	NO
Is drainage directed away from storage area and into containment where it can be properly managed?	☐	☐
Is the salt impacted water tested?	☐	☐
Are the drainage ditches conveying salt-impacted runoff of low permeability (e.g., asphalt lined)?	☐	☐
Where collection and treatment is not practical, is salt impacted drainage is directed away from salt vulnerable areas?	☐	☐
Is salt impacted water:	☐	☐
Released to the environment?	☐	☐
Removed by a licensed waste-hauler?	☐	☐
Directed to an Oil/Water Separator and then to containment for brine production?	☐	☐
Is drainage from outside of the WMA directed off-site in a way that minimizes off-site impacts?	☐	☐

VEHICLE WASHWATER	YES	NO
Is vehicle washwater collected, treated and sent for proper disposal?	☐	☐
Are vehicles swept prior to being washed?	☐	☐

GENERAL	YES	NO
Are you aware of the salt management plan (SMP)?	☐	☐
Have you provided / had training on the SMP?	☐	☐
Have you measured the performance of the SMP?	☐	☐
Have you reported performance through appropriate public reporting methods?	☐	☐
Have you identified salt vulnerable areas (SVA)?	☐	☐
Have you developed strategies for reducing salt impacts to SVAs?	☐	☐

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8.0 – SNOW STORAGE AND DISPOSAL

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.

INTRODUCTION

Over the course of a winter and multiple plowing operations snow can build up along roadways and in parking lots. Areas with limited space for plowed snow storage may develop large snow banks that can:

- obstruct the line of sight of drivers
- reduce vehicle mobility and available parking
- create a hazard to pedestrians
- form barriers causing drifts to form across pavement, and
- fill snow storage areas thus interfering with future plowing operations.

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In these cases, it becomes necessary to remove accumulated snow by melting it in place or transporting it to a site where it is melted by natural or mechanical means.

This snow can be impacted by:

- salts or other snow and ice control chemicals
- oil, grease and heavy metals from vehicles
- litter and debris, and
- normal dirt, dust and airborne pollutants.

Hauled snow must be handled, stored and disposed of in an appropriate manner that manages these contaminants in a way that protects the environment.

A number of methods have been developed to handle and remove snow. The least expensive way is to handle and dispose of the snow close to where it accumulates (i.e. pushed to the sides of roads, walkways and parking lots).

The simplest of these is to wing back the windrows as needed. This works well in areas where there is ample snow storage capacity. However, in many urban areas, this is not always an option. Some jurisdictions have tried spreading the snow banks back onto the paved areas in the spring and broadcasting salt over it to accelerate the melting process. This practice should be discontinued; as it increases the amount of chlorides released into the environment and can create hazardous conditions.

A number of jurisdictions are using mobile snow melters to melt the accumulated snow at the roadside and dispose of the meltwater through the storm sewer system. This method, although generally considered expensive, has merit in areas where haul distances would be excessive or snow disposal site capacity is limited. The ability of the storm sewer system and discharge site to handle the additional capacity and contaminants are important factors to consider before implementation.

Most hauled snow is taken to a location where is can be received, stored and melted. It is at these locations where the contaminated snow and the resulting meltwater accumulate, and measures need to be taken to minimize potential impacts to the envi-ronment.

This Synthesis of Best Practices establishes Guiding Principles to aid in developing appropriate snow removal, stor-age and disposal procedures. It also provides an approach to locating, designing and managing snow disposal facilities in a way that minimizes the potential impacts of con-taminated snow and salt-laden meltwater on the surrounding environment.

RELATIONSHIP TO SALT MANAGEMENT

The primary purpose of snow storage and disposal sites is to manage snow that would otherwise be a hazard to the public or impair winter maintenance operations. The snow that is stored at snow disposal facilities contains contaminants that are deposited on the ground or carried away with the meltwater as the snow melts. The meltwater and debris must be managed and should not be discharged back into the environment until properly treated. It should be kept in mind that currently there is no practical or economical way of removing the chlorides found in snow. Studies[1] have shown that much of the salt that is applied to pavement is not retained in the snow that is removed to snow disposal facilities. This is because chlorides tend to leave stockpiled snow soon after it is plowed. Only a small percentage of the salt that is applied to a road may be reaching the snow disposal facility. The other contaminants are often a greater issue for on-site management.

Most jurisdictions will have some form of regulation, policy or guideline for the protection of water quality, the protection of the environment, disposal of contaminated waste, possibly snow disposal and design approvals. This Synthesis of Best Practices should be used in combination with these regulations, policies and guidelines. Together they will assist in the responsible development of snow handling, storage and disposal procedures and sites.

When planning, designing and operating a snow disposal site, the following guiding principles should apply.

- Public safety is the priority. Organizations must ensure that the hazards caused by accumulated snow are efficiently and safely addressed.

[1] Environmental Study of Richmond Hill Snow Storage Facility, K. Exall et al, presentation to 1st International Conference in Cold Climates, University of Waterloo, May 2009

- Snow disposal sites should be located and operated to minimize impacts to the natural environment and control nuisance effects, including noise, dust, litter and visual intrusion on adjacent landowners.
- The actual snow disposal area within the site boundary should be clearly delineated in a way that is easily identifiable under adverse winter conditions, to ensure that the snow is placed in the proper location on the site.
- Meltwater must be managed in compliance with local water quality regulations and in a manner that protects surface and groundwater resources.
- Onsite litter, debris and sediment from the meltwater settling area must be collected and disposed of in accordance with local waste management legislation.
- Emissions (drainage, noise, dust, litter, fumes) must be controlled to prevent offsite environmental impacts.
- The design of snow handling, storage and disposal facilities must be practical and must not impose undue maintenance requirements.

SALT MANAGEMENT PRACTICES

Good planning and background information are important to the success of any long-term infrastructure develop-ment, including snow storage and disposal sites. A thorough evaluation of existing and new methods and sites is crucial before any preliminary decisions are made on sites and methods that will be used for storage and disposal.

Good site design and construction will have a positive impact on the site's longevity, ease of operation, maintenance costs, environmental impacts and public/agency acceptance. The following sections detail the information, criteria and best practices that other jurisdictions have used at each stage of the process to implement a successful snow removal, storage and disposal program.

Planning

With each stage of the process building on the previous one, the initial planning and information gathering are important. A standard environmental impact assessment approach to site selection should be followed. This involves:

- the determination of the snow disposal needs and ideal site characteristics
- the identification of candidate sites /technologies
- assessment of the potential environmental and operations implications of each site/technology
- evaluation of candidate sites/technologies
- selection of the preferred sites/technologies along with identification of strategies to control unavoidable impacts

Much of the information needed to carry out the planning process may already be available within the organization or with other agencies in your jurisdiction. Figure 1 shows the planning steps and the following discusses each of these steps.

Figure 1 – Site Selection and the Development Process

Needs Assessment

Before developing your snow disposal strategy it is important to understand how much snow you need to handle and the source areas. The needs assessment proc-ess involves the following:

- Determine or review the various snow removal locations and the volumes of snow that are typically removed. If possible include estimates for future snow removal locations due to road network expansion and possible use by private companies. Calculations should be based on both historical trends and worst-case scenarios. A five-year average is a good initial estimation of snow disposal requirements. The worst winter will also help to assess contingency or emergency needs. While it is not economical to have fully engineered sites for the worst-case scenario, it is important to plan for these winters.
- Determine the current cost of snow removal, storage and disposal. Include the costs to:
  - load/haul/dump to land sites, water sites (where permitted by regulations) or sewer chutes
  - melt snow (both stationary and mobile systems), and
  - maintain/repair/upgrade existing sites and dispose of waste materials.
- Determine the size of property needed. A snow disposal site must have an area sufficient to accommodate:
  - the anticipated volumes of snow
  - a site access/control facility
  - drive paths for heavy trucks allowing for simultaneous arrivals and departures and one-way circulation for safety and efficiency
  - a parking and re-fuelling area for on-site equipment (bulldozers, blowers, etc.)
  - temporary storage for large debris
  - berms around the perimeter
  - meltwater collection/ retention/ settling ponds
  - maintenance access
  - monitoring stations/sites, and
  - consideration for other uses if included or desirable.
- To address the capacity needs a road authority may wish to consider:
  - establishing one single large site or several smaller sites, and
  - using the vertical capacity of the site by piling the snow in layers, leveling and freezing each layer in succession, or blowing the snow into higher piles (intensive site management is required for these methods to be successful).

CANDIDATE SITE IDENTIFICATION

Once the needs and desirable service areas have been determined, a technology assessment should be done. For many projects these will be straightforward. Land disposal may be the only option. In other cases, snow melters, sewer chutes etc. may have merit and need to be evaluated.

It is unlikely that snow disposal can be adequately handled without land-based snow disposal sites. The following site selection process should be applied to both permanent and temporary sites:

- There will likely be a need for a variety of sites. This could include permanent sites to handle the snow disposal requirements of most years, and some temporary, contingency or emergency sites for the unusually bad years. The temporary sites would only be used in cases where the permanent sites become overloaded. Snow melters are a good way to accommodate the extra disposal capacity required for heavy snowfall winters.
- Many existing sites may have been established with little regard for the potential environmental issues. As well, historical sites may now be surrounded by incompatible land uses due to urban development. It is important to assess existing sites to determine their acceptability and ability to handle snow disposal needs. Unacceptable sites should be decommissioned and the search for additional capacity undertaken. Deficient sites will need to be upgraded to acceptable standards.
- Review public, agency and staff concerns with existing sites and develop a list of potential concerns that should be resolved during the planning and design process.

- The search for new candidate sites should begin with an environmental scan using GIS and secondary source materials. Many agencies have environmental and land use data that can be compiled onto one constraint map. Such a map provides an excellent visual means for eliminating highly vulnerable areas from further consideration. The land base under consideration can be ranked on the basis of high, medium and low vulnerability. The process should go through a couple of iterations. The first is at a fairly high level and is intended to identify candidate areas where a more detailed site search will take place. This detailed search will be confined to areas with lower environmental risk and will use a finer level of detail. The criteria used in both searches may include:
  - surface water quality and quantity (including potential assimilative capacity)
  - site hydrogeology
  - location of groundwater recharge areas
  - location and nature of salt vulnerable areas including wetlands, sensitive vegetation, agricultural areas, drinking water supplies, shallow ponds etc., and
  - location of sensitive land uses such as residential, institutional and recreational areas.
- Involve the public and government agencies in the site selection process.
- The identification of potential temporary, contingency or emergency sites may focus on smaller more remote sites with natural features supporting the basic siting criteria such as:
  - soils with a low permeability
  - natural slopes with a ponding area
  - discharge to a high volume surface water receiver or sanitary sewer, and
- multiple use sites such as the parking lots of facilities that are not normally used in the winter can make excellent temporary snow disposal areas – particularly if combined with a snow melter.

ASSESSMENT AND EVALUATION

The assessment and evaluation process is iterative with increasing level of detail being used as sites are narrowed down.

Many of the same criteria are used for the evaluation of existing and new snow disposal sites. The following criteria should be considered as part of the assessment and evaluation process.

Snow Hauling Distances

The haul distance is an important criterion to consider when identifying candidate sites. Snow storage and disposal sites should be located as close as possible to the snow removal sites to minimize high snow hauling costs.

A useful approach is to draw concentric circles at 5 km intervals around each major source of snow to be hauled. The goal will be to identify sites that are closer to the sources of snow in order to reduce haul costs and impacts.

This may be less of an issue for temporary sites.

Snow Hauling Routes and Site Access

Snow hauling requires the use of dump or similar trucks and can significantly increase the heavy truck traffic along the routes taken to the snow disposal sites.

Noise and traffic levels and associated complaints may increase along routes through residential areas.

The heavy truck traffic could also significantly reduce the life expectancy of the roads.

The roads leading into and out of the sites and the site access will have to be planned and constructed to accommodate the increase in heavy truck traffic.

Potential haul routes should be plotted so that cycle times and operating costs can be computed. This will also help in assessing the potential community impacts of snow removal operations.

Past and Current Site Land Use

Certain land uses (e.g. wetlands, previously contaminated land and flood prone areas) are incompatible with snow storage and disposal sites and should be avoided.

The use of current and decommissioned solid waste disposal sites must be evaluated carefully. The leachate collection system could easily be overloaded by the addition of meltwater from the stored snow, resulting in the potential release of contaminated leachate.

Sites under electrical transmission lines should be avoided as the lines may interfere with dumping operations and limit the use of loaders, backhoes and snow blowers.

Sites above underground utilities should be avoided. Snow disposal over underground utilities can create significant repair and maintenance problems and the elevated chloride levels may accelerate corrosion.

Surrounding Land Use (Current and Future)

Certain surrounding land uses are incompatible with snow storage and disposal sites. Residential, institutional and year-round recreational land uses should be avoided.

Zoning

The land for the site may have to be acquired and re-zoned to accommodate a snow storage and disposal site. It is likely that any zoning approval will have site plan controls that address noise, dust, light and visual impacts.

The issue of ownership vs long-term leasing may have to be addressed. Because the soils at snow disposal sites can become contaminated, leases may come with a remediation requirement at the end of the term.

Permanent sites allow greater control over surrounding land uses. A temporary site many have to be closed prematurely if it becomes incompatible with future surrounding land use.

Sub-surface Conditions

The underlying soil and rock structures of the site are important features that affect the suitability and design of the site. Preference should be given to sites with low permeable soils with sufficient bearing capacity to handle year-round operation of heavy equipment.

Protection of water quality may be the most important and difficult of issues to address. Consideration should be given to:

- proximity to drinking and irrigation water sources (avoid possible contamination)
- proximity to surface water, downstream effects and the type of aquatic species present (avoid or minimize impacts), and
- meltwater discharge location:
  - When discharging meltwater into a surface water body the receiver must provide enough dilution all year round to protect the aquatic ecosystem. The potential receiver should be evaluated both on its historical flow rate and volume fluctuations and potential for future fluctuations, particularly lower flow periods.
  - Meltwater must not be discharged to salt vulnerable areas. An assessment of the potential impacts should be undertaken.
  - If ultimate discharge is into municipal sanitary system, ensure the treatment system can handle the additional flow and contaminants.
  - Avoid groundwater recharge areas and areas over shallow aquifers.

DESIGN, CONSTRUCTION AND IMPLEMENTATION

The design of snow disposal sites should address the following requirements:

- efficient site operation
- proper base construction
- drainage and meltwater management
- site security, and
- environmental controls.

Temporary sites, by their nature, would likely not include some of the permanent infrastructure. However, the access, site management and environmental requirements would still apply. The following sub-sections discuss these requirements.

EFFICIENT SITE OPERATION

- Accessibility and onsite vehicle management (large trucks can access the site, maneuver and not get stuck) are important. The logistics of snow delivery, dumping, distribution and truck departures need to be carefully considered. Proper onsite and entrance signage should also be installed and maintained.

Truck Routes

- Roads used by trucks entering and leaving the site may have to be upgraded to handle the increase in heavy truck traffic and to provide room for trucks to wait for their turn to dump.
- Queuing lanes may be needed at the entrance depending on the ability of the site to handle the truck volumes.

Vehicle Management and Snow Loading Areas

- A significant amount of snow dumping occurs at night. Therefore, onsite vehicle management may be needed to avoid accidents and to control pile formation. Poles or moveable concrete barriers could be used to clearly mark the travel areas and actual snow disposal areas.
- To reduce nuisance noise from "vehicle reversing warning beepers" the layout of the site should attempt to minimize the requirements for trucks to back-up.

Access to Electrical Power

- Electrical power may be required at the gate as well as around the site for lighting, buildings, monitoring equipment and maintenance.

Permanent or Temporary onsite building

- An onsite building may be required for security personnel, for staff to monitor truck traffic and loads and receive payments for private dumping (if permitted).
- Onsite staff comfort during winter months should be considered.

Accessible Monitoring Points and Monitoring Equipment (Year Round)

- For routine data collection.
- For maintenance purposes.

Maintenance Access for Collection, Treatment and Discharge Areas

- Routine clean out and repair of collection and treatment areas using heavy trucks and equipment.
- Periodic rehabilitation of discharge area may require the use of heavy equipment.

BASE CONSTRUCTION

- A good solid base is required to allow heavy trucks and graders to drive repeatedly over the wet ground without getting stuck or creating deep ruts that could divert or hold meltwater.
- The base must remain firm enough to support vehicle loads even after the frost has gone out of the ground.
- The base should have low permeability to protect groundwater resources.
- Where possible, the base for the snow pile should slope downwards to the north to take advantage of the sun melting the pile from south to north. The snow on the high (south) end melts first running under or around the piles to the meltwater collection facility. In this way, contaminants (sand, silt, litter, etc.) will remain up-stream of the pile and meltwater will not continuously flow across the materials previously released from the pile.
- Some agencies have designed the base with "V" ditches under the pile to channel meltwater to the collection pond.

DRAINAGE AND MELTWATER MANAGEMENT

- Site drainage and meltwater should be directed to a meltwater collection pond.
- Site meltwater should be directed away from the snow piles and dumping area to reduce ponding/ rutting.
- The meltwater collection pond should be designed with an impermeable base, a forebay to collect litter and settle coarse sediments and a larger secondary area (polishing pond) to settle finer particles. An oil/grit separator should be placed in advance of the forebay to capture any oil and grease in the site drainage.
- Where local regulations permit dilution to meet regulated contaminant levels, uncontaminated site drainage and precipitation may be directed to the collection pond to provide dilution of the impacted meltwater. Otherwise, uncontaminated drainage should be isolated from the meltwater.
- The meltwater collection pond should be designed large enough to handle the expected meltwater volume, other site drainage and the periodic additional load from precipitation events.
- The outlet should be controlled to regulate the release to the receiving water body. The point of discharge should be protected to prevent scour.
- Adequate access to the pond needs to be provided to allow for periodic cleanout of sediments.
- The polishing pond should be designed to encourage complete circulation to avoid salt stratification and the potential for higher releases during wet weather flows.
- All required federal, provincial and municipal approvals, permits and licenses will have to be applied for, obtained and met.

SITE SECURITY AND ENVIRONMENTAL CONTROLS

The sites should be secured to avoid illegal dumping, prevent unauthorized access, by both humans and animals, for safety reasons and permit safe efficient operation of the site. Security and environmental considerations include:

- delineation of the site boundary using perimeter fencing with appropriate signage and a gate with controlled access
- provision of adequate lighting for operations, with the lights focused away from adjacent land uses, and
- providing low permeability berms (with or without trees) around the site to prevent uncontrolled offsite release of meltwater. These berms and additional landscaping can also mitigate noise, litter and visual impacts.

OPERATIONS AND MAINTENANCE

Once a site has been approved and commissioned for use, the following ongoing operational and maintenance issues should be addressed:

- site management
- snow pile and meltwater management, and
- off season (spring, summer and fall) maintenance.

Site Management

- Ensure that a single individual is assigned responsibility for the operation of the site; and is accountable for its operation and environmental performance.
- 24 hour security may be required to control unauthorized access and dumping (even during the off season).
- Vehicle management may be needed.
  - Night-time dumping may require onsite vehicle management to help prevent accidents and ensure dumping occurs in the correct location and follows prescribed safe dumping procedures. All dump trucks should lower the truck box prior to leaving the site to avoid contact with overhead power lines.
  - Hauling operations may have to be monitored periodically to ensure drivers are following the designated haul routes.
  - Increased vehicle management may be required later in the season, to limit the number of trucks onsite, as the site fills up with snow and maneuverability becomes an issue.

- Discourage “tailgate banging” and, where possible, trucks backing-up to reduce the nuisance noise levels if adjacent to noise sensitive land uses.

- Large debris management.
  - With any snow removal and disposal operation a significant amount of large debris will be collected and dumped along with the snow.
  - Periodic collection and onsite storage of the large debris will be required. An appropriate offsite disposal area will have to be identified to eventually dispose of the large debris.
  - The types of large debris should be monitored and steps taken to avoid collection in the future. Marking or flagging of mailbox and newspaper box locations has proven successful in reducing the number inadvertently hauled away during snow removal operations.
- Litter control.
  - A significant amount of small, lightweight debris is normally collected and dumped along with the snow. This litter is blown around by the wind and can become a problem both on and off site.
  - Staff should collect litter regularly to prevent it from blowing onto adjacent properties.
  - The installation of a net or fence around the perimeter of a snow disposal facility can help contain the litter within the site.
  - Adjusting or re-scheduling garbage collection to avoid snow removal locations and times has helped reduce onsite litter in some jurisdictions.

SNOW PILE AND MELT WATER MANAGMENT

Traditionally snow was dumped and allowed to melt virtually undisturbed. A number of jurisdictions find it necessary to manage the snow piles to control or enhance melting.

- Pile management (dumping location, pile formation, pile melting management, etc.):
  - The snow pile needs to be managed to ensure that site operations are safe, space is efficiently used and that the pile melts quickly enough to achieve complete melting while the receiving water body has high flow.
  - Minimize handling of the contaminated crust that forms on top of the piles.
  - Spread piles in the spring to increase area, breakup crust and maintain volume of melt water for early spring run.
- Equipment for pile management:
  - The pile can be managed using loaders, dozers or blowers to move, pile and breakup snow.
  - Blowers can be used onsite if it is known that the snow is free of large debris such as wood. If all the snow being delivered to the site was blown into the trucks then it is likely safe to use a blower onsite. Otherwise a bulldozer or loader should be considered.
- Proper and efficient pile melting is important to the smooth operation and long term stability of the site:
  - The snow must be completely melted as early in the spring as possible to allow for maximum dilution in the receiving area.
  - Weather data and long range forecasts can help predict current and future meltwater volumes and discharge rates.
  - Avoid discharging during the summer months when the receiving area cannot dilute it.
  - Meltwater must not become trapped or allowed to pond in the receiving area of the site.
  - Multi-use sites need to be cleared of snow and all debris before the off-winter use begins.
- Efficient flow of meltwater to the collection area must be maintained:
  - Rutting caused by heavy trucks must be kept to a minimum or repaired quickly.
  - Fast flowing, high volume channels of meltwater must not be allowed to develop near the piles to avoid excessive erosion and rutting of the driving and snow pile surface.
  - Sheet flow of meltwater under and near the piles is preferred.

Off Season Maintenance

- Once the snow has completely melted any accumulated contaminants left behind will have to be carefully collected and properly disposed of.
- Check for and repair any damage to the access and haul route roads.
- Check for and repair any damage to the site surface and base and check the drainage channels for erosion.
- Summer/fall maintenance should include:
  - grass cutting on berms and around the collection and treatment areas
  - tree trimming
  - equipment check (lighting, monitoring, security, etc.) and general site repairs, and
  - animal control
    - o animals may come onsite to lick the contaminated residual salts
    - o beavers, muskrat, etc. can tunnel in and damage the pond and discharge receiving area, and
    - o ponds should be cleaned out when the capacity is reduced below the volume needed to handle the worst case year.

SALT VULNERABLE AREAS

To the extent possible, snow storage and disposal areas should be planned and located away from salt vulnerable areas. This requires sufficient investigations of potential sites to identify salt vulnerable areas and to factor them into the site selection and evaluation process. The best way to avoid salt vulnerable areas is by including them in the constraint mapping process discussed in the "Candidate Site Identification" section. Where salt vulnerable areas cannot be avoided, special design measures must be taken to prevent salt impacts.

MONITORING

Site monitoring is often the most neglected aspect of the operation. Site staff and users are more often concerned with hauling and dumping the snow (the most visible cost) then with what happens in the piles and to the meltwater. Staff should monitor:

- what is brought onto the site (inputs)
- what is being discharged from the site (outputs)
- any onsite and downstream contamination and environmental impacts, and
- the operation of the site.

The following sub-section lists items and areas that may require on-going monitoring.

BASELINE CONDITION

- The baseline condition of the site and surrounding areas should be assessed as a benchmark against which future conditions can be compared.
- Test sites and holes drilled for benchmarking the site could be made permanent allowing future comparison data to be collected from the same locations.

SITE INPUTS

- The volume of snow dumped on the site. If the site is used for both public and private snow dumping, separate records for both public and private volumes should be kept including fees collected.
- Regular estimates of the volume of snow left onsite. An estimate of the melt rate may also be needed if there is a timing restriction for discharging into the receiver.

SITE OUTPUTS

- The volume of meltwater being discharged into the receiving area. The volume of flow in the receiving water body should be monitored to ensure it provides sufficient dilution of the discharge.
- The levels of chlorides and other contaminants in the discharge from the meltwater pond.
- The volume and type of large debris collected and sent for disposal.

Environmental Impacts

It must be recognized by all parties involved that snow disposal sites will have an impact on the environment. Most activities should be focused on minimizing or

mitigating these impacts. Monitoring will aid in the determination of the extent of the impacts and effectiveness of the mitigation measures taken.

- Contaminant levels recorded once the site is operational can be compared to the benchmark levels established prior to the site opening to give a true indication of any environmental impacts.
- Contamination levels may be monitored at various points around the site and surrounding area. Various factors can affect the number and location of monitoring points including:
  - urban vs. rural location
  - intensity of site use
  - size of site, and
  - local requirements and sensitivities.
- Where warranted some or all of the following locations may be monitored:
  - beneath the site (groundwater and soil)
  - above and around the site (where air quality is an issue)
  - in the collected meltwater
  - at the discharge site and in the discharged melt water
  - upstream and downstream of the discharge site (in the receiving area or mixing zone), and
  - in the groundwater down gradient of the discharge site.
- There are numerous potential parameters that can be monitored. Some monitoring may be required due to local, provincial or federal regulations. Some land lease arrangements also require monitoring of specific contaminants. Below is a list of some of the important contaminants from a salt management perspective.
  - chloride
  - sodium
  - pH
  - metals
  - total petroleum hydrocarbons (TPH), and
  - suspended solids.
- Depending on the nature of road operations some road authorities may monitor other parameters such as other snow and ice control chemicals used on the road network.

Monitoring can be expensive and should be directed at addressing specific goals. If after monitoring some parameters it becomes clear that they are not relevant, then they should be discontinued.

Site Operation

- The efficiency and remaining capacity of the meltwater collection and treatment areas will have to be monitored. Over time the collection and treatment ponds will silt-up reducing their capacity and ability to handle the meltwater. Regular removal of the material that has settled out will significantly extend the life of the ponds and maintain their efficiency.
- The stability and condition of the snow storage and driving surface. If the surface deteriorates significantly, a site may become unusable until major repairs are done.
- A site that allows both public and private snow dumping may have to be monitored more closely:
  - Some jurisdictions have had problems with mixed load dumping (snow piled on top of waste fill or construction material). Mixed loads may not appear for some time as melting slowly exposes the foreign material.
  - Methods have been developed using transponders and Weigh In Motion (WIM) sensors that can automatically track private dumping volumes and associated fees.

RECORD KEEPING

Record keeping has become an important element in maintaining a snow disposal site. Snow disposal site records should be kept for:

- dealing with public and private complaints
- litigation and showing due diligence
- showing compliance with regulations and licensing
- providing information to regulatory agencies

- determining fees and payments
- improving general knowledge and understanding of the effectiveness of specific designs, and
- decommissioning and future sale of site.

The following lists items and issues for which records should be kept.

- General site information:
  - number of snow disposal sites and their capacity
  - percentage of snow disposal site with run-off collection and/or treatment system(s), and
  - percentage of snow disposal sites with a monitoring program (groundwater, surface soil, etc.).
- The volume of snow dumped and when it was dumped.
- An estimate of the melt rate:
  - Can use estimate of volume of snow left, flow into meltwater collection and treatment system or discharge volume.
  - A record of basic atmospheric data is useful in helping to determine the melting rates.
- Debris volume and type:
  - Some sites have instituted a lost and found so residents and businesses can retrieve items such as mailboxes, garbage cans, signs, etc.
- Contaminant monitoring records (point data, trends, levels, etc.):
  - Benchmark and contaminate monitoring data may need to be kept on file even after the site has been decommissioned.
  - Monitoring records may be subject to periodic audits and third party reviews and need to be kept.
  - Maintenance and operation records.
  - Regularly review site operations and look for ways to improve efficiency of dumping, pile management and melting.
  - Look for ways to reduce debris and litter by tracking type and source.
  - Good records provide an excellent source of information to aid in training new staff and passing on experience.

DECOMMISIONING

The form and extent of the site remediation and decontamination will depend upon the level of contamination. The monitoring records in and around the site will help in designing the type and extent of decommissioning required. Local regulations for de-commissioning contaminated sites will provide relevant cleanup criteria.

It should be noted that soil underlying retired snow disposal sites may fail local soil clean-up guidelines, particularly the Sodium Adsorption Ratio (SAR) and Electrical Conductivity (EC) parameters, and will need to be managed in accordance with local waste management regulations.

TRAINING

A good, thorough, ongoing training program for staff involved in managing the site is critical. It will help ensure the site:

- is operational when needed
- meets or exceeds its life expectancy, and
- minimizes the impact to the environment.

Refer to TAC's Salt Management Syntheses of Best Practices for Training and guidelines on developing training programs with an emphasis on Salt Management. Salt Management training for staff managing snow disposal sites should focus on five key areas or learning goals.

- Understanding how to manage the snow pile to facilitate melting.
- Understanding the measures to be applied to control nuisance effects such as:
  - noise from trucks and equipment
  - visual impacts such as dirty snow piles and vehicle and site lights from night time dumping
  - dust, and
  - litter and debris.
- Understanding how to monitor, and record the chloride, metals, pH, total petroleum hydrocarbons (TPH) and suspended solids in the meltwater discharges.

- Understand how the snow disposal system has to be managed to be cost effective and to reduce environmental and social impacts.
- Understand the importance of proper record keeping and how to complete the required documentation on snow received and quality of meltwater being discharged.

CONCLUSION

Snow storage and disposal sites are used to manage snow that must be removed from roadsides, sidewalks and parking lots in an environmentally responsible way. If these sites are properly located, designed and managed the adverse environmental effects will be controlled. Snow storage and disposal sites should be planned, designed, operated, maintained and decommissioned in accordance with this Synthesis of Best Practices. As well, staff responsible for managing these sites should be properly trained to ensure that the sites are operated in a safe, efficient and environmentally sound manner.

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9.0 – WINTER MAINTENANCE EQUIPMENT AND TECHNOLOGIES

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.

INTRODUCTION

Winter maintenance operating and research personnel in many parts of the world have identified new methods and technologies that can improve snowfighting efficiency and significantly reduce the amount of road salts used to maintain roads, highways, sidewalks and parking lots in the winter. Equipment is now available that incorporates these developments to reduce salt use, control the impact on the environment, improve winter travel conditions, safety and mobility, and reduce overall costs.

When selecting and deploying equipment, proper and timely information is important to good decision-making. In order to properly match equipment and service delivery in a way that optimizes winter maintenance performance, winter maintenance personnel need to understand:

- snow and ice control strategies and methods available to them
- pavement and weather conditions that exist, that are forecasted and that need to be acted upon
- equipment and material availability, capability and limitations in use

Equipment is a significant cost component (along with labour and materials) in a winter maintenance program. It is understood that it takes time to adjust the fleet and to incorporate an acquisition strategy into

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an ongoing budget. Further, it is important for an organization to continuously identify and assess new and innovative technologies that supports best practices. Also, there are seasonality and frequency of use considerations as well as multi-functionality aspects in evaluating the economics of renewing the fleet. Management must balance all of the competing agendas in choosing the preferred equipment configuration, and a phase-in/out strategy for the fleet, with an understanding of salt use considerations.

RELATIONSHIP TO SALT MANAGEMENT

Winter maintenance equipment is primarily used to prevent or control accumulations of snow and ice. A significant amount of the accumulation can be controlled by mechanical methods such as plowing. When mechanical methods alone would be inappropriate or ineffective, deicers must also be used. For a "saltable" situation, the approach is to place an amount of material on the pavement to prevent snow and ice from bonding to the pavement surface, to control the accumulation of snow and ice and to achieve bare-and-wet followed by bare-and-dry pavement within prescribed standards

Winter maintenance equipment, once optimized, can help an organization meet the 4-R's of Salt Management:

- the **R**ight material
- the **R**ight amount
- the **R**ight place, and
- the **R**ight time.

In addition to the 4-R's, a final key to effective salt management is:

- **Keep it on the pavement to work**

Each organization will need to assess the winter materials available, to determine appropriate application rates for a given situation and determine the best time for application in order to achieve the established level of service.

Following a principle of determining what is "right" for a given organization, considering the 4-R's will help any winter maintenance operation optimize the use of salt. Public safety will be maintained while controlling the impact of salt on the environment.

SALT MANAGEMENT PRACTICES

To optimize salt use, it is important to look continually at new and innovative technologies as they are a valuable option. Some salt use "optimization factors" to consider when making equipment choices include:

- Improved information and decision making tools will allow equipment, personnel and salt to be better used and salt applications better timed.
- Efficient mechanical control of snow and ice will minimize the amount of snow and ice to be controlled by chemicals.
- Proper equipment choices will help operators to place a predicted amount of salt at the desired location where it is needed, at the right time.
- Chemical applications should occur at a time that prevents bonding of snow or ice to the surface.
- Keeping good records of snow and ice control actions taken, along with material usage and a record of changing pavement conditions, will improve planning and budgeting and limit an organization's liability.
- The safe and effective use of any equipment requires operators to be properly trained; this is particularly important when introducing new equipment and techniques.

Information & Decision-making Tools

To make the best use of available equipment and personnel and meet the 4 R's of Salt Management, experienced decision-makers in winter maintenance operations need information to support their judgment.

The critical information required can be divided into three categories:

- weather and pavement forecast information (what will happen), for predicting upcoming storms and potential icing events
- current information (what is happening), providing surface temperatures and conditions, and
- status information (what did happen), recording what was done and the Level of Service achieved.

A number of tools are available to help provide the required information. Typical examples follow.

ROAD WEATHER INFORMATION SYSTEMS (RWIS)

Sensor-based RWIS has been in use since the mid 1970s by road and airport authorities around the world. The Canadian network of RWIS stations has grown significantly in the past decade. Beyond giving road information and trends, RWIS sites and networks provide information required to develop specific forecasts as well as some service documentation.

RWIS supports winter operations in the following ways:

- An understanding of pavement temperature forecasts and trends can improve the accuracy of decision-making.
- Sensors embedded flush in the pavement, as well as sub-surface, generate data that can be sent back to central locations allowing trends and forecasts to be developed.
- Pavement sensors can monitor pavement temperature, wet/dry status, freeze point of the solution on the pavement, presence of chemical and concentration (for some chemicals), as well as subsurface temperature.
- Tower-based sensors can also provide real-time information of typical atmospheric conditions such as precipitation, relative humidity, dew point, air temperature, and wind speed and direction.
- Weather forecasting services can use road-based information to provide "road weather" forecasts to help the snowfighters make better decisions regarding snow and ice control.
- Salt use optimization is achieved by more accurate deployment of equipment and application of chemicals.
- Other types of sensors, cameras and systems can be added to RWIS to further support snowfighters (e.g. automated liquid deicer application system – Fixed Automated Spray Technology (FAST), cameras, remove pavement and friction sensors, etc.).

INFARED THERMOMETERS (IRT'S)

Decisions about material application are improved by knowing the current road surface temperature and the temperature trend. There are portable or stationary infrared thermometers on the market that can be used to determine the current surface temperatures.

- Both hand-held and truck-mounted versions are available; with the mounted versions measuring ambient air temperature as well. There are also units that include a humidity sensor thus allowing the dewpoint temperature and relative humidity to be measured.
- Truck-mounted versions allow continuous monitoring of the road surface while the vehicle is moving along the road.
- The data can be recorded and transmitted as part of the data stream of a GPS/AVL system (see Operational Support Equipment later in this document).
- Stationary pole mounted remote surface temperature sensors are also available. These can provide the surface temperature, air temperature, dew point temperature and relative humidity at the specific location. Because they are mounted at the edge of pavement, they avoid the disruption associated with installation of in-pavement sensors.
- Like all equipment, IRTs need to be checked and calibrated to confirm their accuracy and to be confident in the reading.
- Not all of the IRTs on the market can be re-calibrated. A simple way to check the accuracy of an IRT is to create a water/ice mixture and measure the temperature of the surface of the mixture with the IRT. If the IRT is accurate it should record 0° C. The difference between the reading and 0° C will provide the accuracy. It is not unusual for a hand held IRT to have a 1-2 degree discrepancy.

ROAD SURFACE TRACTION MEASUREMENT

Moisture, snow and ice degrade surface friction producing slippery conditions. Road salts and, sometimes, abrasives like sand, are applied to improve traction, increasing the coefficient of friction. Decisions about material application can be improved by having better information about the current friction level of the surface:

- The presence of precipitation or applied winter materials such as anti-icing liquids, sand and salt can provide inconsistent friction across the pavement surface.

- Road authorities around the world are working with suppliers to develop reliable and accurate equipment to measure the available traction on pavement.
- Friction sensors have been used extensively on airport runways, but their high cost is currently restricting widespread use on roads. Alternative designs promise lower cost.
- In some cases friction sensors are mounted on the spreader vehicles and used in conjunction with on-board mounted pavement temperature measurement equipment to automatically control the application rate of snow and ice control chemicals.
- Alternatively, the device could be mounted on a "smart patrol truck" with other winter maintenance tools.
- There are also stationary sensors available that are pole mounted. These use infra-red beams to determine the pavement condition (e.g. dry, moist, wet, icy, snowy/frosty or slushy). They can also measure friction.
- Technically, the equipment can be accurate and dependable, and has the potential to eliminate the unnecessary use of salt where adequate traction exists.

RESIDUAL CHEMICAL MEASUREMENT

After a storm event has passed and the pavement has become bare and dry, there often is a residue of chemical remaining on the surface. This fine layer of chemical will be activated with the next precipitation event. This residual will also help to prevent the formation of frost and can melt a small amount of snow. As well the concentration of salt contained in slush is the determinant of the freeze point temperature of the slush. It is helpful for decision-makers to know the residual salt concentration on the pavement. An RWIS pavement sensor will provide this information. Portable salinity sensors are also available, although their cost and the fact that one needs to stand on the pavement to take the measurement, make widespread use impractical. Another tool being tested is a "chemical presence" sensor that can measure the chloride concentration of pavement spray in a vehicle's wheel well.

Using Mechanical Means to Control Snow and Ice

Mechanical removal of ice and snow is usually preferable and this can be facilitated by preventively treating paved areas with road salts. Such pre- or early-storm applications will often minimize the overall amount of road salts required to achieve the desired surface friction level. Reacting to a snow and ice event and applying road salts after a bond has formed requires significantly more salt to be used.

Some organizations choose to leave a small amount of snow on the pavement before salt is applied in order to keep the salt from bouncing or being blown off the surface by traffic or wind.

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. Repeated plowing operations in areas with limited snow storage will require the stockpiled snow to be removed for disposal. The following discussion provides a general overview of snow removal equipment and some advantages and disadvantages of their use.

SNOW PLOWING

A wide range of plowing options are available including the type of vehicle used to carry the plow, the type of plow and mouldboard and even the type of cutting edge or blade.

VEHICLES

The vehicle type and size must be selected properly to be able to operate in the required area, carry and operate the mounted equipment and provide a safe and comfortable environment for the operator. Vehicles may also be multi-purpose, and be used for other duties during non-storm event times and during the off-season, summer months.

Considerations for typical units in use include the following:

Trucks

- Trucks come in various capacities and dimensions, and are commonly referred to as single axle, tandem axle or tri-axle units.

- Smaller, more maneuverable vehicles may be more suited to urban operations, parking lots and sidewalks, whereas larger, more powerful trucks may be preferred on roads and large parking lots.
- Underbody plows can also be mounted on trucks and be used with down pressure.
- Trucks with front mounted plows and wings often provide the best solution on roads as they can operate at higher speeds. This allows roads to be cleared sooner and allows the truck to operate at safer speeds. Trucks operating closer to the speed of other traffic present less of a safety hazard.
- Trucks operating at higher speeds can effectively "throw" snow a sufficient distance back from the edge of the shoulder to minimize snow bank build up.
- Higher operating speeds may be inappropriate in urban areas and in proximity to environmentally sensitive areas where snow thrown beyond the edge of pavement could damage roadside features and the environment.
- Trucks can be configured with a hopper or tank to serve the dual-duty role of spreading materials as well as plowing.
- Careful attention must be paid to the truck specification to configure it as a frame-stiffened winter truck of suitable horsepower and hydraulics, rather than simply a generic cab-and-chassis off the production line.
- To ensure adequate traction and load baring capacity, both front and rear tires must be selected carefully to ensure suitable tread pattern, material and sufficient load rating to handle both the material load and plows.
- Front axle capacity is a consideration, and the vehicle should meet legal weight requirements as necessary.
- Trucks require locking differentials or electronic traction control to prevent traction loss due to a spinning wheel.

Motor Graders

- Graders are often fitted with plows and wings to remove snow.
- Graders are often readily available for winter road maintenance as they are widely used by municipalities and contractors during the summer for road construction and maintenance, and are little used otherwise during the winter.
- Graders are useful when working in tight quarters on urban streets with cul-de-sacs, elbows, bus bays, and varying road widths.
- They work at lower speeds and promote a safer operation when working in the presence of pedestrians and heavy traffic because of enhanced operator visibility.
- They can be fitted with front plows, including one way and reversible plows, "V" plows, and side wings, with or without driveway gates.
- Graders can also be mounted with a tooth or stacked-disc ice blade to scarify hard ice-pack and provide improved, temporary friction.
- Modern graders can operate at much higher speeds than older models but are limited to thirty to thirty-five kilometres per hour and thus are slower than truck mounted plows.
- Graders are effective during fall freeze-up and spring thaw when roads are soft and susceptible to digging-in by truck-mounted plows.

Loaders

- Loaders are occasionally fitted with plows, wings and snow blowers for snow removal.
- Modern loaders with large glass areas on the sides and front, and a high mounted operator position, provide the operator with excellent vision of the area around the loader.
- Loaders (particularly articulated loaders) are useful when working in tight quarters on parking lots and urban streets with cul-de-sacs, elbows, bus bays and varying road widths.
- They can also be used to pick up and remove snow on parking lots, cul-de-sacs, bridges and other tight areas with limited snow storage.
- Loaders are readily available for winter road maintenance as they are widely used by municipalities and contractors during the summer for road construction and maintenance and are used extensively to load sand and salt onto spreader trucks at the maintenance yards.
- Loaders are also an important tool for loading materials into spreaders. The buckets must be

sized for the spreaders being loaded so that spillage of materials is limited.

PLOWS

- The type of plow and cutting edge must be selected properly to be able to be mounted properly on the vehicle, to operate in the required area and achieve the desired performance in snow clearing.
- The selection of the appropriate type of plow and proper adjustment of the plow will reduce costs and lessen the amount of salt needed to clear the pavement.
- Plows should be operated with sufficient weight on the blade to effectively cut through packed snow and ice, resulting in a near-bare surface, in order to minimize the amount of salt required to fully-bare the pavement.
- Plows for high speed operations should be fitted with shoes to prevent the plow from dropping into holes or catching on obstructions. In low speed operations (e.g. parking lots) the shoes are usually removed to maximize snow removal.
- Plows should be adjusted to minimize the amount of weight carried on the shoes, but the shoes should be close enough to the pavement to absorb the weight of the plow if the plow strikes an obstruction. Castors are sometimes substituted for shoes to minimize wear.
- Plows should be fitted with a tripping mechanism that will reduce damage to the plow if it impacts catch basin or manhole covers, curbing or other obstructions. The trip mechanism will also prevent the truck from being violently deflected from its traffic lane.
- Various plows angles are used depending on the goal. An angle of about 75° between the blade and the pavement provides the most effective cutting of heavily packed snow and ice. An angle of 55° between the blade and the pavement is the most efficient at moving large quantities of snow and causes the least amount of snow to be blown up at the front of the vehicle. One jurisdiction has used a 40° angle to improve snow pickup.
- Various designs and improvements to aerodynamics have been made to improve the operators' visibility by trapping some of the snow cloud kicked up by the cutting edge.

Front Mounted One-Way Plows That Move the Snow to the Right

Front mounted one-way plows are designed to move snow to the right side for plowing roadways. The following are their characteristics.

- This plow provides the most efficient blade available for plowing snow.
- The snow is not thrown as far at the outlet end of the plow so more snow remains on the shoulder.
- The standard shape allows more snow to escape from the mouldboard and contributes to a cloud of snow surrounding the truck. Newer designs improve driving safety by minimizing the amount of snow that escapes into the snow cloud at the point of impact.
- These plows commonly are used for high-speed removal of snow, slush and packed snow.
- They can be used to clear from minor amounts up to approximately 50 cm depths of snow at highway speeds;
- Steel one-way plows can be large and heavy; therefore the truck must be fitted with a high capacity front axle, and heavy duty wheels and tires.
- The size of the vehicle may be a disadvantage when clearing snow in congested urban areas and subdivisions with cul-de-sacs, etc.
- Piston-like cushions are available to reduce the pounding/bouncing of the blade on the road surface, which reduces the impact on both the truck and operator.
- These plows should be fitted with nose points to prevent the plow from catching on bridge expansion joints and cross cracks.
- A thorough training program is required to ensure that the operators are familiar with the adjustments to maximize snow removal and maintain all safety features in a fully functional condition.
- Either right and/or left side plow wings are usually fitted to extend the plowing width (see Wings or Wing-plows).

Front Mounted Reversible Plows

Front mounted reversible plows are used to move snow to the left or right side of the truck. The following are some of their characteristics.

- These plows are useful for clearing left hand lanes (especially adjacent to a median) and ramps.
- They are widely used in urban areas because of their versatility.
- Some manufacturers offer reversible plows with mouldboards that can be reshaped to match the shape of one-way plows when the mouldboard is angled in either direction. These plows have been strongly endorsed by the plow operators, but are significantly more expensive.
- A unique variation of the reversible plow is a centre-hinged-reversible plow that can push left or right or effectively become a V-plow.
- The plows may be fitted with nose points to protect against catching on minor roadway obstructions, bridge expansion joints, etc.

Front Mounted "V" Plows

- Front mounted "V" plows effectively handle deeper accumulations of snow.
- These plows have been designed to lift snow over adjacent windrows and to balance side loading by pushing snow to both sides.
- Their use is now restricted mainly to areas with high snowfall rates and as back-up units to open roads closed during severe storms.
- A smaller version of the v-plow is often used to clear sidewalks.

Wings or Wing-plows

- Wings are smaller side-mounted plows that can be mounted on a tower or mast near the front of the plow truck, or further to the rear at the back of the cab.
- Wings can also be mounted on graders.
- They can be mounted on either or both sides of the plow vehicle, and effectively increase the width of the plowed path.
- One disadvantage of wings is that operator visibility can be impaired.
- Wings improve efficiency and allow for increased snow removal, being especially useful in multi-lane clearing and when operating in an echelon formation since they help prevent leaving a windrow of snow on the traveled surface.
- Wings may be inappropriate in some urban settings where they can throw snow beyond the edge of pavement and damage roadside features.
- Usually the vertical angle of the plow can be adjusted by a cable/chain or hydraulically, allowing the wing to be used for clearing shoulders or for cutting side banks of snow.

Underbody Plows

- The underbody plow is suited to applications on crowded urban streets, urban laneways and back alleys, as well as in some rural settings.
- They effectively serve as a two-way reversible plow and are normally stable.
- They are effective in clearing highly compacted snow and ice by way of variable downward pressure, using the truck's compressed air system or hydraulic pressure and springs, to maximize effectiveness.
- These plows are limited to clearing snow accumulations up to 30 cm.
- Underbody plows are not normally used with side wings so the plowed path is limited and a lane-side windrow of snow is created.
- A rear mounted snow wing can be added to trucks with underbody plows but the plowing width is less than that of a front mounted wing. With this configuration the vehicle might be expected to be less stable than front mounted wings as the side thrust from the wing is located further from the centre of gravity of the truck.
- In some cases the vehicle might be less stable due to excessive down pressure.

Vertical Plows

- A recent development in plows is the vertical blade which is flat but hinged in two locations (at third points) so as to push straight, right or left, or to effectively scoop snow by catching it and pushing it forward.

- This plow is usually loader or tractor mounted, and can accommodate a snow load traveling at slower speeds either forward or in reverse.
- A vertical plow is preferred in areas of unique geometry, or where access is tight.

Tow Plows

- Tow plows consist of a secondary plow towed on a trailer behind a plow truck.
- They are used to plow multiple lanes with one truck on urban multi-lane roadways, rural high speed highways, climbing and passing lanes and rural shoulders.
- The operator can raise and lower the tow plow blade and swing the plow out into the adjacent lane allowing a single truck to clear a width of more than 7.3 meters (24 feet) – the equivalent to 2.5 conventional trucks. This generates over 30% savings on equipment, fuel and manpower costs.
- When not needed, the operator can raise the blade on the tow plow and redirect the unit back behind the truck.
- Tow plow trailers can also be outfitted to spread conventional materials or with liquid tanks for applying straight liquids at the same time the road is plowed. .

Cutting Edge or Blade

- Snowplow cutting edges and blades are available in various designs and configurations for various operations.
- Regular blades are made of heat-treated steel or fitted with tungsten carbide inserts to improve durability (by a factor of up to eighty times in high speed operations).
- Rubber and polymer/plastic blades have been tried to minimize damage to catch basins, bridge expansion joints, centerline pavement markings and raised reflective markers, etc. These blades can be used to effectively “squeegee” the surface to remove slush in areas where the ambient temperatures usually rise above the freezing point during daylight hours after a storm. In areas with colder temperatures the use of theses blades has not been as successful.
- Ice blades are used to cut into hard packed snow and ice that cannot be removed with conventional blades.
- Special plow blades with sliding segments that move up and down vertically facilitate the thorough clearing of rough or distorted pavement, reducing the amount of salt required to bare off the pavement. The manufacturers also claim that these blades minimize damage to the plow and truck from hitting obstructions, such as catch basin covers, as less force is required to retract one segment clear of the obstruction. These blades are well suited for high speed and rural plowing.

SNOW REMOVAL AND DISPOSAL

Over the course of a winter and multiple plowing operations snow will build up along roadways or in parking lots. Areas with limited space for plowed-snow storage may develop visual obstructions for drivers, act as a snow fence causing drifts to form a cross roads, restrict use of the facility and prevent future plowing operations from being productive once the snow capacity of the area is exceeded. In addition, accumulations next to guide rail, barrier walls and bridge approaches can freeze solid and create an unsafe ramping condition.

The piled snow, containing salt and other road contaminants, may need to be removed and disposed of or stored in an appropriate manner. Refer to the Snow Storage and Disposal Synthesis of Best Practices for more information.

Snow removal is usually considered a fair-weather or clean-up operation, and may entail traffic control considerations. Also, most removal operations often leave some snow on the road that must then be treated with abrasives or snow and ice control chemicals to maintain safe driving conditions.

Various removal methods and equipment are available and should be selected based on local needs. The following discussion provides a general overview of methods and equipment used to remove and dispose of accumulated plowed snow, and some advantages and disadvantages of their use.

SNOW MOVING

- Snow bank accumulations may simply be handled by a conventional plow truck and physically relocated further back beyond the roadway and shoulder.
- High-winging or stepped-winging commonly is used to cut the bank height.
- In a rural and/or urban environment, a grader with or without a wing can be used to move the snow further back to create space for subsequent plowable storm events or to act as a barrier (snow ridge) instead of using a snow fence.
- Alternatively, the bank may be cut forward, toward the roadway, immediately followed by a full speed one-way plow run that effectively throws the loosened snow to the fence line.

Loading, Hauling and Dumping

- The most cost effective and easily mobilized removal operation for isolated locations is by means of a loader that fills conventional contractor dump truck(s), which then haul the snow to an appropriate site.
- The capacity of the loader and the truck body will determine the production rate and effective cost.
- Auxiliary equipment may be required to increase the efficiency of the operation. For instance, a grader may “peel” a snow bank into a suitable windrow in order to accommodate the loader and truck position.
- Since a loading operation necessarily impacts the flow of traffic in the area, traffic control or protection is often required, and consideration should be given to doing this work at night.

Mobile Conveyors

- Mobile conveyors are used to load snow from the shoulders or a windrow directly into trucks for removal.
- They can operate entirely on the shoulder with both the unit and the truck being loaded lined up on the shoulder with minimal traffic disruption.
- They are useful in areas with high traffic volumes or limited access

SNOW MELTING

- Snow melters melt snow that is picked up and place into a heated box. The resulting melt water is usually drained directly to the storm sewer system.
- Melters provide a solution for unique problem areas, particularly tight urban areas with limited snow storage available adjacent to the road on the right-of-way. They are also used to melt snow in parking lots where snow volumes are restricting usable parking spaces or meltwater is causing icing problems.
- Melters may be an economical solution where the hauling costs are high (i.e. where snow disposal facilities are far from snow removal locations.
- Melters can be mobile or stationary.
- Mobile melters move under their own power and picks up the snow by a conveyor and delivers it to an onboard melting tank and the melt water is released to the drainage system. The production of mobile melters can be quite slow.
- Stationary melters are melting tanks that are moved and set up at where the demand for melting exists. Snow is trucked to the melter. In some cases these are a temporary set up where once the melting operation is completed, the tank is moved to its home base. In other cases they are permanent set ups.
- Where sanding is a major activity in a winter operation, there can be a problem with plugging when melting sand-laden snow.
- Snow melters may have water/waste treatment, noise and air emission issues (see Snow Storage & Disposal Synthesis of Best Practices).

SNOW BLOWERS

- While blowers can be used during storm conditions, they are a slower production unit than a plow and are normally used for post-storm snow removal.
- Blowers are also used to load trucks for snow removal in urban areas, along roads and in parking lots with limited snow storage space.

- They are often owned by contractors or are a part of an equipment fleet that services a network of open roads in an area with very high snowfall rates.
- All blower operators must be aware of wind direction and the visibility concern that traffic could encounter.
- Blowers are typically mounted on dedicated trucks, tractors or are attached to large front-end loaders.
- They are available with hydraulic powered vanes to control the direction of the blower in snow banks.
- They may also have hydraulic controls on the chutes to accurately direct the snow into the trucks used for haulage.

Blowers can be used simply to widen the snow bank area and relocate the snow by blowing it beyond the bank toward the ditchline (where storage capacity is available).

Using Road Salts to Control Snow and Ice

Preventing a snow and ice bond to the pavement surface should be the top priority. If prevention efforts from early-storm treatments fail and a bond forms, then destroying this bond must be done as quickly as possible. There are many chemicals including road salts that prevent and/or destroy that bond, making mechanical removal easier, and melt that portion of the frozen precipitation that cannot be removed mechanically. The key is to apply the right amount of the right material, in the right place and at the right time. Various chemical control strategies are available.

The following discussion provides a general overview of methods and equipment used to apply salt and sand, and some advantages and disadvantages of their use.

ANTI-ICING/DEICING METHODS

- Anti-icing is the proactive use of any melting agent to assist melting and resist the formation of a bond between snow and ice and the pavement surface.
- Anti-icing can involve application to the pavement of liquids, pre-wetted or pre-treated solid granular materials or dry granular material. Thus, anti-icing is not confined to using liquids.
- Deicing is a reactive strategy of destroying an existing bond between snow/ice and the pavement where a chemical is applied after the bond has formed between the snow and the pavement. In these cases the chemical must work its way through the snowpack to the pavement surface where it can break the bond and allow the snow to be removed mechanically.
- Anti-icing creates a safer condition, quicker and with less chemical than does deicing.

Liquid Deicers

A solid chemical must first dissolve in water, creating brine, before it can melt snow or ice. The lag time while solids dissolve delays the effect of the chemical application.

Liquid deicers are popular because they are already in the state necessary to melt snow and ice. As such they enhance the melting performance of deicing chemicals. They also help to keep solid materials on the surface longer. For these reasons and others, liquid deicers are being applied through direct liquid application (DLA) or to sand and solid salt - either through pre-treatment of stockpiles or through on-board pre-wetting. These techniques are discussed later.

There are a number of liquid deicers available. Most of these liquids are chloride based and are manufactured. Sodium chloride brine is commonly used because it can be made from rock salt by the user inexpensively and its performance is well understood. There are also natural brines available that contain a mixture of chlorides.

Newer liquid products include organic byproducts such as beet juice and carbohydrates (condensed distiller soluble) that claim to reduce the amount of salt needed, reduce the working temperature of the mixture, reduce vehicle corrosion, increase residual and inhibit the refreeze process.

Some liquid road salts such as calcium chloride and magnesium chloride are exothermic (give off heat) and therefore can act synergistically with sodium chloride which is endothermic and requires heat to create brine.

Direct Liquid Application (DLA)

- Direct liquid application (DLA) is the placement of a liquid deicer directly onto the pavement surface.

- DLA is efficient since it provides immediate melt action and does not take the time to dissolve and form brine that a solid chemical does. As well, liquids do not depend on the presence of heat from the ground, sunlight or traffic to dissolve (endothermic reaction).
- Generally, an equivalent weight of salt applied as a liquid (e.g. dissolved in water) performs better than the same weight of dry granular salt because the liquid is fully retained on the pavement surface.
- The cost on a dollar-per-gram basis may be greater for liquid only applications (depending on the liquid used); however the merits of DLA should be assessed on a full cost basis including the offsetting safety benefits.
- The timing of the application of DLA is not as critical as with granular materials. One significant advantage of using a liquid is that it can be applied to dry pavement in advance of the start of a storm provided conditions suit the use of DLA. The resultant residual chemical will be present when the event (frost or snow) occurs. This means that roads, parking lots and sidewalks can be treated during times when traffic is low or parking lots are empty.
- Where the application is earlier than the onset of a storm, the water in NaCl brine will evaporate leaving a salt crystal residue in the surface pores/ texture of the pavement. This residual will later dissolve and form brine when moisture becomes present (either from precipitation or dew).
- Conversely, hygroscopic brines (such as CaCl2 and MgCl2) will attract moisture and continually wet the road until they are dissipated.
- There is evidence that as chemicals move from a liquid state to a solid or from a solid to a liquid, there is a short period where a “slurry” state can occur. With some chemicals this “slurry” state can reduce friction on the pavement creating a short-term slippery condition. Humidity is the most important factor in creating this slippery condition. Temperature also seems important. Higher temperatures and lower humidity can dry out a solution creating the liquid-to-solid transition. On the other hand with high humidity, a dry chemical residual can re-hydrate causing a solid-to-liquid transition. This is more of an issue with hygroscopic chemicals.
- Liquids can also “scrub” the oils from the pores of pavement, especially with an application after a prolonged dry period. The resultant slurry can be slippery. It does not take a lot of liquid to achieve the desired anti-icing effect. Over applying a liquid can cause some of these slipperiness conditions. The impact of this temporary effect can be minimized by using pencil nozzles that leave alternating dry and wetted strips on the pavement.
- The approach to resisting the bond is not to wet the pavement, but simply to provide enough chemical to enhance early-storm safety with an application of chemical that stays on the pavement surface. In most cases, the intention is not to “wash” or even fully wet the pavement with an equivalent chemical loading as that of a granular application.
- It is acknowledged that a direct liquid application has much less “staying power” than granular salt; however the use of this procedure lessens overall chloride loadings per storm and allows for bare pavement to be achieved sooner.
- The application of liquids can be triggered by sensors and sprayed on a surface such as a bridge deck using Fixed Automated Spray Technology (FAST).
- DLA can be applied over multiple lanes by trucks traveling at higher speeds (than conventional salt spreading) with due regard for traffic.
- Trucks used for DLA can range in size, to accommodate frame-mounted or slide-in tanks. Truck configurations may include:
  - small trucks ranging from pickups and two-tons with tanks or collapsible bladders, to vehicles used for vegetation spraying or bridge washing in the off-season
  - larger trucks used for water applications or calcium dust suppression applications in the off season, and
  - full-size, larger capacity tractor trailer tanker units used for long distance hauling in the off season.
- Trailer-mounted tanks are also used.
- Custom built units may be required for specialized high-speed, multi-lane, long-range applications, or small scale operations such as sidewalks and transit platforms.

- Mid-sized trucks used for DLA can also be outfitted with a plow and wing harness for subsequent use later in the storm.
- Tank, pump and nozzle configurations, as well as the controller, will determine the preferred application practice and route range.
- The liquid is delivered to the pavement by means of pumps or gravity-fed nozzles. The preferred applications makes use of "pencil-sized" streams at 200 mm to 300 mm spacing; this prevents misting or atomizing the liquid that then blows away and doesn't make it to the road surface.
- An alternative to pencil-nozzles is the use of tube-trailers that run from each nozzle to the road surface and directly target the liquid without the stream passing through the air; though the tube has to be adequately clamped and will wear from the pavement surface, it better targets the liquid onto the pavement.

PRE-WETTING METHODS

- Pre-wetting is a commonly used practice to improve performance and keep material on the pavement by reducing the effects of bouncing, blowing and sliding of the salt or sand particles. This technique uses a liquid chemical to wet the sand or salt as it is spread on the pavement.
- Pre-wetting enhances the melt action of the chemical present by speeding the dissolving of salt and the formation of brine.
- Practical considerations relate to the gradation of the salt being wetted, the maximum liquid to solid ratio that can be mixed, the amount of mixing action, caking/clumping concerns, etc.
- Adjustment of the spray nozzles is critical. Tests by one US state department of transportation showed that they never achieved more than 60% coverage of the salt. The remaining 40% of the pre-wetting liquid was effectively being applied directly onto the pavement.
- As the wetting agents are corrosive, it is important that corrosion resistant nozzles and non-contact pumps are used to ensure dependable performance.
- Pre-wetting provides significant potential for reductions in salt use but can increase the complexity of the required equipment and controller.
- Pre-wetting requires additional equipment. Storage tanks for the liquid(s), or brine making equipment are required, along with pumps to load the spreaders.
- The on-board liquid capacity and loading time are factors to consider.
- The application pumps on the spreaders should be regulated by ground speed controllers to ensure the correct liquid application rate is maintained under all conditions.
- Additional maintenance is required such as ensuring that the liquid filters, lines and nozzles are purged and the equipment cleaned at the end of the storm to prevent clogged lines and seized equipment.

Pretreatment

- Pretreatment is the addition of a liquid to solid salt at the time it is stockpiled.
- Pretreated salt can have the same benefits as pre-wetted salt without having to invest in new equipment thus providing an easy entry into the use of liquid technology.

Spreaders

- The total amount of salt used for winter maintenance is significantly influenced by the characteristics of the spreader equipment.
- Spreader controls must be capable of delivering several precise application rates.
- The application rate should be consistent whether the spreader is full or nearly empty, regardless of material variations, or temperature changes.
- When purchasing new equipment, organizations should require test results from suppliers to confirm that the equipment will achieve precise application rates under all conditions.
- Spreaders must operate in a severe environment of low temperatures, high moisture, poor visibility and corrosion.
- Spreaders must be easy to load, and simple to operate.

- Ideally, a spreader should be adaptable for other tasks, or the hopper should be easily removed so the trucks can be used for other operations during the summer.
- Hoppers must be constructed so that all sand and salt can be easily removed from the body.
- Spreaders should be fitted with screens to ensure that frozen clumps of material or other contaminating material that would jam the chain/conveyor mechanism are not loaded into the spreaders.
- Cab shields should be fitted to assist in loading the spreaders to ensure that all loaded salt enters the box, and material is not spilled over the truck or on the ground.
- Spreaders should be manufactured from a material that will resist corrosion. Special chlorinated rubber primers and epoxy-based primers will increase coating life. Stainless and galvanized steel and fiberglass bodies are available but can be relatively expensive. High strength, low alloy self-coating steel, used with good surface preparation and special primers has been proven to provide a cost effective body life of up to fifteen years. Manufacturers also supply spreader bodies constructed of fiberglass. These bodies are lighter and thus provide increased payload possibilities, but are also more expensive than steel.
- Electrical wiring for controls and lighting, and hydraulic components must be enclosed in vapour proof, or sealed systems.
- Neoprene spinners are frequently used to improve durability and spreading efficiency.

Spread Patterns

- Salt and sand application methods can be modified to meet differing requirements.
- Typically one of two spread patterns is used: i) Placing a windrow on the crown or high side of the pavement; and ii) Broadcasting material uniformly over the pavement.
- In most cases on roads, solid or pre-wetted salt should be applied in a continuous narrow windrow along the centerline of the road. The concentrated mass of material minimizes the tendency of the material to bounce or be blown off the road by passing traffic. Salt going into solution drains down the crossfall of the road, and can migrate under packed ice and snow; a uniform section of road is then bared off initially along the centre of the road to provide two-wheel stability for traffic. This reduces the unnecessary loss of salt that can come from broadcast operations.
- Application in a windrow is achieved without using the spinner, by dropping the material from a chute. In some cases the salt is dropped onto a slowly rotating spinner centered over the crown.
- Windrowing on the centre line will not work if the crown of the road is not consistently on the centerline, or the road surface is badly deteriorated which could cause the salt brine to pond in some areas.
- Centre line application is not appropriate if the entire road surface is slippery and immediate de-icing is required. In these situations, higher salt application rates may need to be spread across all traffic lanes using a spinner.
- Some rear-discharge spreaders have the ability to vary the spread pattern (widths and symmetry) allowing the operator to adjust the spread pattern to unique road network conditions. For example to pick up an acceleration/deceleration lane or bus stop or to address a super-elevation.
- Application ahead of the drive wheels can provide improved traction under the drive wheels of the spreader vehicle. Application close to the driver's cab also enables the driver to monitor the application to ensure that material flow has not been impeded.
- One argument in support of rear-discharge spreaders is that the drive wheels should not have enhanced friction if the steering wheels do not also have the benefit of improved friction. Otherwise, the driver may not be able to control the steering as the front wheels slide while the drive wheels continue to push forward. This is not normally an issue on bare-pavement policy roads unless there are significant grades in the area.
- Spreaders designed with discharge at the rear can allow for a slide-in capability that can be mounted and dismounted quickly.
- Discharge at the center-rear of the vehicle is simple but may restrict the vehicle to treating the lane in which the vehicle operates; some designs

allow for the spinner "throw" to place the material at an offset from the vehicle.

- Broadcast spread patterns are suited to situations where broad coverage is needed immediately. This is typical on parking lots and sidewalks.
- Broadcast spreading is also appropriate on roads where immediate traction and melting over the entire surface is required. This would be in the case of freezing rain or black ice or when placing sand.
- Drop spreaders are best for sidewalks because the material can be confined to the sidewalk and not lost to the vegetated areas.

SPREADER TYPES

Manufacturers provide different spreader types to meet various requirements. The various designs have different characteristics that must be considered when a spreader is selected for a particular application. These include hopper spreaders, tailgate spreaders, reverse dumping spreaders, and some new variations of these types.

Hopper Spreaders

- Hopper spreaders have provided optimum performance and durability in the past.
- These spreaders are usually installed on trucks during the winter and removed and replaced by standard dump bodies or other equipment for the summer (e.g. water tanks, concrete mixers, etc.).
- The design incorporates steeply sloping sides to eliminate material hanging up.
- A conveyor chain, belt or auger is used to move the material to the discharge location. Conveyor chains have proven over the years to be more trouble free than belts, and both can be more accurately calibrated than augers.
- Augers have shown very high wear and poor accuracy in material control.
- The application rate of the material being spread is controlled by adjusting both the speed of the chain used to convey the material to the chute or spinner and the gate opening on the body.
- A constant source of power to drive the hydraulic pump was once provided by an integral small gasoline or diesel engine. Though a few are still in use, these engines are problematic and a constant source of downtime and maintenance. Reliable hydraulic pumps, driven from the truck engine, are now common.
- Conventional hopper spreaders provide good control of material application and dependable service. However, they are the least versatile for other operations during the off-season.
- New hopper designs, including rear-discharge, slide-in units with a longitudinal agitator bar and belt conveyor is gaining popularity, particularly for pre-wetted applications.

Tailgate Spreaders

- Tailgate spreader units mount on the rear of the truck dump box and are filled by raising the body and dumping salt into the integral hopper. The salt is then conveyed to the spinner by a chain or auger and applied in a windrow or broadcast over the surface using a spinner.
- These spreaders are considered a simple and dependable unit. They are used extensively in areas where storms are less frequent and the trucks can be used for other purposes, or as backup units for hopper spreaders.
- Their primary limitation is the inconvenience of raising the dump box and the possibility that the box will not be raised high enough to ensure that sufficient material is dumped in the hopper to provide consistent delivery.
- The rear discharge restricts the operator view of the operation and ability to ensure that the material is being discharged at the right location.
- The vertical clearance and the upward and rearward shift of the centre of gravity when the box is raised can cause instability and can be a safety concern.

Reverse Dumping or Dual Dump Spreaders

- These spreaders were developed to overcome problems identified for tailgate spreaders while still providing a multi-purpose spreader that could be used year round.
- They function as regular rear dumping bodies when not being used to apply winter maintenance materials.

- The pivot pins can be repositioned so the standard hoist can be used to raise the rear of the body. This moves the salt or sand to the chain conveyor at the front of the body that moves the material to the distribution point ahead of the rear wheels.
- These spreaders have the advantage of providing year round service and can be switched from hauling construction materials to winter maintenance use with no adjustments required.
- Disadvantages of this spreader are the high weight compared to a regular dump truck, and the need to raise the body while driving to move the material to the front of the truck. This reduces the truck's stability and care is required by the operator to ensure that sufficient material covers the cross conveyor at the front to maintain a precise application rate. The pivots have been a source of failure and replacement is expensive.
- A variation of the reversing dump body is the side-tipping floor. The floor and passenger side of the box are raised to move sand or salt to the driver's side of the truck where a longitudinal conveyor moves the material to the front of the box for distribution ahead of the rear wheels. This arrangement eliminates the strong weight shift to the front of the vehicle and the material is distributed ahead of the rear wheels where the operator can easily monitor the application. The complexity involved in ensuring that the box is tipped far enough to cover the conveyor is a disadvantage. Some problems have been encountered with body integrity, as the full support of the contractors dump box is not available. The vehicle is also more heavily loaded on the driver's side and braking on slippery roads could be affected.

Multipurpose Spreaders

- Multipurpose spreaders incorporate most benefits of the other spreaders.
- They use a longitudinal conveyor to transport salt or sand to the front of a large modern contractors dump box.
- A recent design makes use of a U-shaped box to ensure that no material hangs up in the box and that all material can be easily removed from the box at the end of the shift.
- A lateral conveyor at the front transports the material to the left or right side of the body for distribution ahead of the rear wheels.
- The material is either discharged in a windrow using a chute for concentrated action, or spun across the lane using spinners.
- The spreader provides precise application rates and all the advantages of distribution in front of the rear wheels.
- The cross conveyors are easily removable during the summer so that there is no tare weight penalty.
- The units are lightweight and provide year round use.
- The body can be easily switched to carrying construction materials (simply by installing a pan or tray across the floor conveyor).
- These units can carry substantial loads so care must be exercised to ensure that adequate truck components, axles, springs and wheels, are specified to carry the load. This is particularly important on combination units that are also equipped with snow plows.

Rearward Casting Spreaders (e.g. Zero Velocity)

- With normal spreaders, a high percentage of the dry salt applied to the road bounces off the road due to the combination of the impact of the granules hitting the pavement, and the speed of the spreading vehicle. This is reduced somewhat by pre-wetting or pre-treating materials.
- Most organizations now theoretically constrain their spreading speed to avoid wasting salt due to the scatter effect at higher speeds. In practice however, speeds of 40 km/hr and more are not uncommon. If salt could be applied at higher speeds, combination units would be much more productive as the unit could apply salt at plowing speeds. This would allow for safer operating condition since trucks could move at the speed of traffic.
- Casting material rearward has shown potential for salt use reduction by increasing the percentage of applied salt that is retained on the road, and in the required location on the road.

- This is a concept by which the salt is discharged rearward at exactly the same speed as the spreading vehicle is traveling forward. The two velocity components cancel each other causing the salt to drop on the road as if the spreading vehicle was standing still.
- To-date, the available equipment has experienced some operational problems such as material caking, uneven discharge and mechanical complications (fan/blower) under certain conditions and is not in broad use.
- One manufacturer makes use of a shielded-spinner at the mid-chassis discharge location, discharging at a point just beyond the width of the rear wheels where the material is "flung" rearward.
- Another manufacturer used a high-speed blower to discharge the salt rearward. This results in a large cloud of salt that can be hard to control and may be affected by side winds.
- Also, the spreader units may not suitably handle pre-wetted material or finer sands.
- Though useful for salt applications, there is no good way to spread sand with these spreaders.

Rear-discharge Spreaders

- Based on the premise that no salt particle should be placed dry onto the road surface, and that fine salt is the gradation of choice for prompt dissolving and melting, certain spreader design characteristics cater better to liquid and fine salt use in pre-wetted applications.
- The salt must be of a fine gradation in order for it to retain the brine moisture content and fine salt does not travel as easily on certain chain-type conveyor systems.
- Increased liquid use can have detrimental effects on equipment when the discharge location is other than at the rear.
- These spreaders allow a "high-ratio" salt application rates up to 255 litres per tonne of salt, or at a ratio of 30:70 liquid-to-solid by weight. This requires a large capacity of onboard liquid and adequate pumping capability which may not be possible or practical on a conventional retro-fitted unit.
- These spreaders are either frame-mounted or slide-in rear-discharge v-hoppers that can stand on self-contained stilt legs in the maintenance yard, and remain tarped until needed.
- In one design, an internal longitudinal agitator bar meters salt from the hopper, while breaking down chunks in the load, onto a belt conveyor that moves the material to the rear-discharge location.
- Calibration by weight can be done accurately off the rear belt.
- Pre-wetting liquid can be applied directly on the spinner that is designed to spread the material across a given area of the road cross section.
- Some of these units are also configured to apply DLA either from the spinner or using a spray bar.
- Though some units are considered to be well-built, they cost more than conventional spreaders.
- One consideration is that areas that only have access to coarser salt may find that the liquid component must be reduced since saturation can be achieved with less liquid.
- Overall spreader designs are evolving and are worthy of continual investigation.

Electronic Spreader Controls

- All spreaders require an accurate electronic controller to ensure that the appropriate application rate is achieved.
- Simple hydraulic circuits, used to maintain a steady application rate, are still in use in many road authorities and most private contractors servicing parking lots. This equipment starts to exceed the desired application rate as soon as the truck speed drops below the design speed and an excessive salt application is then dumped on the road.
- Early models of the electronic controllers were not dependable and required extensive maintenance. The new models are improved but can still require some patience.
- Modern spreaders use electronic groundspeed spreader controls to provide consistent, accurate application rates. The truck speed is monitored from the truck's speedometer drive, and the spreader output is adjusted to maintain a steady output at the set rate per kilometre. Both open loop and closed loop systems are available to monitor material flow and provide increased

accuracy of the spread rate (closed loop systems provide confirmation of the actual application rate).

- Electronic controllers automatically increase the output rate if a second spinner is actuated (if so equipped) to treat truck climbing and turning lanes.
- With some electronic units, calibration settings can be applied electronically using infrared controls.
- Information that is captured and logged can include: amount and type of material applied, gate position, run time, blast information, average speed, spread width/symmetry, etc.
- Manufacturers can now provide units that record, for printing, information about the amount of salt used, the time it was used and the associated application rate, for analysis and control by the organization.
- Modern controllers incorporate global positioning systems (GPS) for automated vehicle location (AVL) and to identify where the material was discharged (either generating a passive history or a live transmission).

CALIBRATION

Regardless of the spreader chosen, the service provider must calibrate each spreader to have faith that the application rate settings are indeed accurate. A calibration policy should be established to assure the material settings are correct. Preferably, if application is by weight, then calibration should also be by weight. All spreaders should be calibrated before the start of the season and recorded. Calibration checks or recalibration should take place several times during the season, including:

- after repairs to and system that can affect salt delivery
- when distribution calculations show a discrepancy between theoretical and actual
- spot-checks on units in the fleet throughout the season

OPERATIONAL SUPPORT EQUIPMENT

Various types of equipment support the winter maintenance program either by helping manage the operations by generating useful data or by supporting the service delivery itself. These are discussed in the following sections.

MATERIAL USAGE MONITORING

There is the saying – **You Can't Manage What You Don't Measure!** Review of salt management practices over the past 5 years shows that most road organizations have many if not all of the tools to properly manage their salt use but the actual salt use is not always being optimized.

Often what is missing in salt management practices is active tracking of salt use against targeted objectives and a concerted effort to adjust wasteful practices.

The following sections discuss equipment that is available to help with this monitoring process.

BENCHMARKING

It is important to know how much material should be applied for given precipitation and pavement temperature conditions over a given area.

- Snowfighting organizations should have multiple application rates (low, medium, high) for each type of material they are applying that are geared to weather and pavement conditions.
- The size of the various areas to be serviced (e.g. routes, parking lots, sidewalks, platforms etc.) should be determined.
- The amount of each material required to service specific areas can be determined for the various application rates by multiplying the area by the application rate.
- This benchmarking only needs to be done once and reviewed when changes are made to the rates or the service area.
- Some road authorities print the amount of salt needed to service an area (route or lot) on the beat/route maps provided to the operators.
- It is these benchmarks and their monitoring/ reporting system that allow organizations to ensure that they are placing the right amount of salt and meeting their goals.

LOADER MOUNTED ELECTRONIC WEIGHING EQUIPMENT

- Loading extra material onto a spreader can lead to overloading or the temptation to over apply the salt. In the past, operators tended to load a little extra salt as there was no exact method of determining the amount of material loaded, and they did not want to run out without completing the route.
- Overloaded trucks also contribute to contamination in the area of the salt storage facilities. Salt heaped above the side boards is thrown off the trucks as they negotiate curves to exit the yards.
- With electronic scale control systems operators can more precisely load the right amount of salt.
- This device is a relatively inexpensive, durable and accurate weighing device consisting of a transducer load cell mounted to the loader bucket arm.
- These devices can measure a predetermined load size for the scheduled route (length of route X application rate + a limited contingency amount for bridge decks, intersections, etc.). In other words the benchmarked amount for the conditions of the event.
- Models are available that will record with the loader in motion so that the loader operation is not impeded.
- The units will record the amount loaded and can download or print out a ticket for tracking purposes.
- Though the equipment can be overridden, it provides the operators with a mechanism to accurately measure and control the amount of material loaded on the spreaders.

Truck Scales

- Weighing the trucks as they enter and leave the maintenance yard is a way of confirming the amount of material loaded and how much was spread on the serviced route.
- This function can be automated with a weigh-in-motion pad that tracks the equipment movement and can serve to reconcile the data from the spreader controller and other documentation.

Liquid Meters

- Pump meters at the brine loading station should be used to measure the amount of brine delivered to each truck in order to track loading times and quantities.
- There should be records kept of the amount of liquid loaded onto pre-wet and DLA units as well has how much liquid is used for each round. This will help to confirm overall usage and proper application rates for management and legal purposes.
- It is also important to have testing methods for confirming that liquids are at the ideal concentration. Some liquid production units measure concentrations on an ongoing basis during the production process and only deliver the completed brine to storage once the desired concentration has been reached. Brine concentrations should be checked using other means to ensure that the production process is delivering the desired product.

Automated Vehicle Location (AVL)

- AVL is a way of tracking equipment movements along with the services provided using GPS receivers/transmitters and software.
- The process usually involves a third-party provider that receives and assembles the vehicle position data from the GPS and operational data from the vehicle's controller by cell phone and provides it to the client over the internet.
- Many organizations have had difficulty getting quality data and management reports from their third party provider. Typical issues relate to equipment failure, operator sabotage, holes in the cell phone coverage and software mismatches.
- The electronic records can either be actively followed real-time or can be passively recorded for later analysis. It is also archived for future reference in the event of an incident or for review and management purposes. On-board data storage help to manage transmission costs, deal with communication gaps and ensure data integrity.
- The AVL provider needs to be able to collect and properly interpret the data from the controllers and relay this to the client. Because all controllers

do not use a common protocol for exchanging data the AVL needs to provide an interface that translates the output from each controller into common language. A problem occurs when there is a mismatch between the translation software and the controller. This can happen when a controller is changed and the translation software is not matched to the new controller. In this case the data is useless. Purchasers of this service should insist that the AVL supplier has a quality control system that can detect and report when data issues occur. Otherwise incorrect data can be collected.

- The electronic record can either be actively followed real-time or can be passively recorded for later analysis. It is also archived for future reference in the event of an incident or for review and management purposes.
- This equipment can provide operational support to greatly enhance the monitoring of salt usage, to demonstrate prudent usage and to correlate with the achievement of the required level of service. It is also useful for proving that specified services were provided, which is useful in defending against legal action.
- AVL can support a number of management needs including:
  - route optimization to rationalize the number of trucks required and thus the expected salt to be used on the roads serviced
  - thermal mapping where pavement temperatures from on-board sensors can be related to location
  - automatic spreader adjustments by location
  - determining salt loadings on service segments or within salt vulnerable areas

MATERIAL LOADING AND HANDLING

Bulk Salt Handling by Loaders

- Extensive environmental contamination has been identified in proximity to salt storage yards. Much of this contamination results from poor salt handling practices.
- Conveyors are available which are designed to allow salt trailers to dump directly into the conveyor for movement into the storage facility.
- Loaders used to fill spreader vehicles are often fitted with buckets that are too large for the spreader hopper bodies. This results in spillage.
- Though they have a slower production rate, smaller buckets are available for most loaders, or side dumping bucket attachments can be used which provide quick precise loading.

Bulk Material Conveyors

- Various bulk facilities are in use as follows (and are further described in the Design and Operation of Road Maintenance Yards SOBP):
  - Pre-loaded drop-hopper loaders meter salt into spreader trucks
  - Overhead silos can be pre-filled with salt to similarly meter salt into spreader trucks
  - Pneumatic handling equipment can handle fine material that is used for either direct application onto the road or for blending with sand
- Whatever equipment is used for moving salt, it should provide a way of tracking the flow so the quantities can be recorded and reconciled.

Sand/Salt Blend Mixers

- Salt is normally blended into stockpiled winter sand for the main purpose of keeping the sand free-flowing and to prevent it from freezing in the winter.
- High-ratio mixes are rarely necessary; an exception might include anticipated periods of rapid temperature fluctuations.
- Ideally, blended winter sand stockpiles are put up in favourable, dry conditions.
- Relatively dry sand stored indoors should not require more than 1-2% salt by weight; more moisture in the sand may require more blended salt (up to 5%), but the purpose still is to keep the sand free-flowing, and not to support melt action.
- Traditionally, blending took place on the apron to the storage shed, with several buckets of sand spread level, followed by one bucket of salt trickled on the surface; the resulting blend was loaded in the dome, and the process was repeated.

- Though highly inefficient, it was also highly inaccurate, and produced sporadic result on the pavement surface.
- Equipment to support high-production stacking and uniform, light blends now involves a form of dual-auger pugmill or a twin conveyor feed. In either case, two supply lines are metered to an accurate ratio and the final conveyor stacks the completed mixture.

BRINE SUPPLY EQUIPMENT

The following two sections discuss aspects of brine production and delivery. Further issues on brine supply and liquid storage are contained in the Design and Operation of Maintenance Yards SOBP.

Brine Production Equipment

- Several manufacturers offer equipment to manufacture salt brine for pre-wetting and direct liquid applications.
- Both batch plants and higher capacity continuous flow plants are available.
- Water is added to rock salt in the batch plants to produce a saturated brine solution.
- In the continuous flow plants, normally water is forced through salt under pressure. Solution strength can be metered and controlled automatically.
- Overhead drop-hoppers can slowly meter the salt into the water for quicker dissolving.
- In all cases, the concentration should be checked with a hygrometer or refractometer. The hygrometer measures the specific gravity of the solution. The percent of saturation is determined by reference to specific gravity charts for the specific solution temperature. Hygrometers are calibrated to a specific temperature and can give different readings at different temperatures. Refractometers may be more reliable.
- Water supply flow rates are a critical factor. Production sites may require cisterns that capture surface drainage to ensure adequate water supply where well production rates are poor.
- Most salt supply specifications allow for some insoluble contaminants in the salt. This can amount to approximately 100kg of waste grit when using a 96% pure salt source per one-bucket (2m3) or 10,000 litre brine batch. Clean-out time should be accounted for in production rates.
- Manufactured salt brine can be pumped directly into tanks mounted on the spreaders or transferred to holding tanks at the maintenance yards.
- Stored brine will normally stay in solution as long as there is not evaporation or a drop in temperature below eutectic.
- Additives such as corrosion inhibitors may complicate long-term storage, in which case agitation or recirculation could be considered.

Brine Delivery Equipment

- Unlike brine production, no special equipment is required for liquids that are delivered.
- When liquids are purchased laboratory test data should be provided to ensure that the concentrations are correct for the temperatures at which the liquid will be stored and used.
- Brine that is delivered should be tested to ensure that it meets the desired specification before it is used or mixed with other brine.
- Sampling containers and a refractometer or a properly calibrated hygrometer should be available for sampling and testing the concentration.

SALT VULNERABLE AREAS

Having proper equipment and effectively using this equipment are the most effective ways of ensuring that the right amount of salt is placed at the right time and in the right location. Organizations should strive to improve their fleet as quickly as possible given their fiscal realities.

As new equipment is phased in, priority should be given to allocating the new equipment to Service areas adjacent to salt vulnerable areas, and reallocating less salt-efficient equipment to less sensitive areas.

Technologies such as the use of liquids should be implemented as a way of reducing salt use and improving safety.

MONITORING & RECORD KEEPING

The data logging and reporting capabilities of loader scales, electronic controllers and GPS/AVL systems can assist organizations in more accurately tracking their salt use. Progress in implementation of best salt management practices can be measured in improvements to the fleet and the type and quantity of materials used. Monitoring and record keeping should include:

- type and amount of winter materials being placed per unit area
- percentage of fleet equipped with electronic spreader controllers
- percentage of fleet equipped with pre-wetting
- percentage of fleet equipped with direct liquid application
- percentage of fleet calibrated annually
- percentage of staff trained in equipment use

TRAINING

Traditionally, equipment-related training focused on equipment maintenance and the safe operation of the vehicle. This was followed by specific training on the differences between vehicles, which covered the spreader controller features and how to change settings, etc.

These aspects of staff training are still essential to the safe and effective use of equipment. Further equipment-related training, however, should also emphasize the impact of the operator's decisions made along the route, the range of settings and methodologies available to the operator and tie these to her/his roles as a "snowfighter" and "decision-maker." Equipment training should be integral with other winter maintenance topics such as the science of salt and record keeping.

In the past, a plow operator could be forgiven for only plowing, just as a spreader operator might only spread. That was the job after all. With today's understanding of best practices for snow and ice control and with the more sophisticated equipment that is available, operators need to understand that "decision-making" means choosing to spread when appropriate, and, equally important, choosing not to spread when it is not required. It is also important to choose to plow the accumulated snow and slush, but also important to not prematurely plow salt-laden slush before the salt has done its job.

To ensure operators are confident in their duties and in using the assigned equipment, they should have training in such equipment-related topics as:

- route/site familiarization (preferably during daylight)
- pre-season driver training
- spreader calibration (specific to those doing calibration)
- "circle-check" procedures
- spreader controller operation
- brine equipment operation
- equipment washing procedures
- minor equipment repair
- good housekeeping practices
- record keeping
- effective loader operation (specific to loader operators)
- use and interpretation of pavement sensor data and forecasts
- infrared thermometer use;
- agency policies

The following equipment-related learning goals should be included in a training program:

- Understand the concept of putting out the right material, in the right amount, at the right time, and leaving it there long enough to do the job.
- Understand how the electronic controller and gate settings on each spreader must be set to achieve the specified application rates.
- Understand how to calibrate each spreader to ensure that the right amount of material is being spread. The equipment should be calibrated to multiple rates for low, medium and high applications.
- Understand how to recognize when re-calibration is necessary.

- Understand the importance of timely plowing.
- Understand how to efficiently plow each beat/route/lot/sidewalk etc.
- Understand the role and effective placement of snowdrift control devices (structural snow fences, snow ridging, agricultural stubble, living snow fences).
- Understand how to fill spreaders and direct liquid units with liquid chemicals.
- Understand the health, safety and environmental precautions that need to be taken when handling liquid chemicals.
- Understand how to measure brine concentrations.
- Understand the components and purpose of RWIS installations.
- Understand how to properly mount a truck-mounted IRT so as to avoid erroneous readings.
- Understand that IRTs are for measuring temperature trends not exact temperatures.
- Understand precautions about handling and using IRT's.
- Understand the importance of proper record keeping and how to complete the required documentation on equipment maintenance and salt use.

CONCLUSION

Modern snowfighting equipment used to clear snow and ice, including snowplows and spreaders, has improved significantly in recent years. Using new technologies, together with implementation of anti-icing and the expanded use of liquid materials, winter maintenance can be completed to the same or higher standard and with a substantial reduction in salt use.

Equipment is available to facilitate more precise controlled applications of material, at the newly reduced rates established as a result of extensive research and testing. This equipment is much more sophisticated, durable and easier to use, but the potential benefits can only be realized if maintenance staff are thoroughly trained and material use is closely monitored.

Snowfighting activities can be tied into sensor based information systems including real time data, forecasts, friction measurements, surface temperature measurements and global positioning equipment. As the use of this technology evolves, considerable planning, organization and evaluation are required to ensure the best use of the equipment that is available.

A transition strategy will be required to shift to new technologies. This changeover cannot happen overnight, but the shift can occur strategically. For instance, the spreaders on the highest salt routes or in proximity to vulnerable areas could be targeted first for replacement, and the most versatile mechanical removal equipment could be stationed where it will help lessen salt loadings. To gain experience in new methodology, new equipment could be assigned to preferred "champions" in the organization for demonstrated use on less significant areas until there is confidence in the new practices.

Organizations should review their equipment needs and fleet management strategy regularly, and stay current with changes in the business.

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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.

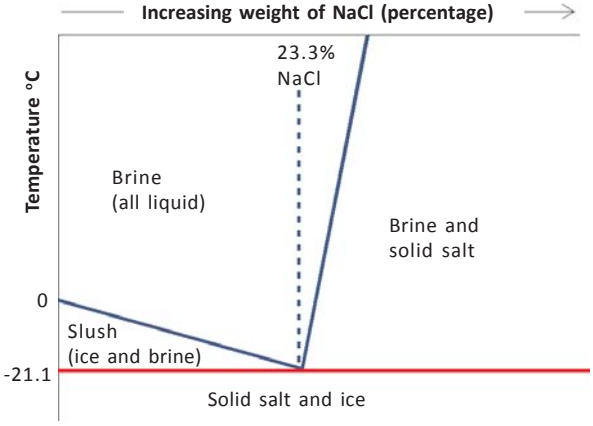

Figure 1 - Generalize Phase Diagram of Salt (NaCl) and Water

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