This report represents the results of research conducted by the authors and does not necessarily represent the views or policies of the Minnesota Local Road Research Board, the Minnesota Department of Transportation, or SRF Consulting Group, Inc. This report does not contain a standard or specified technique. The authors, the Minnesota Local Road Research Board, the Minnesota Department of Transportation, and SRF Consulting Group, Inc. do not endorse products or manufacturers. Any trade or manufacturers’ names that may appear herein do so solely because they are considered essential to this report.
# TABLE OF CONTENTS

**Introduction**

**Section 1: Snow and Ice Control Strategies**
- Snow Plowing
- Types of Snow Plows
- Plow Diagram
- Snow Plow Vehicles
- Snow Plow Cutting Edges
- Solid Material Spreaders
- Liquid Material Applicators
- In-Cab Controls
- Importance of Calibration

**Section 2: Snow Plows and Equipment**
- Snow Plowing
- Types of Snow Plows
- Plow Diagram
- Snow Plow Vehicles
- Snow Plow Cutting Edges
- Solid Material Spreaders
- Liquid Material Applicators
- In-Cab Controls
- Importance of Calibration

**Section 3: Winter Maintenance Materials**
- Winter Maintenance Materials
- Benefit-Cost of Plowing and Material Usage
- Blended Products and Corrosion Inhibitors

**Section 4: Winter Maintenance Technologies**
- Road Weather Information System (RWIS)
- MnDOT’s RWIS System
- Maintenance Decision Support Software (MDSS)
- Automatic Vehicle Location (AVL)

**Section 5: Winter Maintenance Policies and Best Practices**
- Minnesota Snow and Ice Control Handbook
- Importance of Having a Snow and Ice Control Policy
- Training Opportunities
- Resources

---

**ACKNOWLEDGMENT**

We wish to thank the Minnesota Local Road Research Board (LRRB) and its Research Implementation Committee (RIC) for the financial support to make this important report a reality. The Technical Advisory Panel (TAP) that steered this project was extremely helpful in identifying key issues and concerns. In addition, the TAP was very generous with its time in attending meetings, reviewing, and providing oversight for this final document. The authors would like to thank TAP members and their organizations for their contributions to this document.

**Technical Advisory Panel**

The following members comprise the project’s Technical Advisory Panel (TAP) that contributed to this project:

- John Brunkhorst, McLeod County (Chair)
- Tom Broadbent, EnviroTech Services
- Steve Collin, City of Minneapolis
- Bruce Holdhusen, MnDOT
- Matt Morreim, City of St. Paul
- Mike Kennedy, City of Minneapolis
- Mike Legg, Carver County
- Renae Kuehl, SRF
- Mike Marti, SRF
- Scott Petersen, SRF
- Tim Plath, City of Eagan
- Brian Pogodzinski, Houston County
- Kathleen Schaefer, MnDOT
- Stephen Schnieder, Nobles County
- Joe Spah, City of St. Paul
- Ryan Sutherland, Itasca County
- Rick West, Otter Tail County
INTRODUCTION

This Snow and Ice Control Guidebook summarizes common snow and ice control tools and serves as an introduction to the field of winter maintenance for operators and managers.

Minnesota local agencies perform winter maintenance to keep roads clear for the traveling public. However, agencies must balance public safety, cost, and environmental concerns to effectively manage their winter maintenance policy.

Minnesota cities and counties should retain an up-to-date policy for winter maintenance that specifies desired pavement conditions.

Winter Pavement Condition Definitions*

**Bare Pavement**
May be wet. Accurate and precise plowing and chemical use may be needed to achieve this condition and maintain normal travel speeds.

**Bare Wheel Paths**
Some slush may remain. Plowing and chemical applications have been made. The roadway is open to near-normal travel.

**Plowed and Treated**
Wheel paths may or may not be visible, some snowpack remaining, plowing and chemical use performed.

**Plowed to Snowpack**
Maintenance is being performed, but snowpack remains across the roadway.

*Final winter pavement conditions are defined by each agency based on their own service goals, budgets, and policies.
Before the Storm (Anti-icing/ Pretreatment)

Anti-icing is the application of liquid chemicals to the roadway before a winter storm.

- Prevents ice from bonding to the pavement.
- May reduce the amount of time required to restore the roads to bare pavement.
- Can be performed before the storm, during a regular shift.
- May offer cost savings over de-icing (material, personnel, and equipment).
- Pretreatment may be performed with solid materials as well.
- Material may be washed away if rain comes first, or wasted if forecasts are wrong.

During and After the Storm (De-icing)

De-icing is the application of chemicals during or after a storm.

- Improves ability for plows to clear ice and snow from the road by loosening compacted snow and ice.
- Aids in getting to bare pavement goals.
- Plowing and de-icing can be performed independently or to complement each other.
- Prewetting de-icers may improve effectiveness.

Effectiveness of material application can be improved with prewetting.

Prewetting is adding brine or other liquids to granular material to help jump start the melting process. Prewetting can be done at the spinner, in the pile, or by adding brine in the spreader box.

Benefits of Prewetting

- Achieve faster melt
- Reduce material use
- Prevents material scatter
SNOW PLOWING

Snow plowing is the removal of snow and ice from the roadway by mechanical means.

Final winter pavement condition expected varies depending on precipitation type, snow moisture content, temperatures, and conditions. Agencies may only be able to achieve “plowed and treated” or “plowed to snowpack” conditions with plowing alone. It may take time and repeated efforts to reach final goals.

Plowing snow is typically complemented with applying de-icing chemicals. For some conditions it may be necessary to plow and treat the roadway with sand or other abrasives.

Plowing alone may have no environmental impacts from chemical use, but the trade-off is less effective snow removal, lower levels of service, and potentially a higher risk to public safety.

Tandem plowing, echelon plowing (commonly called “gang plowing”), or tow plows may be used to clear multiple lanes in one pass.
**Types of Snow Plows**

**Front End Plow**
Front end plows are the most common, basic type of plow. Front plows come in many variants including left/right (reversible) plows, fixed, V-plow and high-speed plows.

**Wing Plow**
Wing plows are used in conjunction with other plows. They push snow and ice further to the side to create a wider clearing path. Wing plows may be positioned at the vehicle’s front, middle, or rear.

**Underbody Plow**
Underbody plows are located behind the front wheels, and can exert down-pressure. They may be used by themselves, or in conjunction with a front plow in deeper snows for optimal clearing.

---

**Plow Diagram**

- **Mold Board**
- **Cutting Edge**
  - ("Frog" joins the cutting edge to the mold board)
- **A Shoe**
  - (additional cutting edge mounted on the end of the mold board used primarily by municipalities to protect the plow from the curb and gutter)
SNOW PLOW VEHICLES

A variety of construction equipment can be used for plowing and other winter maintenance operations, either as-is, or by fitting the equipment with appropriate apparatus or attachments.

- Dump Truck with underbody and front plows as well as a material spreader
- Loader with reversible front plow, which allows snow to be thrown to the left and right, as needed
- Motor Grader with wing plow attachment (currently in the raised position)
- Snow removal using trucks and loader with blower
SNOW PLOW CUTTING EDGES

Commonly Used Cutting Edges

Steel
- Wears faster than carbide.
- Often used by cities that plow roads with metal hardware in the pavement (manholes, water valves).
- Can be stacked in front of a carbide blade to protect the carbide edge.

Carbide
- More expensive than steel, but long-lasting.
- More resistant to wear than steel, but also more susceptible to breaking.

Combination
- Segmented blade that is a combination of steel, carbide, and rubber.
- Long-lasting.
- Blade segments conform to the profile of the road (for example, rutted roadways).
- Reduced noise and vibration.
- Clears roadway better than standard cutting edges.

Newer Cutting Edge Options

Multi-Blade System
- Consists of two to three cutting edges.
- Relatively high cost.
- Each cutting edge has a separate function.
- Removes slush, cuts snow/ice, and removes snow.

Ceramic Cutting Edge
Rubber Cutting Edge

Other Materials
- Ceramic, composite, and rubber-encased cutting edges have also been used, but these have high cost and are typically used for specific applications such as brick roadways.
**SOLID MATERIAL SPREADERS**

Solid material spreaders are used to distribute granular material on the roadway in a consistent and measured way.

Various solid material spreaders are available for trucks:
- V-box, slide-in or permanent mount
- Pan
- Single or dual spinner
- Center or side discharge

Different spreader configurations provide various options for how the solid chemical is applied to the roadway, such as a spinner in the back, or deposited in front of the rear wheels.

Basic spreaders have the least amount of control over how effectively and efficiently the material is spread, or rates of application. Modern technology, such as ground speed controllers and prewetting equipment, can greatly enhance performance and material control.

Calibration of all types of spreaders is essential for optimal and effective use.

**LIQUID MATERIAL APPLICATORS**

Liquid material applicators are used to consistently apply liquid chemicals to the roadway in a deliberate and controlled spray pattern.

Liquids in anti-icing are typically applied using a “pencil-line” stream.

Liquid may be dispensed by gravity or by pressurized depending on the available equipment.

Side sprayers on pressurized units may be added for multi-lane applications.

Various types of tanks are used to hold liquids on trucks depending upon the intended use. For instance, saddle tanks are generally used for prewetting material at the spinner, and bladder or standard tanks for anti-icing.

Liquids are the most common and effective way to apply anti-icing chemical. Applying as lines rather than a spray pattern has been found to be most effective.

Calibration of the applicator is essential for effective use.
SOLID SPREADER AND LIQUID APPLICATOR IN-CAB CONTROLS

Plow operators regulate material application rates using in-cab controls. Good control systems are easy to operate, ergonomic, and provide adequate control.

Various types of in-cab controls allow the operator to adjust plows and chemical application:

- Joysticks
- Knobs or push buttons
- Dial control (set rate 1-10)

Operators set spread rates (pounds of solids per lane-mile or liquid application rates) or rates can be automatically set by onboard computer systems. Older-style manual controls (levers) are being phased out.

Computer-controlled systems can be set for “blast” mode to apply extra material in a targeted area, such as within an intersection. Be sure to use the calibrated application rate to avoid over use of material.

Ground speed control spreaders can automatically adjust application rates based on vehicle speed.

Control systems are often integrated with automatic vehicle location systems (AVL) for supervisors to remotely track maintenance activity.

IMPORANCE OF CALIBRATION

Calibration is an essential procedure to measure the amount of liquid and solid material applied to the roadway at various settings in relation to truck speed. No matter how sophisticated or simplified the operations, always calibrate or verify calibration annually.

The Minnesota Snow and Ice Control Field Handbook for Snowplow Operators provides additional guidance about calibration and offers the following calibration resources:

- Clear Roads has links to manufacturers’ calibration instructions and a comprehensive calibration guide: clearroads.org/project/calibration-accuracy-of-manual-and-ground-speed-control-spreaders/
- MnDOT also has calibration instructions: www.dot.state.mn.us/maintenance/training.html.
- For sander calibration training, contact the Minnesota Circuit Training and Assistance Program (CTAP) instructor at www.mnltap.umn.edu/about/programs/ctap/.
- For liquid calibrations, see the MnDOT Anti-icing Guide at www.dot.state.mn.us/maintenance/training.html.

Source: Force America
Source: Varitech Industries
WINTER MAINTENANCE MATERIALS

A variety of winter maintenance materials are available for local agencies to use to manage snow and ice. This table summarizes the commonly used materials, their uses, attributes and environmental impacts.

<table>
<thead>
<tr>
<th>Abrasives</th>
<th>Solid Rock Salt</th>
<th>Salt Brine</th>
<th>Magnesium Chloride</th>
<th>Calcium Chloride</th>
<th>Acetates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usage</td>
<td>Mix with salt to provide traction to slippery roads.</td>
<td>Deicing or anti-icing</td>
<td>Prewetting and anti-icing</td>
<td>Deicing, prewetting, and anti-icing</td>
<td>Deicing</td>
</tr>
<tr>
<td>Typical Form</td>
<td>Sand (paved roads) or gravel (unpaved roads). Mixed with salt (20% to 33% salt).</td>
<td>Solid granular</td>
<td>Liquid</td>
<td>Liquid or solid</td>
<td>Liquid</td>
</tr>
<tr>
<td>Lowest Practical Melting Temperature</td>
<td>15˚ F</td>
<td>15˚ F</td>
<td>-10˚ F</td>
<td>-20˚ F</td>
<td>20˚ F</td>
</tr>
<tr>
<td>Positive Attributes</td>
<td>- Provides temporary traction</td>
<td>- Excellent melting capacity</td>
<td>- Prevents snow and ice from bonding to pavement (anti-icing)</td>
<td>- Reduced amount of product used, reduced salt and abrasive use over rock salt</td>
<td>- Better cold temperature performance than rock salt</td>
</tr>
<tr>
<td></td>
<td>- More effective than chemicals at very low temperatures and for spot traction at targeted locations (hills, curves, bridges, intersections, shaded areas, windblown areas)</td>
<td>- Lower cost compared to other chemicals</td>
<td>- Lower cost compared to other chemicals</td>
<td>- Better cold temperature performance than rock salt</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Clear roads of snow and ice</td>
<td>- Reduced cost compared to other chemicals</td>
<td>- Reduced granular scatter when used for prewetting</td>
<td>- Persist on the road surface, aiding in longer black ice prevention than sodium chloride</td>
<td>- Reduced amount of product used</td>
</tr>
<tr>
<td></td>
<td>- Useful alternative in environmental sensitive locations (no salt roads)</td>
<td>- Low cost</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Non-corrosive</td>
</tr>
</tbody>
</table>

- Often used on bridge anti-icing systems
<table>
<thead>
<tr>
<th></th>
<th>Abrasives</th>
<th>Solid Rock Salt (NaCl)</th>
<th>Salt Brine</th>
<th>Magnesium Chloride (MgCl₂)</th>
<th>Calcium Chloride (CaCl₂)</th>
<th>Acetates</th>
<th>Calcium Magnesium Acetate</th>
<th>Potassium Acetate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Negative Attributes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Recovery from storms is slower than chemicals when used alone or in combination with only plowing</td>
<td>- Corrosion</td>
<td>- Corrosion</td>
<td>- Pavement deterioration</td>
<td>- Corrosion deterioration</td>
<td>- Expensive</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- More plow passes and applications are required than if chemicals are used</td>
<td>- Impacts on roadside and waterways</td>
<td>- Impacts on roadside and waterways</td>
<td>- Corrosion</td>
<td>- Corrosion</td>
<td>- Expensive</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Cannot achieve deicing</td>
<td>- Pavement deterioration</td>
<td>- Corrosion to vehicles and infrastructure</td>
<td>- More corrosive than sodium chloride</td>
<td>- More corrosive than sodium chloride</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Requires clean up after winter season</td>
<td>- Corrosion to vehicles and infrastructure</td>
<td>- Corrosion</td>
<td>- Pavement deterioration</td>
<td>- Corrosion deterioration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Environmental Impacts</strong></td>
<td>- Abrasives can enter the waterways and clog streams, clog drains, can impact water quality and aquatic species</td>
<td>- Entry into waterways</td>
<td>- Entry into waterways</td>
<td>- Entry into waterways</td>
<td>- Entry into waterways</td>
<td>- Expensive</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Straight abrasive use does not pose corrosion issues, but abrasive-salt mixes can cause this issue</td>
<td>- Impact to roadside soil, vegetation</td>
<td>- Impact to roadside soil, vegetation</td>
<td>- Impact to bridge infrastructure</td>
<td>- Leaching/run-off from stockpiles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Their decomposition consumes dissolved oxygen, resulting in lower oxygen levels in water.</td>
<td>- Leaching/run-off from stockpiles</td>
<td>- Impact to bridge infrastructure</td>
<td>- May mobilize heavy metals in soil releasing them into the water</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Chemical Application Rates**

Detailed provisions about material application rates are given in the Minnesota Snow and Ice Control Handbook.

The Clear Roads pooled fund commissioned an analysis of the costs and benefits of various winter maintenance strategies. This analysis found that plowing is the most effective and basic form of winter maintenance and material usage can supplement plowing at various rates. The analysis included safety benefits, agency resources, corrosion to infrastructure and vehicles, and environmental impacts.

<table>
<thead>
<tr>
<th>Material Usage Benefit-Cost Ratio* (Assumes Plowing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plowing</td>
</tr>
<tr>
<td>Abrasives</td>
</tr>
<tr>
<td>Solid Rock Salt (NaCl)</td>
</tr>
<tr>
<td>Salt Brine</td>
</tr>
<tr>
<td>Magnesium Chloride (MgCl₂)</td>
</tr>
<tr>
<td>Calcium Chloride (CaCl₂)</td>
</tr>
</tbody>
</table>

*When applied with typical methods

Read more about this study here:

Blended Products
- Blended products can combine benefits of various chemicals, such as the low cost of rock salt with the low freezing point of calcium chloride as well as a corrosion inhibitor.
- Can be blended on site or purchased pre-blended.

Corrosion Inhibitors
- Corrosion inhibitors are generally additives that reduce the corrosiveness of a chemical.
- Premixed chemicals with corrosion inhibitors can be purchased under trade names or are organics, such as beet juice or molasses.
- Typically used in spot locations.

More information about corrosion inhibitor effectiveness can be found here:
ROAD WEATHER INFORMATION SYSTEM (RWIS)

Overview

A Road Weather Information System (RWIS) is a combination of field hardware and software that provides detailed and timely road-weather information that is used to support operations and maintenance decisions.

RWIS’s are comprised of a network of field Environmental Sensor Stations (ESS) that measure atmospheric and pavement conditions.

- Atmospheric data
  - Air temperature
  - Humidity
  - Visibility distance
  - Wind speed and direction
  - Precipitation type and rate
- Pavement data
  - Pavement temperature
  - Pavement condition (dry, wet, ice, frost)
  - Subsurface temperature

MNDOT’S RWIS SYSTEM

MnDOT maintains a RWIS system for the state roadways.

rwis.dot.state.mn.us/

Local agencies can benefit from this system and use it to determine weather conditions of nearby roads.
MAINTENANCE DECISION SUPPORT SOFTWARE (MDSS)

The MDSS provides reliable weather, road condition, and maintenance information enabling transportation agencies to accomplish their winter maintenance missions.

Current road conditions are supplemented with RWIS and entries from operators/supervisors in trucks to determine the near to medium term weather forecast and recommend sound winter maintenance strategies:

- Treatment type
- Application rates
- Application timing
- Predict the resulting road conditions

MDSS Deployment Guide, FHWA
ntl.bts.gov/lib/30000/30400/30467/14439.pdf
AUTOMATIC VEHICLE LOCATION (AVL)

Overview

Automatic Vehicle Location (AVL) systems are used to automatically determine and transmit the location of a vehicle.

AVL systems provide a dispatch center the capability to monitor the location of all vehicles continuously in real time to monitor progress of snow removal operations during the event and re-deploy equipment to meet changing weather conditions.

AVL is usually integrated with digital communications and Geographic Information System (GIS) mapping systems to streamline instructions from the dispatcher who is able to view vehicle itineraries and locations graphically.

AVL systems can automatically generate “end-of-shift” reports that determine the amount of material used rather that the operator manually filling out a worksheet.

Automated End-of-Shift Reports

AVL hardware

Some AVL systems have a mobile data terminal operator interface
MINNESOTA SNOW AND ICE CONTROL HANDBOOK

- Promotes “the understanding of the tools, best practices, and limitations for snow and ice control.”
- “…encourages progressive changes in snow and ice control practices that will help you reduce salt/sand use and environmental impacts while meeting the safety and mobility needs of roadway users.”

Offers “standard best practices expected in a quality snow and ice control program.”


IMPORTANCE OF HAVING A SNOW AND ICE CONTROL POLICY

- Allows the agency to manage risks
- Encourages the agency to study, develop, follow policies
- Communicates the policy to citizens and staff
- Provides an opportunity for the agency to review and monitor the processes
- Allows the agency to learn and improve


The League of Minnesota Cities provides a model Snowplowing and Ice Control Policy, [www.lmc.org/media/document/1/modelsnowplowingpolicy.pdf](http://www.lmc.org/media/document/1/modelsnowplowingpolicy.pdf)

Minnesota Pollution Control Agency Smart Salting (S2) Certification, [stormwater.pca.state.mn.us/index.php/Smart_Salting_(S2)_training_information](http://stormwater.pca.state.mn.us/index.php/Smart_Salting_(S2)_training_information)

[www.pca.state.mn.us/water/training](http://www.pca.state.mn.us/water/training)
**TRAINING OPPORTUNITIES**

- MnDOT’s Minnesota Snowplow and Safety Simulator Training for Local Agencies
- Snow Plow Operator Training (SPOT)
- Defensive Snow Plow Technical Training
- Dakota County Technical College
- St Cloud State Advanced Driving Skills Snow Plow Operators/Wing & Plow/Road Maintenance
- Minnesota Fall Maintenance Expo
- MnLTAP/CTAP Snow and Ice Material Application and Calibration classes
- MPCA Level 1 Certification Course: Snow & Ice Control Best Practices
- APWA North American Snow Conference
- APWA Winter Maintenance Supervisor Certificate Workshop
- Western Snow Conference
- University of Wisconsin – Managing Snow & Ice Control Operations Workshop

**RESOURCES**

- LRRB YouTube Video – Winter Chemicals for Local Agencies, 2015
- Clear Roads studies:
  - Cost-Benefit of Various Winter Maintenance Strategies
  - Roadway Salt Best Management Practices
- Chloride Free Snow and Ice Control Material, MnDOT Transportation Research Synthesis, June 2014
- Effect of Pre-wetting Brines on the Ice Melting Rate of Salt at Very Cold Temperatures, Cargill
- Salt Brine Blending to Optimize de-icing and Anti-Icing Performance and Cost-Effectiveness
  - Phase I, 2012
    - Anti-Icing Cost Model REV (Excel) (Password: Mankato)
    - De-icing Cost Model REV2 (Excel) (Password: Mankato)
  - Phase II, 2014
  - Phase III in progress as of 2016
- MPCA Winter Maintenance Assessment Tool
- Local Government Snowplow Salt and Sander Controller Calibration Guide
- SALT Symposium– Risk Management Presentation