Minnesota Department of Transportation

RESEARCH SERVICES

Office of Policy Analysis, Research & Innovation

# Salt Brine Blending to Optimize Deicing and Anti-Icing Performance

Stephen J. Druschel, Principal Investigator
Center for Transportation Research and Implementation
Minnesota State University, Mankato

**July 2012**

Research Project
Final Report 2012-20

*Your Destination...Our Priority*

## Technical Report Documentation Page

| 1. Report No. | 2. | 3. Recipients Accession No. | |
|---|---|---|---|
| MN/RC 2012-20 | | | |
| 4. Title and Subtitle<br>Salt Brine Blending to Optimize Deicing and Anti-Icing Performance | | 5. Report Date<br>July 2012<br>6. | |
| 7. Author(s)<br>Stephen J. Druschel | | 8. Performing Organization Report No. | |
| 9. Performing Organization Name and Address<br>Minnesota State University, Mankato<br>Center for Transportation Research and Implementation<br>205 Trafton Science Center East<br>Mankato, Minnesota 56001 | | 10. Project/Task/Work Unit No.<br>11. Contract (C) or Grant (G) No.<br>(c) 96319 | |
| 12. Sponsoring Organization Name and Address<br>Minnesota Department of Transportation<br>Research Services<br>395 John Ireland Boulevard, MS 330<br>St. Paul, MN 55155 | | 13. Type of Report and Period Covered<br>Final Report<br>14. Sponsoring Agency Code | |
| 15. Supplementary Notes<br>http://www.lrrb.org/pdf/201220.pdf | | | |
| 16. Abstract (Limit: 250 words)<br>This research evaluated the ice melt capacity and field performance factors of deicers and deicer blends and then developed a temperature-based cost model for comparing the relative field performance of the evaluated deicers and deicer blends. Both solid and liquid deicers were evaluated for both deicing and anti-icing methods. | | | |
| 17. Document Analysis/Descriptors<br>Deicers, Halite, Sodium chloride, Magnesium chloride, Calcium chloride, Snow, Ice, Roadway, Ice melt capacity, Traffic lanes | | 18. Availability Statement<br>No restrictions. Document available from: National Technical Information Services, Alexandria, Virginia 22312 | |
| 19. Security Class (this report)<br>Unclassified | 20. Security Class (this page)<br>Unclassified | 21. No. of Pages<br>151 | 22. Price |

# Salt Brine Blending to Optimize Deicing and Anti-Icing Performance

## Final Report

*Prepared by:*

Stephen J. Drschel

Center for Transportation Research and Implementation
Minnesota State University, Mankato

**July 2012**

*Published by:*

Minnesota Department of Transportation
Research Services
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155

# Acknowledgments

This report would not be possible without the support of the maintenance professionals at the Minnesota Department of Transportation. Their input, evaluation and teaching greatly increased the quality of this report and the applicability of the laboratory testing. Many vendor representatives provided samples for evaluation; their willingness is greatly appreciated. City and county personnel from throughout Minnesota provided valuable response during discussions of initial results.

Student workers from the Civil Engineering program at Minnesota State University, Mankato contributed substantial effort in support of this project: Alex Raymond, Sarah Green, Andrew Schweim, Breanna Brown were mainstays while Cassie Orcutt, Nriprendra Bastogna, Shaun Bulfur, and Graham Stock provided spot service. Pam Baker of the Center for Transportation Research and Implementation assisted with document preparation and administration services.

This project was funded by the Minnesota Department of Transportation through Agreement 96319. MnDOT's support is gratefully acknowledged.

# Table of Contents

**Chapter 1: Introduction ..... 1**
1.1: Literature Search ..... 1
1.2: Summary of Research Methodology ..... 1
1.3: Performance Factor Selection Process ..... 2
1.4: Deicers Selected for Study ..... 2
1.5: Stakeholder Concerns ..... 5
**Chapter 2: Ice Melt Capacity Study ..... 6**
2.1: Test Method ..... 6
*2.1.1: Ice Specimen Preparation ..... 6*
*2.1.2: Deicer Preparation and Application ..... 7*
*2.1.3: Brine Measurement ..... 7*
*2.1.4: Temperature Establishment ..... 8*
2.2: Experiments ..... 8
*2.2.1: Individual Deicers ..... 8*
*2.2.2: Deicers Blends ..... 9*
2.3: Discussion ..... 11
**Chapter 3: Deicer Field Performance Study ..... 12**
3.1: Test Methods ..... 15
*3.1.1: Deicer Bounce Test ..... 15*
*3.1.2: Deicer Penetration Test ..... 16*
*3.1.3:Deicer Undercutting Test ..... 16*
3.2: Results ..... 17
*3.2.1: Deicer Bounce Test ..... 17*
*3.2.2: Deicer Penetration Test ..... 17*
*3.2.3: Deicer Undercutting Test ..... 23*
3.3: Discussion ..... 26
**Chapter 4: Cost Model ..... 27**
4.1: Methods ..... 27
4.2: Results ..... 28

4.3: Discussion ..... 28
**Chapter 5: Conclusions ..... 30**
**References ..... 31**
**Appendix A – Ice Melt Capacity Evaluation of Rock Salt and Salt Brine Deicers**
**Appendix B – Ice Melt Capacity Evaluation of Deicers Other Than Rock Salt and Salt Brine**
**Appendix C – Stockpile Treatment Analysis**
**Appendix D – Brine Blend Rate Analysis**
**Appendix E – Bounce Test Results**
**Appendix F – Penetration Test Photographic Results**
**Appendix G – Cost Model Spreadsheet for Deicing and Prewet Applications**
**Appendix H – Cost Model Spreadsheet for Anti-Icing**
**Appendix I – Cost Model Factor Evaluation**

## List of Tables

Table 1. Deicers considered in this study, with active components as listed by the vendor. ..... 4

Table 2. Ice melt capacities interpreted from laboratory results and used in the cost model. ..... 10

Table 3. Deicers evaluated in this task for field performance measures. ..... 14

Table 4. Factors incorporated into the cost model. ..... 29

## List of Figures

Figure 1. Deicers evaluated in this study, generally grouped as: (in center front) Blanche rock salt (beaker), salt brine (flask), (from left) acetates (two vials), treated rock salts (three vials), magnesium chlorides (four vials), dyed magnesium chlorides (two vials), calcium chlorides (three vials), and carbohydrate/agricultural byproducts (six vials). ..... 3

Figure 2. Ice specimens prepared for study in beakers within a thermal stabilization unit. ..... 7

Figure 3. Bounce test apparatus showing aluminum plate (0 ºF at start of test) inclined at 30º above horizontal, twin lines of capture paper, and side boards. Not shown is vial formerly containing 30.0 g of deicer (Rock Salt, Passing #10 Sieve, Retained on #20 Sieve) at 3 feet above floor (paper) level. Note spray pattern of deicer on paper. ..... 15

Figure 4. Bounce test of deicer particles. ..... 18

Figure 5. Penetration test of solid deicers (0.5 mL, placed in ¼ inch diameter by 1 inch long hole, with frozen 20 uL fluorescent dye, for 30 minutes at 23 ºF). ..... 19

Figure 6. Penetration test of liquid deicers (0.5 mL, placed in ¼ inch diameter by 1 inch long hole, with frozen 20 uL fluorescent dye, for 30 minutes at 23º F). ..... 21

Figure 7. Penetration test of blended liquid deicers (0.5 mL, placed in ¼ inch diameter by 1 inch long hole, with frozen 20 uL fluorescent dye, for 30 minutes at 23º F). ..... 22

Figure 8. Undercutting test (a to h: 30mL water in 75 mm Petri dish, 0 ºF; ..... 24

# Executive Summary

This report presents the evaluation of the ice melt capacity and field performance factors of deicers and deicer blends, and the development of a temperature-based cost model for comparison of relative field performance through the evaluated deicers and deicer blends. Ice melt capacity is the amount of ice melted (brine created) per the amount of deicer applied. The units of ice melt capacity depend upon whether the deicer is applied as a solid (units of mL brine created / g of deicer applied) or liquid (units of mL brine created / mL of deicer brine applied). Values of ice melt capacity observed in this study ranged from zero (no melting caused) to 12.7 mL brine created / mL of deicer brine applied, and were generally found to be strongly associated with temperature.

Factors other than ice melt capacity that influence deicer effectiveness were indicated to investigators during eleven meetings or presentations by MnDOT Maintenance and Operations staff plus municipal, county, and vendor personnel. Factors such as road surface characteristics, traffic characteristics, deicer transportation, equipment corrosion, environmental consequences, and storage stability were considered important but not appropriate for laboratory study and were, therefore, recommended for subjective inclusion in the cost model. Four factors were selected as potentially contributing to better relative performance between deicers (e.g., creating a difference in cost effectiveness):

1. Deicer bounce, the characteristic of not adhering to or settling on an inclined surface;
2. Deicer penetration, the characteristic of melting a vertical column through ice rather than spreading laterally within the ice;
3. Deicer undercut, the characteristic of spreading laterally on the pavement surface beneath ice after deicer penetration; and,
4. Deicer grain size, a secondary factor in which the relative size of the deicer particle might or might not influence bounce, penetration, or undercutting.

Of these four factors, only grain size was found to be statistically significant in providing performance differences. Deicers did not vary by type or product for bounce, penetration, or undercut. From these results it was concluded that ice melt capacity is the most significant factor in performance for evaluation in the cost model.

The cost model was built based on the effectiveness of a proposed deicer and its delivered cost in comparison to a known performance, that of rock salt at 28 °F, assuming all neutral field conditions, across a range of temperatures. Cost per lane mile is calculated in the cost model using the proposed application rate and specified levels of field conditions. Rock salt at 28 °F was selected as the base performance standard because it was assumed that most people are strongly familiar with this optimistic performance level, as they typically might start with the image of performance of rock salt at 28 °F then adjust either expectations or application.

# Chapter 1: Introduction

This report presents the results of research addressing performance of salt brine mixtures as a function of cost. Over twenty different deicing products are currently in consideration by MnDOT, and potential benefit is offered by blends of various products. Under the Strategic Highway Research Program, performance is defined as a combination of ice melting capacity, penetration of deicers, ice undercutting, frictional characteristics, and deleterious effects on concrete and steel. Between the number of products, the number of performance measures and the changing price structure across the winter season, it can be very difficult for a maintenance supervisor to select the most appropriate and cost effective deicing compound for a given temperature and precipitation situation.

## 1.1: Literature Search

Chappelow et al (1992) provides methodology for 12 main and 50 ancillary tests for evaluating chemical deicers under standards put forth as SHRP-H-332. These tests address ice melting capacity, penetration of deicers, ice undercutting, frictional characteristics, and deleterious effects on concrete and steel. Research sponsored by the State of Wisconsin under the Clear Roads Pooled Fund (Shi, 2008) is in process of developing alternative methods to improve precision and ease of evaluation; however, these are in current development are not yet accepted for widespread use.

Research sponsored by the Colorado Department of Transportation (Shi and Fay, 2009) indicates that deicer variation is greatest in ice melt capacity, with much less variation in penetration, friction, and undercutting for the main tests of deicer performance. The ice melt test is performed by freezing, melting and refreezing water in a glass pan, applying deicer, then removing for measurement the water melted after 1 hour with a syringe.

Costs of deicers are not included in these performance studies. Costs typically vary through the deicing season for each deicer compound or product, with the variation having different patterns for different types of products.

## 1.2: Summary of Research Methodology

Methods have been developed under SHRP to evaluate the effectiveness of chemical control of winter snow and ice on roadways. However, these methods do not account for the cost of deicers, only the performance. Further, mixtures and combinations of deicers have been anecdotally shown by deicing operators to improve handling and effectiveness of deicing efforts when applied in field situations. These observations have not before been fully evaluated with reproducible conditions and assessment of variability, nor have the cost implications of these mixtures been evaluated.

Ice melt testing of 22 available deicer products plus combinations of products was done at 11 different temperatures (from +30° F down to – 30°F, in 5° F increments). Multiple applications of each combination and temperature were used to reduce variability. Field performance factors were also assessed.

This effort resulted in a spreadsheet tool with a graphical output that allows a maintenance supervisor to make informed choices about deicer performance as a function of actual cost at the time and temperature of use.

### 1.3: Performance Factor Selection Process

Selection of performance factors to be addressed originated with an assessment of existing practices and stakeholder concerns regarding deicers and deicer blends, and the storage, management and application of these deicers and deicer blends. For purposes of this project, stakeholders are defined as District Salt Solutions Coordinators, Maintenance Supervisors and the Operations Management Group, all of MnDOT. Secondary stakeholders including municipal and county roadway maintenance personnel are considered represented by the primary stakeholders listed above.

Eleven meetings or presentations by MnDOT Maintenance and Operations staff plus municipal, county and vendor personnel were the basis of the assessment of existing practices and stakeholder concerns. These meetings and presentations included:

- April 29, 2010 Technical Assistance Panel (TAP) meeting at MnDOT Central Office;
- September 21, 2010 Operations Management Group meeting at MnDOT District 7;
- October 20, 2010 Statewide Maintenance Supervisors meeting at MnDOT District 7;
- January 5, 2011 meeting with Gordon Regenscheid, Joe Huneke and Kathy Schaefer at MSU Mankato Environmental Engineering Laboratory;
- April 27, 2011 District Salt Solutions Coordinators Winter Wrap-Up meeting at MnDOT District 7;
- June 7, 2011 (twice) Transportation Equipment Showcase at the Lakeville Truck Facility;
- September 7, 2011 Salt Coordinators meeting at Arden Hills Training Facility;
- September 22, 2011 Operations Management Group meeting at MnDOT District 4;
- October 5 and 6, 2011 Minnesota Fall Maintenance Expo presentations; and,
- October 6, 2011 District Salt Solutions Coordinators meeting in Duluth.

Additional information including the "brewmaster" list of deicers and blends was provided by email.

### 1.4: Deicers Selected for Study

Table 1 lists the deicers identified for study, tabulated by base component. Vials of the deicers are shown in Figure 1, grouped by type. The deicer list are meant to be inclusive of deicers considered for use in Minnesota as of Winter 2010-2011, but not necessarily all deicer compounds possible. Specific deicers and deicer blends were selected for this study and provided by MnDOT.

**Figure 1. Deicers evaluated in this study, generally grouped as: (in center front) blanche rock salt (beaker), salt brine (flask), (from left) acetates (two vials), treated rock salts (three vials), magnesium chlorides (four vials), dyed magnesium chlorides (two vials), calcium chlorides (three vials), and carbohydrate/agricultural byproducts (six vials).**

Deicer blends, listed by volume of mixed products, include the following mixtures currently in use by MnDOT:

Salt (NaCl) Brine Blends:

- Articlear Gold (MgCl and sugar beet byproduct) – 20%;
- Calcium Chloride (CaCl) – 10%;
- Calcium Chloride (CaCl) – 20%;
- Calcium Chloride (CaCl) – 30%;
- LCS (Corn byproduct) – 10%;
- LCS (Corn byproduct) – 20%;
- Univar Ice Bite (Sugar beet byproduct) – 10%;
- Univar Ice Bite (Sugar beet byproduct) – 20%;
- Univar Ice Bite (Sugar beet byproduct) – 30%;

Rock Salt (NaCl) Stockpile Treatments:

- Freezegard Zero Chloride (MgCl with corn byproduct) – 6 gallons per ton;
- Geomelt 55 (Sugar beet byproduct) – 6 gallons per ton;
- Iceban 200M (MgCl with corn byproduct) – 6 gallons per ton;
- RGP-8 (CaCl with sugar beet byproduct) – 6 gallons per ton;
- SOS (MgCl) – 3 gallons per ton;
- SOS (MgCl) – 6 gallons per ton;
- Univar Ice Bite (Sugar beet byproduct) – 6 gallons per ton;

**Table 1. Deicers considered in this study, with active components as listed by the vendor.**

| Deicer | Main Component | Secondary Component(s) | Company/ Manufacture |
|---|---|---|---|
| District 7 Rock Salt | NaCl | none | North American Salt |
| Salt Brine | NaCl (23.3%) | none | North American Salt |
| Blanche Rock Salt | NaCl | none | North American Salt |
| CaCl | CaCl | none | Tiger Calcium |
| Alpine Ice Melt | Potassium Acetate | Potassium Acetate | Scotwood Industries |
| AP Liq Deicer | $MgCl_2$ | not provided/none | Envirotech |
| Meltdown Apex | $MgCl_2$ | Corn based modifier | Envirotech |
| Apogee Non-Cl | Not Cl (possibly carbohydrate based) | not provided | Envirotech |
| Articlear Gold | $MgCl_2$ | Molasses or Sugar beet | North American Salt |
| CF-7 | 50% Potassium Acetate | Corrosion Inhibitors | Cryotech Technologies |
| Clearlane Enhanced | 29% $MgCl_2$ | not provided | Cargill |
| Freezegard Zero | $MgCl_2$ | Corn based modifier | Scotwood Industries |
| Geomelt 55 | 55% sugar beet | not provided | SNI Solutions |
| Geomelt S | 55% sugar beet | Salt Brine | SNI Solutions |
| Ice Ban 200M | 28% $MgCl_2$ | Corn based modifier | Scotwood Industries |
| Ice Slicer Granular | Complex Cl's | Trace minerals (sulpur, iron, zinc, iodine) | Envirotech |
| LCS 5000 | Corn salt | none | Envirotech |
| NAAC (pellets) | 97% Sodium Acetate | none | Cryotech Technologies |
| RGP-8 | 26.5% CaCl | 3.1% $MgCl_2$ 2.2% other Cl | Tiger Calcium |
| SOS | $Mg_2Cl$ | none | Envirotech |
| TC Econo | 2% CaCl $MgCl_2$ | 20% NaCl Brine | Tiger Calcium |
| Thawrox MG Plus | 26% $MgCl_2$ | Corn based modifier | North American Salt |
| Thawrox MG Clear | 26% $MgCl_2$ | Corn based modifier | North American Salt |
| Univar Ice Bite | Sugar beet | not provided | Univar |

These mixtures were defined through the brewmasters list, producer literature and discussions with salt solutions coordinators. It was noted by operations staff that magnesium chloride products should not be mixed with salt brine.

### 1.5: Stakeholder Concerns

Stakeholders expressed interest in the following characteristics of deicer operations and performance being addressed through research and modeling:

- Deicer performance variation due to:
  - Road surface exposure to wind;
  - Road surface exposure to sun;
  - Road surface color;
  - Road surface texture; and,
  - Traffic frequency and truck proportion of traffic.

- Deicer application variation due to:
  - Grain size of deicer;
  - Color of deicer (operator awareness of recent application);
  - Bounce of deicer as function of temperature, deicer grain size and stickiness;
  - Hardness of deicer;
  - Moisture content of deicer; and,
  - Component separation during storage or transportation.

- Handling characteristics of deicers:
  - Deicer corrosion of equipment;
  - Environmental consequences of chlorides or organic components;
  - Storage stability of deicers; and,
  - Mixing methods of deicer blends.

# Chapter 2: Ice Melt Capacity Study

This chapter presents the results of ice melt capacity testing and analysis of deicers and deicer blends. Ice melt capacity is the amount of ice melted (brine created) per the amount of deicer applied. The units of ice melt capacity depend upon whether the deicer is applied as a solid (units of mL brine created / g of deicer applied) or liquid (units of mL brine created / mL of deicer brine applied).

## 2.1: Test Method

### *2.1.1: Ice Specimen Preparation*

Ice specimens were prepared in 160 mL borosilicate glass beakers using 50.0 mL of tap water (City of Mankato public water system). Once loaded with water, beakers were covered with foil and placed in a thermal stabilization unit consisting of a 12 inch square, ¾ inch thick aluminum plate underlain by a 1 inch thick polystyrene foam insulation with 3 inch high walls made of 1 inch thick polystyrene foam insulation/1/8$^{th}$ inch hardwood plywood composite. Up to 15 beakers were placed in each thermal stabilization unit, along with a spirit thermometer placed in 50 mL of salt brine within a 120-mL Erlenmeyer flask (Figure 2).

After being loaded with water, foil covered and loaded into the thermal stabilization units, beaker sets were placed in a laboratory freezer for a minimum of 16 hours at a selected temperature typically of 0 to 5 °F (-18 to -15 °C) to create ice specimens.

Measurement of temperatures in this study was made by immersion of spirit thermometer bulbs into liquid salt brine mixtures for improved representation of equivalent ice temperature. Liquid contact with the thermometer bulb was thought to improve thermal conductivity over direct ice contact, while providing thermal stability from transitory drafts. Approximate liquid volumes of 50 mL were used to provide the thermal characteristics of the 50 mL ice specimen. Spirit thermometers used in this study were generally of a -4 to 248 °F (-20 to +120 °C) range, except for colder test conditions (-4 to -30 ° / -20 to -30 °C) when spirit thermometers of a -58 to +458 °F (-50 to +220 °C) range were used.

**Figure 2. Ice specimens prepared for study in beakers within a thermal stabilization unit.**

*2.1.2: Deicer Preparation and Application*

Deicers were kept in a refrigerator at 39 °F (4 °C) until measurement for application and use. Solid deicers were measured to a precision of ±0.1 g using an electronic balance. Liquid deicers were measured to a precision of ±0.01 mL using the full capacity of a 1.00 mL gas tight syringe (triple rinsed in water after use) or a 1.00 mL Type A glass pipet. Deicer was applied to the center of an ice specimen top surface after removal of the foil cover. After 30 minutes, any melted brine that had been generated was pulled into a dedicated plastic syringe (typically 20 mL, though 10 mL syringes were used for colder temperatures). The brine volume was recorded and the brine returned to the ice specimen by a gentle spray across the exposed surface. Three cycles of brine measurement and return were done at 30 minute increments (30, 60 and 90 minutes after application of the deicer).

*2.1.3: Brine Measurement*

At 120 minutes after application of deicer, a beaker was removed from the freezer or cooler and a brine measurement made using a 25 mL (10 mL for colder temperatures) glass syringe with a blunt point steel pipetting needle. The glass syringe has a precision of 0.25 mL (0.1 mL for the 10 mL syringe). The steel needle allowed for collection of sample from depressions and cavities in the ice.

*2.1.4: Temperature Establishment*

Temperatures of 5 °F (-15.0 °C) or colder were created using the programmable temperature control of the laboratory freezer, set for a minimum of 48 hours for temperature stabilization after an adjustment. Tests were conducted at these temperatures by temporarily moving the thermal stabilization units out of the freezer for deicer application and brine measurement/reapplication.

Temperatures between 30 and 5 °F (-1 and -15.0 °C) were created using an ice brine solution, made with sodium chloride at a concentration selected to provide a lowered freezing point near the target temperature. Brine solutions were prepared in 5-gallon buckets and placed in the laboratory freezer at 5 °F (-15.0 °C) or colder for a minimum of 16 hours to create an ice-brine solution. Through the provisions of the Second Law of Thermodynamics, the ice-brine solution would maintain a consistent temperature while both ice and liquid (brine) were present, if well mixed.

In preparation for tests, brine solution buckets were removed from the freezer and the ice broken up to provide a uniform mixture with solids less than 2 inches in diameter. Brine was then placed in a cooler and a thermal stabilization unit sunk into the brine such that the ice specimens were within the liquid. An additional 8 beakers of ice specimens were placed into the liquid using a thin plastic pan for stability. Thermometers were placed within the cooler to monitor temperature in three locations: in the ice brine, in a Erlenmeyer flask with 50 mL brine in the thermal stabilization unit, and in a Erlenmeyer flask with 50 mL brine in the plastic pan. Ice specimens were allowed a minimum of two hours for thermal adjustment and equilibrium to be achieved prior to test initiation.

## 2.2: Experiments

*2.2.1: Individual Deicers*

Individual deicers were tested for ice melt capacity as a function of temperature using two application levels of deicers: 1.0 and 3.0 g for solid deicers, and 1.0 and 3.0 mL for liquid deicers. Tests were performed over range of temperatures, generally from 28 to -2 °F (-2 to -18 °C), to evaluate ice melt capacity at seven or more temperatures representing the working range of deicing. All deicing products supplied were analyzed, whether recommended for individual or combined application, in order to evaluate the deicing effect specific to the individual deicing product.

Results were analyzed for effect of temperature, normalizing for application rate. The results for rock salt and salt brine are provided in Appendix A. For deicers other than rock salt and salt brine, evaluation results are provided in Appendix B, with the results of Blanche Rock Salt included on each graph as a comparative reference.

*2.2.2: Deicers Blends*

Stockpile treatments, in which a liquid deicer is applied to rock salt as an additive, were tested for ice melt capacity as a function of additive rate. A 2.0 g mass of rock salt was applied to the top surface of an ice specimen then the liquid deicer additive applied using a glass syringe, selected to be at full volume to provide optimum measurement precision (±1% of the full volume). Four levels of additive rate were used, representing 3, 6, 12 and 30 gallons of liquid deicer additive per ton of rock salt. Triplicate specimens were tested for each of the four additive levels, for twelve total specimens per temperature. Specimen testing for a given temperature was done at the same time and in the same thermal condition (ice brine cooler or freezer), maintaining a high degree of uniformity to reduce confounding. Typically, tests sets were conducted at three different temperature levels.

Stockpile treatment results were analyzed for the effect of deicer additive rate, as provided in Appendix C. Linear regression models of ice melt capacity as a function of additive rate are shown on the deicer graph of results, organized by temperature level.

Brine blends, in which a liquid deicer is blended with salt brine, were also tested for ice melt capacity as a function of additive rate. Blends were mixed in 90/10%, 80/20% and 70/30% (brine/additive) proportions, then cooled to 39 °F (4 °C) by placement and storage in a refrigerator. A 1.0 mL blend volume was applied to the top surface of an ice specimen using a glass syringe, selected to be at full volume to provide optimum measurement precision (±1% of the full volume). Triplicate specimens were tested for each of the three levels, for nine total specimens per temperature. Specimen testing for a given temperature was done at the same time and in the same thermal condition (ice brine cooler or freezer), maintaining a high degree of uniformity to reduce confounding. Typically, tests sets were conducted at three different temperature levels.

Brine blend results were analyzed for the effect of deicer additive rate, as provided in Appendix D. Linear regression models of ice melt capacity as a function of additive rate are shown on the deicer graph of results, organized by temperature level.

The ice melt capacities used in the cost model were interpreted from the laboratory results and placed into the cost model at 5 °F increments (Table 2). For temperatures at which rock salt and many other deicers provide no melting, values of 0.01 were used in the cost model. In response to questions at meetings and presentations described previously, additional testing was done at -30 °F to determine ice melt capacity for deicers that did not solidify at this temperature, as shown in Table 4. These values were entered into the cost model for -30 °F and approximated for temperatures from -5 to -25 °F.

**Table 2. Ice melt capacities interpreted from laboratory results and used in the cost model.**

| Temperature° F | Rock Salt | Clearlane Enahnced | SOS @ 6 gal/ton | Thawrox Gold Treated | Ice Slicer | Ice Bite @ 3 gal/ton | Salt Brine | AP Liquid Deicer | Articlear Gold | Freezeguard | Ice Ban 200M | Meltdown Apex | TC Econo | Thawrox Gold Alternative | Calcium Chloride | RGP-8 | Geomelt 55 | Geomelt Gen 3 | LCS 5000 | Ice Bite |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **30** | 10.0 | 11.5 | 11.5 | 10.8 | 7.5 | 9.9 | 3.9 | 6.4 | 3.6 | 7.2 | 4.8 | 5.1 | 4.5 | 5.0 | 6.1 | 5.4 | 3.5 | 4.0 | 2.7 | 12.7 |
| **25** | 8.0 | 6.5 | 6.9 | 8.7 | 6.6 | 8.2 | 2.8 | 5.2 | 2.9 | 5.1 | 4.0 | 3.6 | 3.3 | 3.5 | 4.6 | 2.6 | 2.2 | 2.1 | 1.3 | 5.8 |
| **20** | 5.8 | 4.6 | 5.2 | 6.9 | 5.7 | 7.0 | 2.1 | 4.2 | 2.2 | 3.7 | 3.2 | 3.2 | 2.4 | 2.8 | 3.5 | 2.0 | 2.2 | 2.0 | 1.2 | 4.5 |
| **15** | 3.9 | 3.6 | 4.2 | 5.4 | 4.5 | 5.0 | 1.6 | 3.1 | 1.9 | 2.8 | 3.0 | 2.7 | 1.6 | 2.3 | 2.7 | 2.1 | 1.6 | 1.2 | 1.0 | 4.2 |
| **10** | 2.0 | 3.2 | 2.3 | 3.1 | 2.4 | 2.4 | 1.2 | 2.0 | 1.4 | 2.0 | 2.3 | 2.1 | 1.7 | 1.9 | 1.9 | 2.2 | 1.5 | 1.4 | 0.8 | 4.0 |
| **5** | 3.4 | 3.0 | 3.2 | 4.3 | 2.2 | 2.0 | 1.5 | 2.8 | 1.0 | 1.4 | 1.4 | 3.9 | 1.8 | 1.3 | 1.2 | 1.3 | 1.5 | 1.5 | 0.3 | 3.8 |
| **0** | 0.01 | 2.0 | 2.0 | 0.01 | 0.01 | 0.01 | 0.01 | 2.3 | 1.0 | 1.7 | 1.3 | 2 | 1.5 | 1.3 | 0.01 | 1.7 | 0.01 | 1.6 | 0.01 | 0.01 |
| **-5** | 0.01 | 0.4 | 0.3 | 0.01 | 0.01 | 0.01 | 0.01 | 1.8 | 1.0 | 1.7 | 1.3 | 1.8 | 1.2 | 1.3 | 0.01 | 1.3 | 0.01 | 0.3 | 0.01 | 0.01 |
| **-10** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 1.8 | 1.0 | 1.7 | 1.3 | 1.6 | 0.8 | 1.3 | 0.01 | 1.8 | 0.01 | 0.8 | 0.01 | 0.01 |
| **-15** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 1.8 | 1.0 | 1.7 | 1.3 | 1.5 | 0.8 | 1.3 | 0.01 | 1.8 | 0.01 | 1.3 | 0.01 | 0.01 |
| **-20** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 1.8 | 1.0 | 1.7 | 1.3 | 1.5 | 0.8 | 1.3 | 0.01 | 1.8 | 0.01 | 1.3 | 0.01 | 0.01 |
| **-25** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 1.8 | 1.0 | 1.7 | 1.3 | 1.5 | 0.8 | 1.3 | 0.01 | 1.8 | 0.01 | 1.3 | 0.01 | 0.01 |
| **-30** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 1.8 | 1.0 | 1.7 | 1.3 | 1.5 | 0.8 | 1.3 | 0.01 | 1.8 | 0.01 | 1.3 | 0.01 | 0.01 |

## 2.3: Discussion

In the temperature range of 5 to 30 °F, individual deicers do not show substantial improvement over rock salt for ice melt capacity, and many of the evaluated deicers show ice melt capacity much reduced compared to rock salt. Rock salt provided ice melt capacities from a low of 1 mL ice brine created from 1 g deicer added at 8 °F to a high of 8 mL ice brine created from 1 g deicer added at 30 °F. Some marginal gains may be seen for specific compounds, but these gains are neither significant enough nor of sufficient wide temperature span to make much difference. Many of the deicers considered produce dramatically lower ice melt capacities; it appears that the advantage of these "lower power" deicers may lie in attributes other than ice melting, such as low chloride content, adhesion to roadway surface, or low corrosion tendency.

Stockpile treatments likewise demonstrate no significant improvement in ice melt capacity with increasing application rate. Ice melt capacities are fairly constant for a given temperature across the range of applications from 3 to 30 gallons per ton, suggesting no benefit to ice melting from increasing application of stockpile treatments. As with individual deicers, it appears that the advantage of stockpile treatments may be in providing color for post-application visibility and adhesion to road surface to limit wind erosion of the applied deicer combination. It should be noted for reference that 6 gallons per ton, the normal rate recommended by vendors, is an approximate additive rate of 2.5%, so it is not surprising that ice melt capacity effects would be limited, particularly given the results of the individual component evaluation.

Brine blends, in contrast, do show modest but significant improvement from secondary components at higher proportions, with ice melt capacities up to 4 mL ice brine created from 1 mL deicer brine added. Across a range of 0 to 30% additive, gains in ice melt capacity of up to 2 mL ice brine created from 1 mL deicer brine added were observed. This improvement is likely to occur because increase the additive increases the total deicer, as salt brine starts generally at 23% NaCl, which is the NaCl saturation concentration at operating temperature. Assuming additive components (when added) can dissolve into the brine (being different than either Na or Cl), more deicer ions will be available to react with ice upon contact. As with individual compounds, the ice melt capacities of brine blends are highly related to the application temperature.

# Chapter 3: Deicer Field Performance Study

Factors other than ice melt capacity that influence deicer effectiveness were indicated to MSU, Mankato research staff during several meetings with MnDOT Maintenance and Operations staff plus during discussions held at two municipal and county outreach presentations during May, 2011. These factors include:

- Deicer performance variation due to:
  - Road surface exposure to wind;
  - Road surface exposure to sun;
  - Road surface color;
  - Road surface texture; and,
  - Traffic frequency and truck proportion of traffic.

- Deicer application variation due to:
  - Grain size of deicer;
  - Color of deicer (operator awareness of recent application);
  - Bounce of deicer as function of temperature, deicer grain size and stickiness;
  - Hardness of deicer;
  - Moisture content of deicer; and,
  - Component separation during storage or transportation.

- Handling characteristics of deicers:
  - Deicer corrosion of equipment;
  - Environmental consequences of chlorides or organic components;
  - Storage stability of deicers; and,
  - Mixing methods of deicer blends.

While many of these factors are intuitively significant to effective deicing, MSU Mankato research staff selected four factors as potentially contributing to better relative performance between deicers (e.g., creating a difference in cost effectiveness). These four factors are:

1. Deicer bounce, the characteristic of not adhering to or settling on an inclined surface;
2. Deicer penetration, the characteristic of melting a vertical column through ice rather than spreading laterally within the ice;
3. Deicer undercut, the characteristic of spreading laterally on the pavement surface beneath ice after deicer penetration; and,
4. Deicer grain size, a secondary factor in which the relative size of the deicer particle may or may not influence bounce, penetration or undercutting.

Factors related to roadway surface and traffic was deemed likely to affect all deicers equally, at least within the limits of determination observed during Chapter 2. Handling, storage and transportation factors were considered to be best handled subjectively within the cost model, assuming there will be a significant input from MnDOT personnel about actual adjustments required by variations in deicer characteristics.

Physical samples of rock salt were prepared at moisture contents of 0 to 5.0% (increments of 0.5%), in preparation for evaluation during this study. However, MSU Mankato research staff observed that even low amounts of moisture caused significant deterioration in handling and mixing operations. Based on conversations with MnDOT personnel, it was decided to omit analytical evaluation of moisture content effects; rather to assess the factor effects subjectively during the cost model implementation.

Specific deicers and deicer blends evaluated in this study are listed in Table 3. Three gradations of rock salt (Blanche mine source) were evaluated:

- Course gradation: Passing #4 sieve, retained on #10 sieve (dried pea sized);
- Medium gradation: Passing #10 sieve, retained on #20 sieve (sugar sized); and,
- Fine gradation: Passing #20 sieve (course table salt sized).

Deicers and deicer blends were selected for testing based on comments from MnDOT personnel relating to: (1) differences observed between deicers; and (2) commonly used deicers and deicer blends.

**Table 3. Deicers evaluated in this task for field performance measures.**

| Deicer | Blend | Form | Bounce | Undercut | Penetration |
|---|---|---|---|---|---|
| Rock Salt: Passing #4 Sieve, Retained on #10 Sieve | None | Solid | X | | X |
| Rock Salt: Passing #10 Sieve, Retained on #20 Sieve | None | Solid | X | | X |
| Rock Salt: Passing #20 Sieve | None | Solid | X | | X |
| CaCl | 20%/80% NaCl Brine | Liquid | | | X |
| Salt Brine | None | Liquid | | | X |
| Apogee Non-Cl | None | Liquid | | | X |
| Articlear Gold | 20%/80% NaCl Brine | Liquid | | X | X |
| CF-7 | None | Liquid | | | X |
| Clearlane Enhanced | 6 gal/ton Rock Salt | Solid | X | | X |
| Geomelt Gen 3 | 20%/80% NaCl Brine | Liquid | | | X |
| Ice Slicer Granular | As supplied from vendor | Solid | X | X | X |
| LCS 5000 | 20%/80% NaCl Brine | Liquid | | | X |
| RGP-8 | 20%/80% NaCl Brine | Liquid | | | X |
| SOS | 20%/80% NaCl Brine | Liquid | | X | X |
| SOS Treated Salt | 6 gal/ton Rock Salt | Solid | X | | X |
| Thawrox Gold Treated Salt | As supplied from vendor | Solid | X | X | X |
| Ice Bite (Treated Salt?) | As supplied from vendor | Solid | X | | X |

Note: Ice Bite is listed with the notation "Treated Salt?" because it appears to have rock salt as a base, but rock salt is not listed by the vendor as an ingredient.

### 3.1: Test Methods

The test methods used in this study were developed specifically for this evaluation, and do not strictly conform to any standard. These methods were developed with the goal of comparing performance between deicers, to reduce reliance upon anecdotal observations and potentially biased interpretations.

*3.1.1: Deicer Bounce Test*

A 30.0 g mass of deicer was gently released from 3.0 feet onto a chilled aluminum plate (0º F at start of test) inclined at 30º above horizontal (Figure 3). Particle release was done by rotating a 50 mL centrifuge tube containing the measured deicer from vertical to inverted. Deicer particles that bounced off and away from the aluminum plate were captured on two lines (side by side) of 8.0 x 11.5 inch rectangles of copier paper, each with 0.5 inches of joint overlap (7.5 x 11.0 inch net capture dimensions). Side boards, 6 inches high, contained particles that angled away from the plate surface upon bounce. After deicer release then bounce, the papers were photographed, noted for location then individually massed. Each deicer was tested in triplicate.

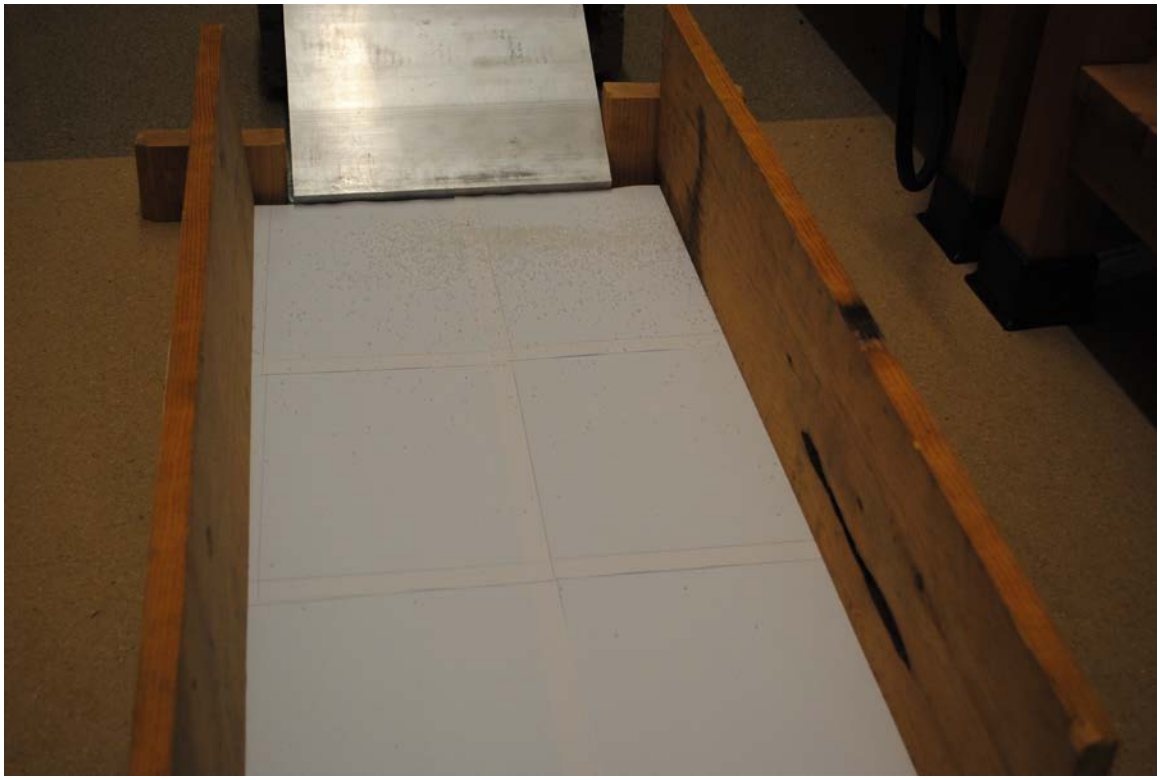


**Figure 3. Bounce test apparatus showing aluminum plate (0 ºF at start of test) inclined at 30º above horizontal, twin lines of capture paper, and side boards. Not shown is vial formerly containing 30.0 g of deicer (rock salt, passing #10 sieve, retained on #20 sieve) at 3 feet above floor (paper) level. Note spray pattern of deicer on paper.**

*3.1.2: Deicer Penetration Test*

Ice specimens were prepared from 35 mL of tap water placed in 50 mL centrifuge tubes that have dimensions of approximately 1 inch diameter by 4 inches long. A ½ inch lead ball was placed in the bottom of the tube to provide buoyant stability. Specimens were initially frozen at 5º F for at least 48 hours. Specimens were then removed from the freezer and, starting at the center of the top surface, drilled ¼ inch diameter by 1 inch deep using an electric drill. A 20 uL aliquot of yellow-green fluorescent dye was placed at the bottom of the drilled hole, and the specimen returned to the freezer for at least 1 hour.

The penetration test began by submersing the ice specimen and their tubes into an ice-brine mixture at a stable temperature (23º F for this evaluation). Three alcohol thermometers were used to evaluate and monitor the temperatures of the ice-brine mixture. Ice specimens were floated in the ice-brine mixture for a minimum of 2 hours to adjust the ice temperature and achieve thermal stability (same technique as used for ice melt capacity determination described in Chapter 2). Specimens floated with a vertical orientation due to the lead ball weighting, and had a freeboard of approximately ¾ inch to prevent ice-brine mixture from contacting the ice specimen.

Deicer was measured out (0.5 g mass for solids, 0.5 mL for liquids measured with a glass syringe at full syringe capacity) and placed in the drilled hole of the ice specimen. Ice specimens were marked with a label of the deicer name and left to remain in the ice-brine mixture. After 30 minutes, the ice specimens were removed from the ice-brine mixture, placed in a location backlit with ultraviolet light to excite the fluorescent dye, and photographed (Nikon D3000 digital camera, 55-200 mm zoom lens on full zoom, automatic light and shutter settings, auto focus, tripod mounted). Ice specimens were photographed at room temperature (20º C) approximately 15 seconds after removal from the ice-brine; observations of the ice specimens suggested temperature-induced dye/deicer movements could begin to occur in as little as 3 minutes after removal from the thermal stability of the ice-brine mixture.

*3.1.3:Deicer Undercutting Test*

Thin plates of ice were created for testing, starting as 30 mL of tap water in a 75 mm diameter Petri dish or varying amounts of tap water in metal baking pans with non-stick coating. The water in either preparation was frozen at a temperature of 0º F to a thickness of approximately ¼ inch thick.

Petri dish specimens were tested in a 0º F freezer environment (minimum freeze time prior to testing 48 hours). Baking pan specimens were first frozen in a 0º F freezer (minimum freeze time prior to testing 48 hours) then floated for a minimum of 30 minutes in an ice-brine mixture to achieve a thermally stable condition of 23º F, prior to deicer application.

Deicers were applied to the center of the ice specimens in varying amounts.

## 3.2: Results

### *3.2.1: Deicer Bounce Test*

Bounce tests were done in triplicate for each deicer evaluated. A total of 24 tests were preformed. Selected photograph results are shown in Figure 4. Results tabulated by bounce distance, proportion, and cumulative proportion are provided in Appendix E, complete with graphs of cumulative proportion by distance. Course grained rock salt results are provided in every bounce test graph to provide a visual reference during comparisons.

Two statistical analyses were done using these results. First, a one way Analysis of Variation (ANOVA) comparing proportion of total by deicer material and by distance. The ANOVA compares data between deicer to see if there are statistical differences. Second, a least squares estimation of cumulative proportion by distance. The least squares estimation creates a predictive model from the data, then provides comparisons between the models, incorporating an evaluation of the model fit. The statistical comparisons are also included in Appendix E.

From these results, two outcomes are clear. First, grain size is a statistically significant factor for the amount of bounce experienced by a deicer, demonstrated by course grained rock salt bouncing further than either medium or fine grained rock salt, and medium grained rock salt bouncing further than fine grained rock salt. Second, individual deicers do not statistically vary in their bounce characteristic, at the level of measurement of this analysis, with the exception of Ice Slicer that had less bounce than other deicers. Note that Ice Slicer contains a significant proportion of fine particles (Figure 4d); therefore, grain size may be the controlling factor in limiting the bounce of Ice Slicer.

It is interesting to note that solid deicers blended with carbohydrate-based additives, which are sticky to the touch, did not provide statistically significant bounce. While the "stickiness" may provide adhesion to prevent wind dislocation of the deicer and thereby be helpful, as a factor it does not significantly reduce the bounce of a deicer particle.

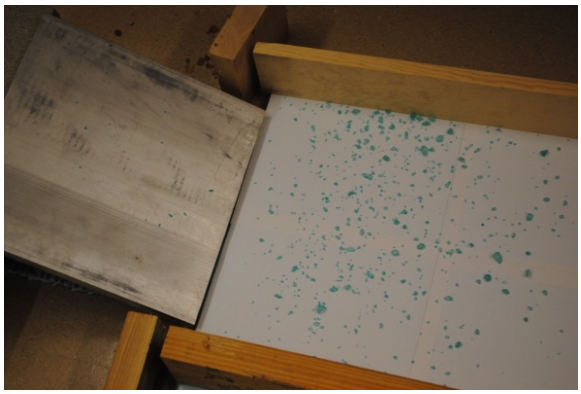
### *3.2.2: Deicer Penetration Test*

Individual deicer penetration tests examples are shown in Figures 5, 6 and 7 for solid, liquid (non-blended), and blended liquid deicers, respectively. Full results are provided in Appendix F for all deicer tests, done and grouped in triplicate by deicer.

Deicers were evaluated through photographic interpretation, assessing the dispersal of the fluorescent dye. Penetration was judged by depth, breadth and size of the fluorescent dye plume, assuming that the dye moved with the melt water caused by the deicer. Comparison was made across the three triplicates of each deicer to assess uniformity of response, then between deicers.

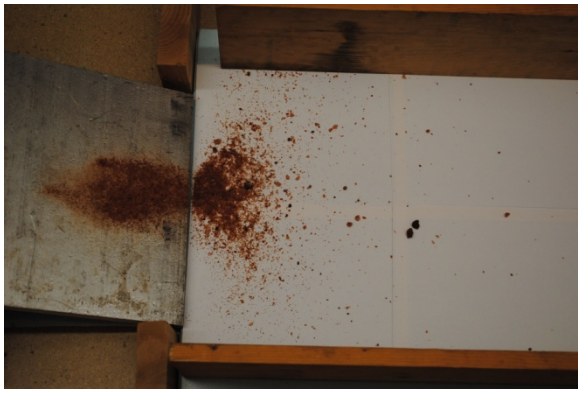
The first observation is that deicers did little penetration beneath the drill hole and mostly widened out the hole. This behavior may be related to the deicer contact area being greater on the sides than on the bottom of the hole; hole geometry may be having an effect here. However, it can be plainly seen that the deicers did not "burrow" deep into the ice at these levels of application.

a) Ice Bite



b) SOS Treated Rock Salt

c) Clearlane

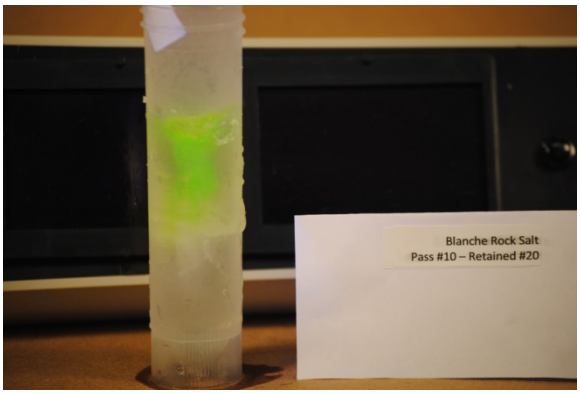


d) Ice Slicer

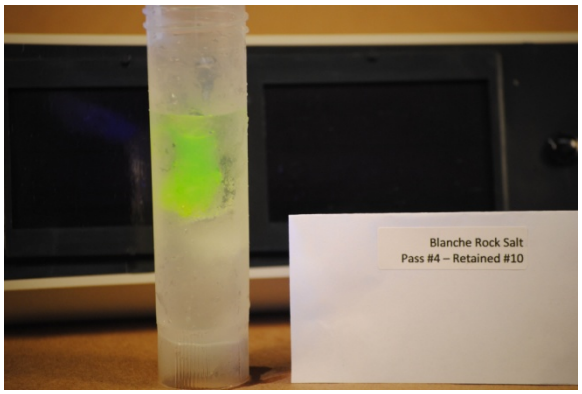
e) Thawrox Gold

f) Rock Salt (passing #4/retained on #10)

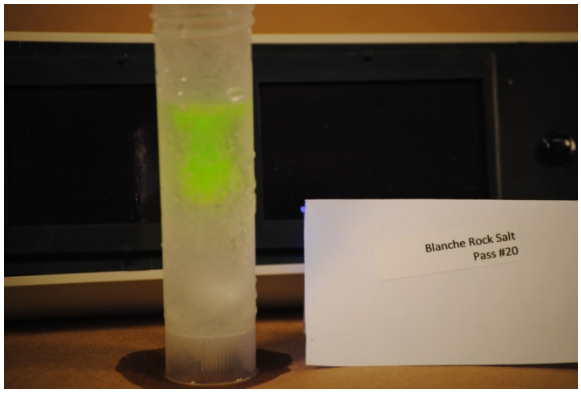
**Figure 4. Bounce test of deicer particles.**



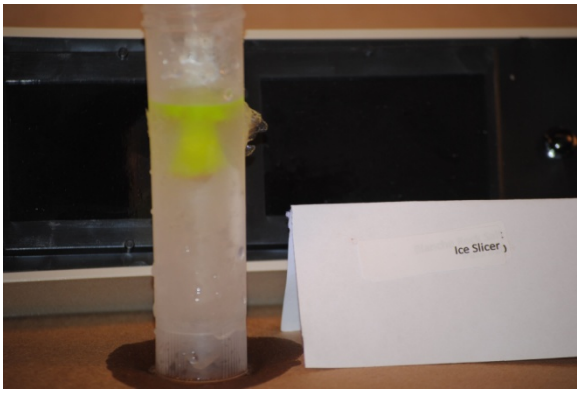

a) Rock Salt, Course Gradation




b) Rock Salt, Medium Gradation

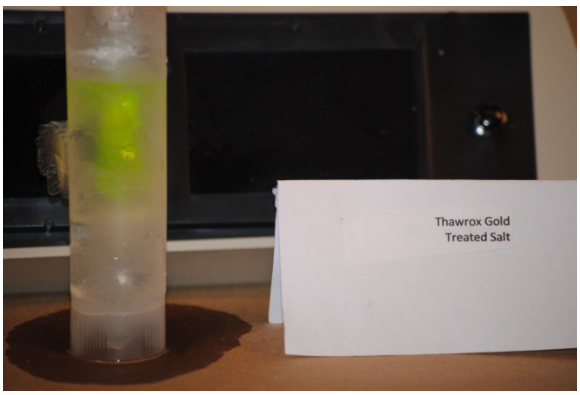



c) Rock Salt, Fine Gradation



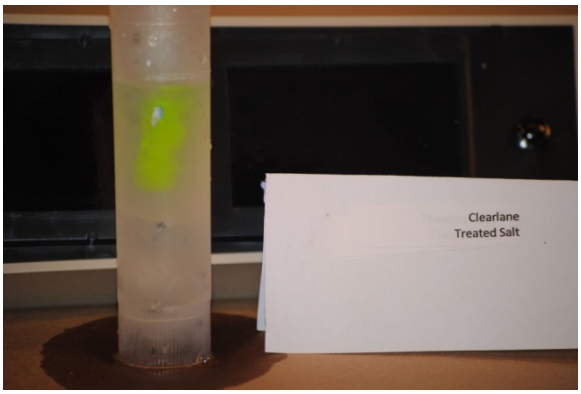

d) Ice Slicer


e) Ice Bite Treated Salt




f) Thawrox Gold Treated Salt

**Figure 5. Penetration test of solid deicers (0.5 mL, placed in ¼ inch diameter by 1 inch long hole, with frozen 20 uL fluorescent dye, for 30 minutes at 23 ºF).**




g) Clearlane Treated Salt


h) SOS Treated Salt

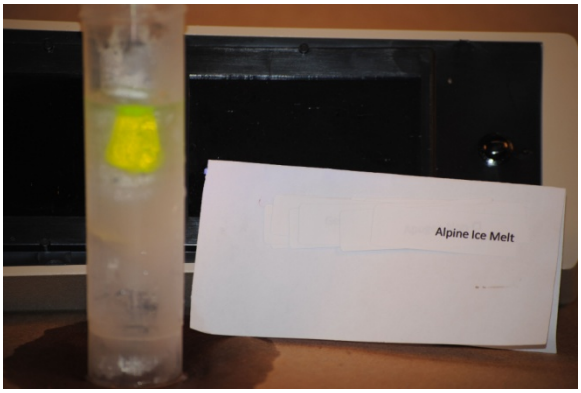
**Figure 5 (Continued). Penetration test of solid deicers (0.5 g, placed in ¼ inch diameter by 1 inch long hole, with frozen 20 uL fluorescent dye, for 30 minutes at 23º F).**

Perhaps a comparison done with lined holes that prevent deicer from contacting the sides would illustrate the causation. Some differences between deicer penetration were noted, most of which matched ice melt capacity differences described in Chapter 2. This effect was most apparent comparing solid deicers with liquid salt brine, which has an ice melt capacity of about $1/4^{th}$ that of rock salt due to the inclusion of the water.

Solid deicers did not have much difference between deicers. Liquid deicers, even though comparison was made between salt brine and acetate deicers, similarly did not have much difference. Some slight difference was observed for the liquid blends though, as fluorescent dye appeared to be more contained around a central zone for LCS 5000 and Articlear Gold blends. Perhaps the carbohydrate molecules in these additives prevented exploitation of seams and fractures within the ice matrix, as there may have been "sealing" by the relatively larger molecules of carbohydrate in comparison to the relatively small ions of chloride.

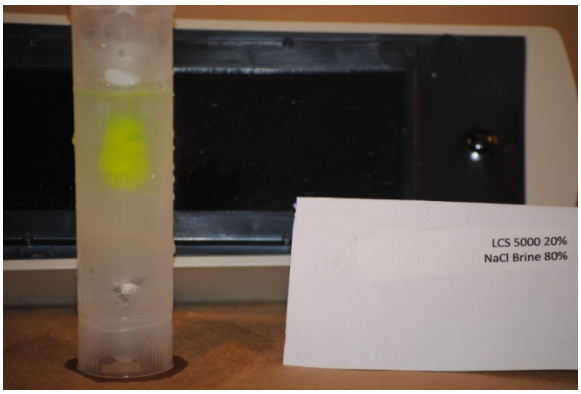

a) CF-7


b) Apogee Non-Cl

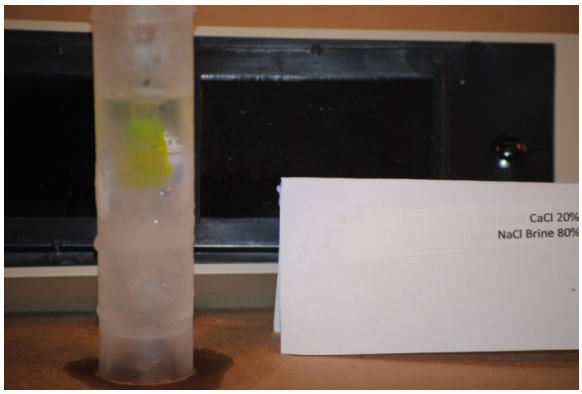



c) Salt Brine (mislabled as Alpine Ice Melt)

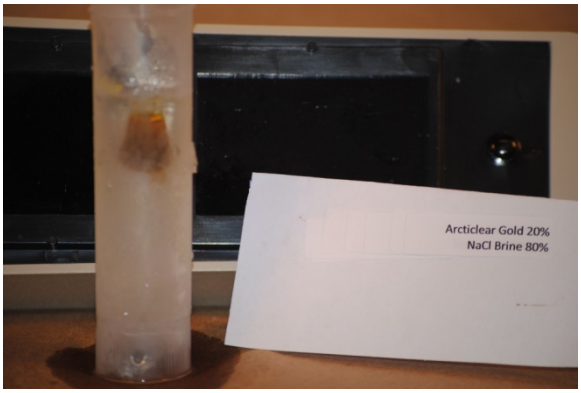
**Figure 6. Penetration test of liquid deicers (0.5 mL, placed in ¼ inch diameter by 1 inch long hole, with frozen 20 uL fluorescent dye, for 30 minutes at 23º F).**



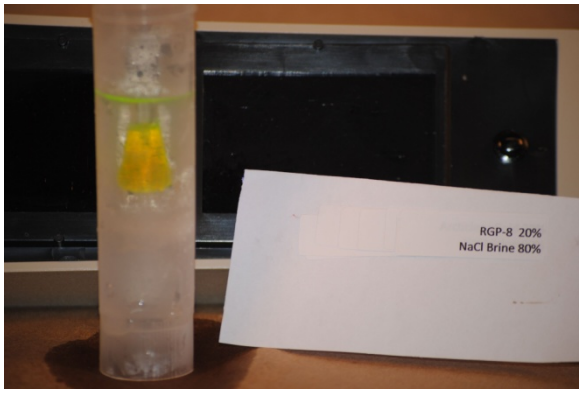

a) LCS 20%, Salt Brine 80%



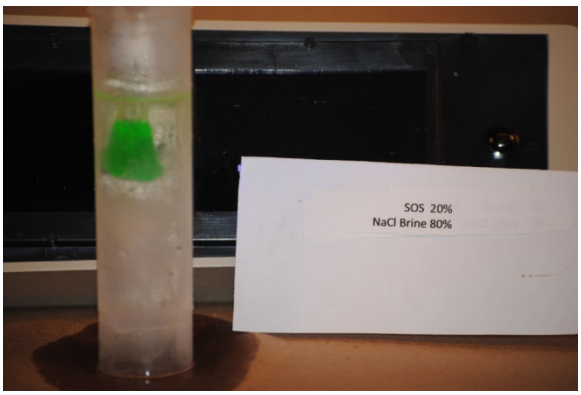

b) CaCl 20%, Salt Brine 80%



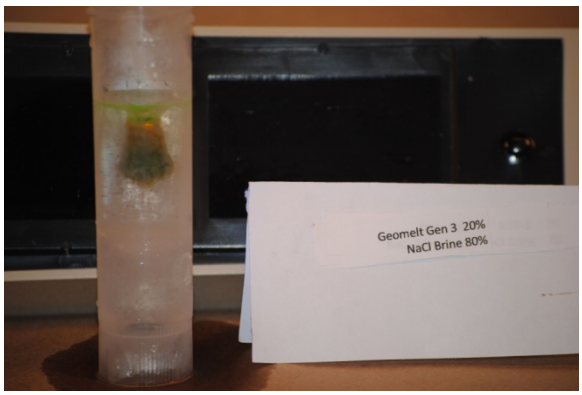

c) Articlear Gold 20%, Salt Brine 80%




d) RGP-8 20%, Salt Brine 80%




e) SOS 20%, Salt Brine 80%



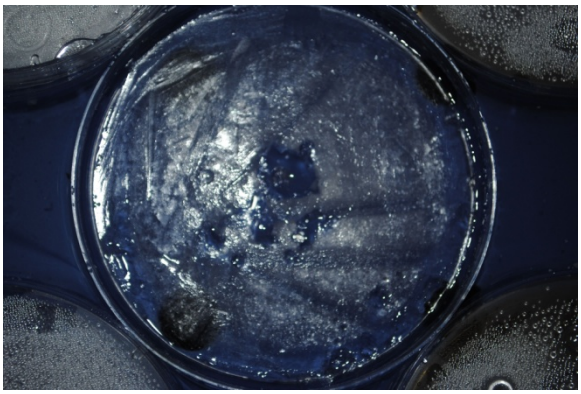

f) Geomelt Gen-3 20%, Salt Brine 80%

**Figure 7. Penetration test of blended liquid deicers (0.5 mL, placed in ¼ inch diameter by 1 inch long hole, with frozen 20 uL fluorescent dye, for 30 minutes at 23º F).**

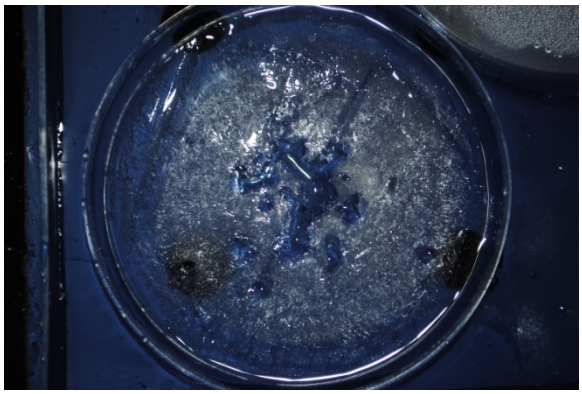
*3.2.3: Deicer Undercutting Test*

Photographic results of the deicer undercutting test are shown in Figure 8. Deicer-caused melting of the ice surface, body and underneath are somewhat visible. However, it appears that these tests, as currently done, are perhaps too rough and variable to return uniform results. The results of this test, attempted several times with different approaches, were so rough that the test was discontinued after the results reported here.

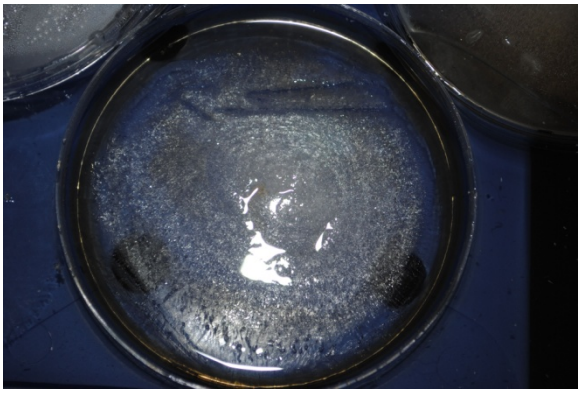
Ice uniformity appears to be the biggest factor in directing the ice melting and extent of undercutting. Physical characteristics of the deicer may be significant too, including such factors as gradation, particle shape and application uniformity. If there is interest in attempting this test in the future, preparation of the ice and deicer will need to be improved. Regarding the ice preparation, it is suggested that the ice be protected from wind within the freezer, as the blower seemed to pile up ice crystals in a non-uniform manner on one side of the ice specimen. Even with such protection, the ice may need several cycles of partial warming and refreezing to establish a uniform surface able to support an undercutting assessment.



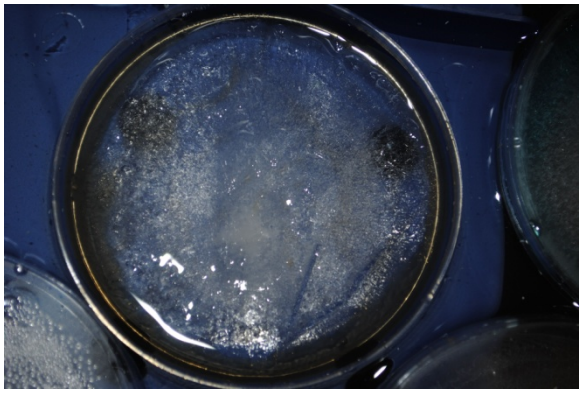
a) Thawrox Gold Treated Salt



b) Thawrox Gold Treated Salt



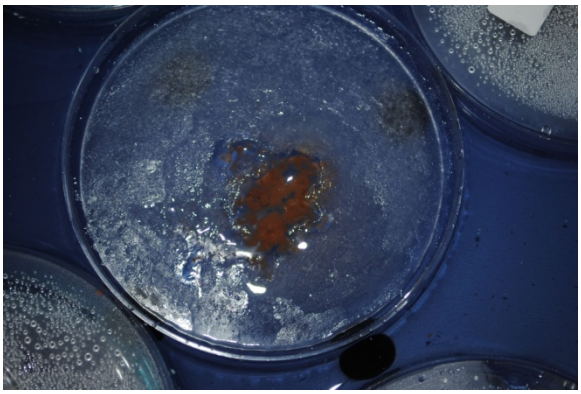
c) Articlear Gold 20% /Salt Brine 80%



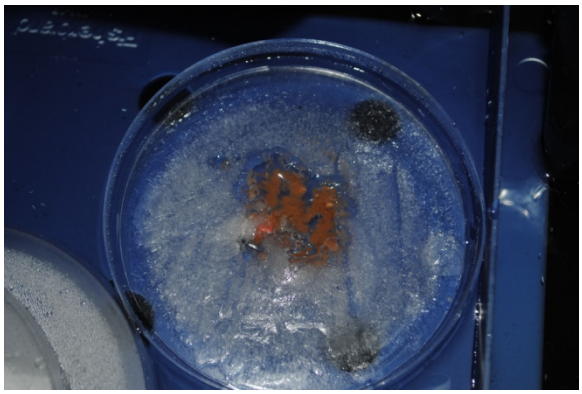
d) Articlear Gold 20% /Salt Brine 80%

**Figure 8. Undercutting test (a to h: 30mL water in 75 mm Petri dish, 0 ºF; i: 0.25 inch ice thickness, 8 x 8 inch square pan, 23º F).**

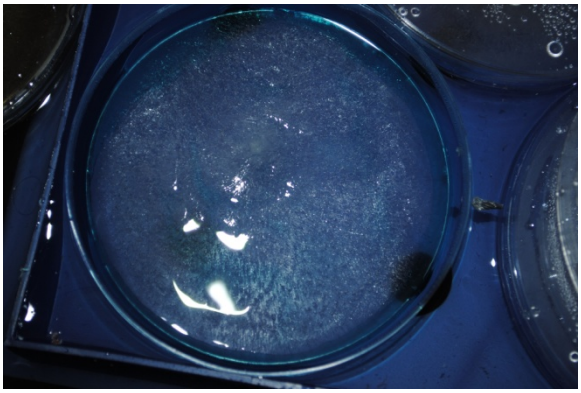
For this study, ice melt capacity (Chapter 2) seems to be of greater importance than undercutting, as ice melt capacity controls the location and amount of ice melted relative to the deicer applied. This observation may be magnified by the effect of traffic loads and truck proportion of traffic under field conditions.



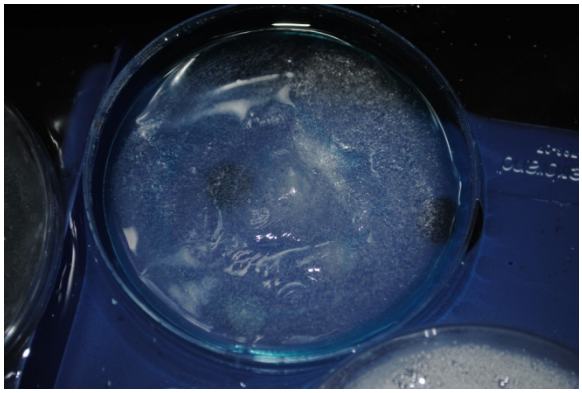
e) Ice Slicer



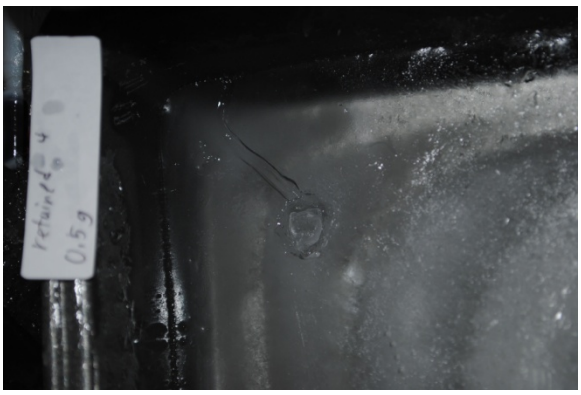
f) Ice Slicer



g) SOS 20% /Salt Brine 80%



h) SOS 20% /Salt Brine 80%



i) Rock Salt (passing #4 sieve), 23 ºF

**Figure 8 (Continued). Undercutting test (a to h: 30mL water in 75 mm Petri dish, 0 ºF; i: 0.25 inch ice thickness, 8 x 8 inch square pan, 23º F).**

### 3.3: Discussion

Four factors potentially contributing to better relative performance between deicers (e.g., creating a difference in cost effectiveness) were evaluated in this study. These four factors are:

1. Deicer bounce, the characteristic of not adhering to or settling on an inclined surface;
2. Deicer penetration, the characteristic of melting a vertical column through ice rather than spreading laterally within the ice;
3. Deicer undercut, the characteristic of spreading laterally on the pavement surface beneath ice after deicer penetration; and,
4. Deicer grain size, a secondary factor in which the relative size of the deicer particle may or may not influence bounce, penetration or undercutting.

Additional factors such as road surface characteristics, traffic characteristics, deicer transportation, equipment corrosion, environmental consequences, and storage stability were considered important but not appropriate for laboratory study. These factors are recommended for subjective inclusion in the cost model of Chapter 4.

Of the four factors selected for study in this task, only grain size was found to be statistically significant in providing performance differences. Grain size affected deicer bounce, with fine grained deicers hardly bouncing at all while course grained deicers bouncing away from the initial landing point. Deicers did not vary by type or product for bounce, penetration, or undercut, except by the difference in ice melt capacity associated with ice brine (23% NaCl) as compared to rock salt (pure NaCl).

From the results observed in this task, we conclude that ice melt capacity is a much more significant factor in performance, as shown by the results presented in Chapter 2.

# Chapter 4: Cost Model

This report presents the cost model regarding the ice melt capacity and field performance factors of deicers and deicer blends, representing the work done under Task 4 of MnDOT Agreement 96319, Salt Brine Blending to Optimize Deicing and Anti-Icing Performance and Cost Effectiveness. This work was performed by Minnesota State University (MSU), Mankato in the Environmental Engineering laboratory, as part of the Center for Transportation Research and Implementation.

Factors other than ice melt capacity that influence deicer effectiveness were indicated to MSU, Mankato research staff during eleven meetings or presentations by MnDOT Maintenance and Operations staff plus municipal, county and vendor personnel. These meetings and presentations included:

- April 29, 2010 Technical Assistance Panel (TAP) meeting at MnDOT Central Office;
- September 21, 2010 Operations Management Group meeting at MnDOT District 7;
- October 20, 2010 Statewide Maintenance Supervisors meeting at MnDOT District 7;
- January 5, 2011 meeting with Gordon Regenscheid, Joe Huneke and Kathy Schaefer at MSU Mankato Environmental Engineering Laboratory;
- April 27, 2011 District Salt Solutions Coordinators Winter Wrap-Up meeting at MnDOT District 7;
- June 7, 2011 (twice) Transportation Equipment Showcase at the Lakeville Truck Facility;
- September 7, 2011 Salt Coordinators meeting at Arden Hills Training Facility;
- September 22, 2011 Operations Management Group meeting at MnDOT District 4;
- October 5 and 6, 2011 Minnesota Fall Maintenance Expo presentations; and,
- October 6, 2011 District Salt Solutions Coordinators meeting in Duluth.

Additional information including the "brewmaster" list of deicers and blends was provided by email.

## 4.1: Methods

The cost model is based on the effectiveness of a proposed deicer and its delivered cost in comparison to the performance of rock salt at 28 °F, assuming all neutral field conditions, across a range of temperatures. Cost per lane mile is calculated using the proposed application rate for both all neutral field conditions and specified levels of field conditions. The selection of rock salt at 28 °F as the base performance standard was done as it was assumed that most people are strongly familiar with this optimistic performance level, as they typically may start with the image of performance of rock salt at 28 °F then adjust either expectations or application.

Factors other than deicer ice melt capacity that influence deicing effectiveness were identified as previously described. These factors were streamlined for incorporation into the cost model (Table 4) using a theorized relative impact with associated factor values, rolled into a grand efficiency factor, in the following equation:

Cost/lane mile = cost/ton x application rate x ice melt capacity of rock salt at 28 °F / ice melt capacity of the selected deicer / (product of all efficiency factors)

### 4.2: Results

Ice melt capacities, performance factors and deicer costs (2011-2012) were all placed in the cost model spreadsheet with the cost/lane mile equation, saved with password protection ("Mankato") and set to open as a "read only" file. Shading was used to make suggestions about where the user should enter information or make selections and where the user should not make changes. Input boxes are presented without shading to select or specify the following items:

- Deicers to consider and show on graphs;
- Delivered costs of deicers; and,
- Performance factors to be considered, selected by favorable/neutral/unfavorable.

Performance factors were set based on recommendations from the Technical Assistance Panel on January 20, 2012.

The spreadsheet print out includes the data input sheet as page 1, two graphs (one each for granular and liquid deicers) with deicer cost/lane mile by temperature with no performance factor consideration as page 2, and two graphs (one each for granular and liquid deicers) with deicer cost/lane mile by temperature with performance factor consideration as page 3. Sample outputs are included as Appendix G for granular deicers and prewet application and Appendix H for anti-icing.

### 4.3: Discussion

Clearly, this cost model needs to be tested, challenged and commented upon in order to assess its usefulness and efficacy. To assist the conversation, factors have been evaluated in their individual effects on both rock salt granular deicing and salt brine liquid anti-icing; these results are provided as Appendix I.

**Table 4. Factors incorporated into the cost model.**

| Factor | Relative Impact Theorized | Rationale |
|---|---|---|
| Ice Thickness (inches) | High | Ice thickness directly influences deicing difficulty. |
| Temperature Movement | Low | Dropping temperature can make deicing more difficult. |
| Repeat Time (of Deicer Application) | Medium | Reapplication of deicer will likely improve overall distribution of deicer on ice. |
| Traffic | Medium | Higher traffic volume improves breakup of roadway ice. |
| Truck Proportion | Medium | Truck traffic typically improves breakup of roadway ice due to tire pressure. |
| Pavement Material | High | Asphalt deices easier than concrete which deices easier than gravel. |
| Pavement Surface Age | Medium | Newer pavement surfaces deice easier than aged pavement surfaces. |
| Sun Condition | High | Sun intensity directly influences deicing. |
| Wind Condition | Medium | Wind can blow deicer off roadway during distribution and can mitigate benefit of solar heating. |
| Roadway Shade | Medium | Shading of roadway can prevent benefit of solar heating. |
| Storage | Low | Difficult storage conditions can increase deicing costs. |
| Loading | Low | Difficult loading conditions can increase deicing costs. |
| Loss / Spoilage | Medium | Excessive loss or spoilage of deicer compounds can increase deicing costs. |
| Sensitivity to Corrosion | High | Degradation of corrosion-sensitive structures creates a programmatic cost. |
| Sensitivity of Environment | Medium | Degradation of chloride-sensitive environment creates a programmatic cost. |

# Chapter 5: Conclusions

This report presents the evaluation of the ice melt capacity and field performance factors of deicers and deicer blends, and the development of a temperature-based cost model for comparison of relative field performance through the evaluated deicers and deicer blends. Ice melt capacity is the amount of ice melted (brine created) per the amount of deicer applied. The units of ice melt capacity depend upon whether the deicer is applied as a solid (units of mL brine created / g of deicer applied) or liquid (units of mL brine created / mL of deicer brine applied). Values of ice melt capacity observed in this study ranged from zero (no melting caused) to 12.7 mL brine created / mL of deicer brine applied, and were generally found to be strongly associated with temperature.

Factors other than ice melt capacity that influence deicer effectiveness were indicated to investigators during eleven meetings or presentations by MnDOT Maintenance and Operations staff plus municipal, county, and vendor personnel. Factors such as road surface characteristics, traffic characteristics, deicer transportation, equipment corrosion, environmental consequences, and storage stability were considered important but not appropriate for laboratory study, and were, therefore, recommended for subjective inclusion in the cost model. Four factors were selected as potentially contributing to better relative performance between deicers (e.g., creating a difference in cost effectiveness):

1. Deicer bounce, the characteristic of not adhering to or settling on an inclined surface;
2. Deicer penetration, the characteristic of melting a vertical column through ice rather than spreading laterally within the ice;
3. Deicer undercut, the characteristic of spreading laterally on the pavement surface beneath ice after deicer penetration; and,
4. Deicer grain size, a secondary factor in which the relative size of the deicer particle might or might not influence bounce, penetration, or undercutting.

Of these four factors, only grain size was found to be statistically significant in providing performance differences. Deicers did not vary by type or product for bounce, penetration, or undercut. From these results it was concluded that ice melt capacity is the most significant factor in performance for evaluation in the cost model.

The cost model was built based on the effectiveness of a proposed deicer and its delivered cost in comparison to a known performance, that of rock salt at 28 °F, assuming all neutral field conditions, across a range of temperatures. Cost per lane mile is calculated in the cost model using the proposed application rate and specified levels of field conditions. Rock salt at 28 °F was selected as the base performance standard because it was assumed that most people are strongly familiar with this optimistic performance level, as they typically might start with the image of performance of rock salt at 28 °F then adjust either expectations or application.

# References

Chappelow, C.C., McElroy, A.D., Blackburn, R.R., Darwin, D, de Noyelles, F.G., and Locke, C.E. (1992). *Handbook of Test Methods for Evaluating Chemical Deicers*, SHRP-H-332, Strategic Highway Research Program, National Research Council, Washington, D.C.

Shi, X. (2008). *Research Progress Report for the Quarter Ending: September 30, 2008, for project Development of Standardized Test Procedures for Evaluating Deicing Compounds*, Clear Roads 07-02/WisDOT 0092-08-32, for the Department of Transportation of the State of Wisconsin., Madison, WI.

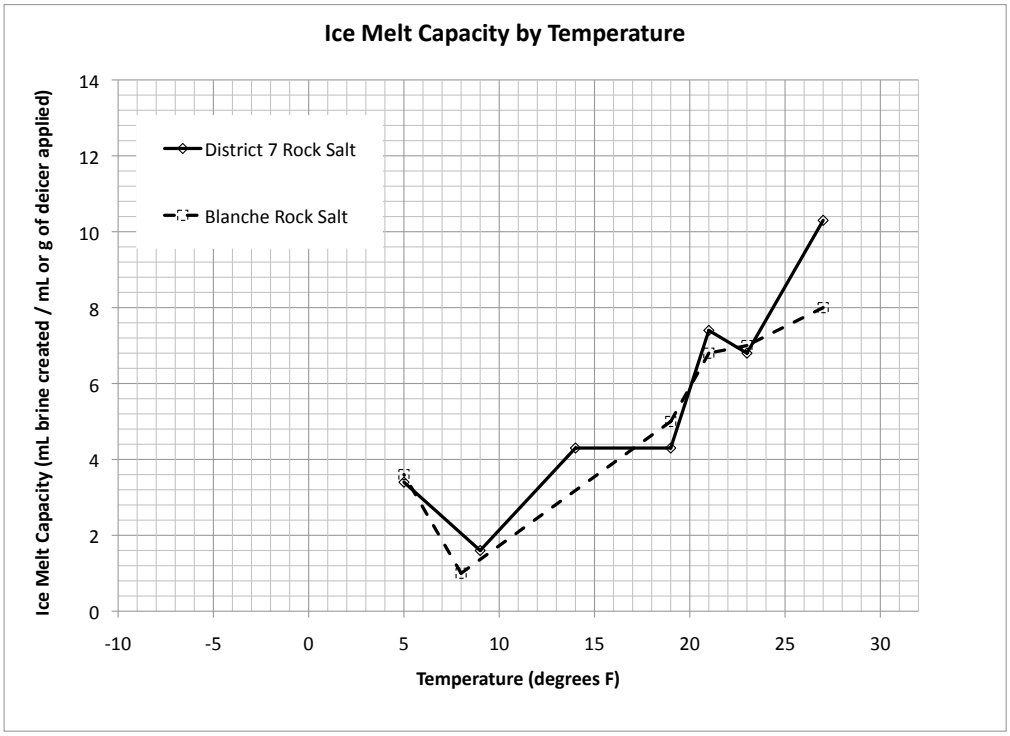
Shi, X. and Fay, L. (2009). *Evaluation of Alternate Anti-icing and Deicing Compounds Using Sodium Chloride and Magnesium Chloride as Baseline Deicers – Phase I*, Western Transportation Institute, Montana State University – Bozeman, report prepared for the Colorado Department of Transportation and the Research & Innovative Technology Administration (RITA) at the U.S. Department of Transportation, Washington, D.C.

# Appendix A – Ice Melt Capacity Evaluation of Rock Salt and Salt Brine Deicers

Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

| | | | | | | | | | Best Fit Analysis from JMP | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
| District 7 Rock Salt | NaCl | | -3 | 27 | 1 | g | 12 | 2 | | 3.50 | 8.50 | 10.3 |
| District 7 Rock Salt | NaCl | | -3 | 27 | 3 | g | 29 | | | | | |
| District 7 Rock Salt | NaCl | | -5 | 23 | 1 | g | 6 | 2 | | -1.50 | 7.50 | 6.8 |
| District 7 Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| District 7 Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9 | 2 | | 3.25 | 5.75 | 7.4 |
| District 7 Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 20.5 | | | | | |
| District 7 Rock Salt | NaCl | | -7 | 19 | 1 | g | 5 | 2 | | 1.50 | 3.50 | 4.3 |
| District 7 Rock Salt | NaCl | | -7 | 19 | 3 | g | 12 | | | | | |
| District 7 Rock Salt | NaCl | | -10 | 14 | 1 | g | 5.2 | 2 | | 1.80 | 3.40 | 4.3 |
| District 7 Rock Salt | NaCl | | -10 | 14 | 3 | g | 12 | | | | | |
| District 7 Rock Salt | NaCl | | -13 | 9 | 1 | g | 1 | 2 | | -1.25 | 2.25 | 1.6 |
| District 7 Rock Salt | NaCl | | -13 | 9 | 3 | g | 5.5 | | | | | |
| District 7 Rock Salt | NaCl | | -15 | 5 | 1 | g | 3 | | | | | |
| District 7 Rock Salt | NaCl | | -15 | 5 | 1 | g | 1 | | | | | |
| District 7 Rock Salt | NaCl | | -15 | 5 | 3 | g | 18.5 | 4 | 0.47 | -2.75 | 4.75 | 3.4 |
| District 7 Rock Salt | NaCl | | -15 | 5 | 3 | g | 4.5 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |

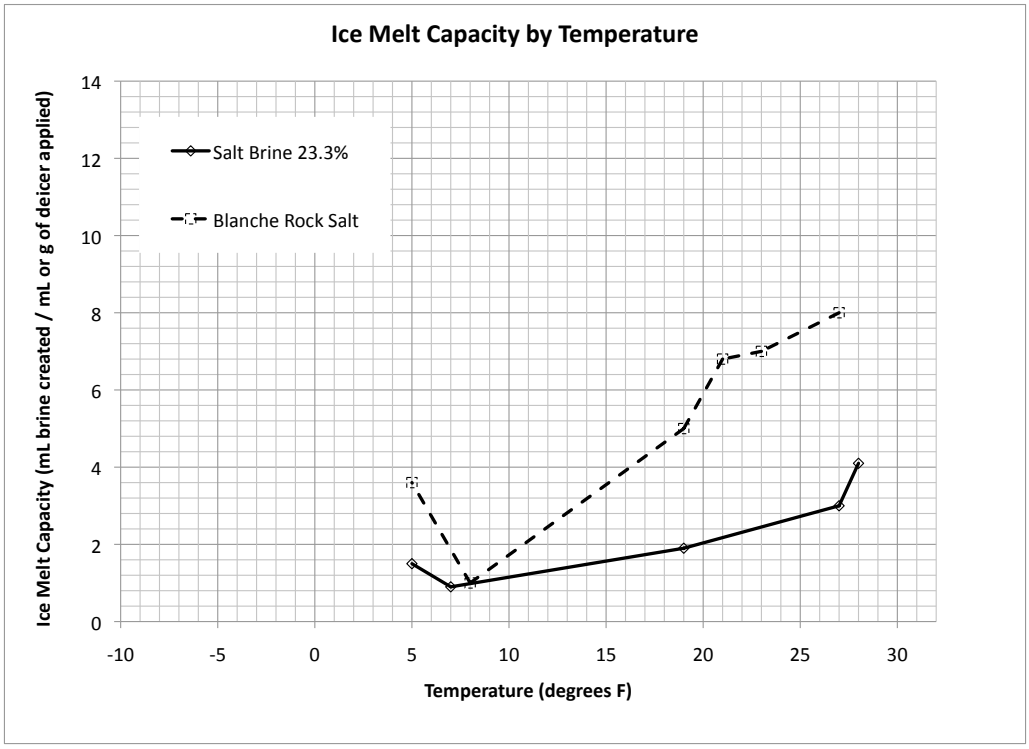


Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

Best Fit Analysis from JMP

| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Salt brine 23.3% | NaCl | | -2 | 28 | 1 | mL | 4.5 | 2 | | 0.75 | 3.75 | 4.1 |
| Salt brine 23.3% | NaCl | | -2 | 28 | 3 | mL | 12 | | | | | |
| Salt brine 23.3% | NaCl | | -3 | 27 | 1 | mL | 3 | 2 | | 0.00 | 3.00 | 3.0 |
| Salt brine 23.3% | NaCl | | -3 | 27 | 3 | mL | 9 | | | | | |
| Salt brine 23.3% | NaCl | | -7 | 19 | 1 | mL | 2 | 4 | 0.92 | -0.05 | 1.95 | 1.9 |
| Salt brine 23.3% | NaCl | | -7 | 19 | 1 | mL | 1.8 | | | | | |
| Salt brine 23.3% | NaCl | | -7 | 19 | 3 | mL | 6.6 | | | | | |
| Salt brine 23.3% | NaCl | | -7 | 19 | 3 | mL | 5 | | | | | |
| Salt brine 23.3% | NaCl | | -14 | 7 | 1 | mL | 0.5 | 2 | | -0.75 | 1.25 | 0.9 |
| Salt brine 23.3% | NaCl | | -14 | 7 | 3 | mL | 3 | | | | | |
| Salt brine 23.3% | NaCl | | -15 | 5 | 1 | mL | 1 | 4 | 0.67 | -1.00 | 2.00 | 1.5 |
| Salt brine 23.3% | NaCl | 2 reapplies | -15 | 5 | 1 | mL | 1 | | | | | |
| Salt brine 23.3% | NaCl | | -15 | 5 | 3 | mL | 7 | | | | | |
| Salt brine 23.3% | NaCl | | -15 | 5 | 3 | mL | 3 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |



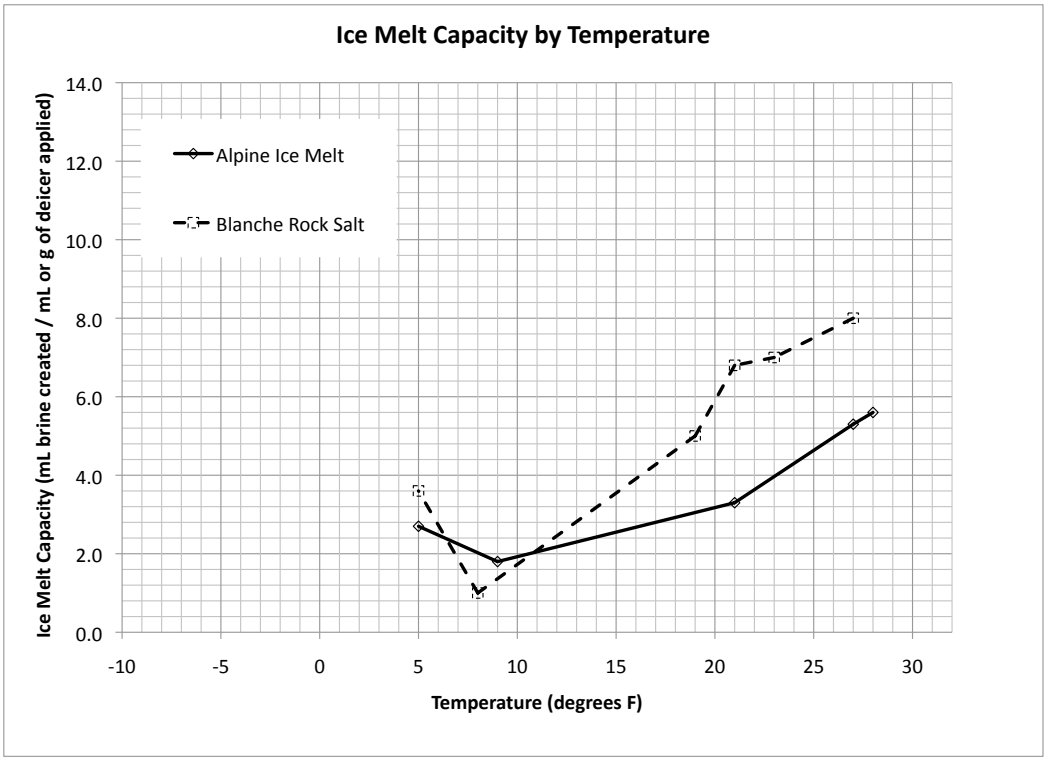
# Appendix B – Ice Melt Capacity Evaluation of Deicers Other Than Rock Salt and Salt Brine

Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

Best Fit Analysis from JMP

| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alpine Ice Melt | Acetate | | -2 | 28 | 1 | mL | 6 | 2 | | 0.75 | 5.25 | 5.6 |
| Alpine Ice Melt | Acetate | | -2 | 28 | 3 | mL | 16.5 | | | | | |
| Alpine Ice Melt | Acetate | | -3 | 27 | 1 | mL | 5 | 2 | | -0.50 | 5.50 | 5.3 |
| Alpine Ice Melt | Acetate | | -3 | 27 | 3 | mL | 16 | | | | | |
| Alpine Ice Melt | Acetate | 2 reapplies | -6 | 21 | 1 | mL | 4 | 2 | | 1.50 | 2.50 | 3.3 |
| Alpine Ice Melt | Acetate | 2 reapplies | -6 | 21 | 3 | mL | 9 | | | | | |
| Alpine Ice Melt | Acetate | | -13 | 9 | 1 | mL | 1.5 | 2 | | -0.63 | 2.13 | 1.8 |
| Alpine Ice Melt | Acetate | | -13 | 9 | 3 | mL | 5.75 | | | | | |
| Alpine Ice Melt | Acetate | | -15 | 5 | 1 | mL | 1 | 4 | 0.77 | -1.81 | 3.56 | 2.7 |
| Alpine Ice Melt | Acetate | | -15 | 5 | 1 | mL | 2.5 | | | | | |
| Alpine Ice Melt | Acetate | | -15 | 5 | 3 | mL | 11.5 | | | | | |
| Alpine Ice Melt | Acetate | | -15 | 5 | 3 | mL | 6.25 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |

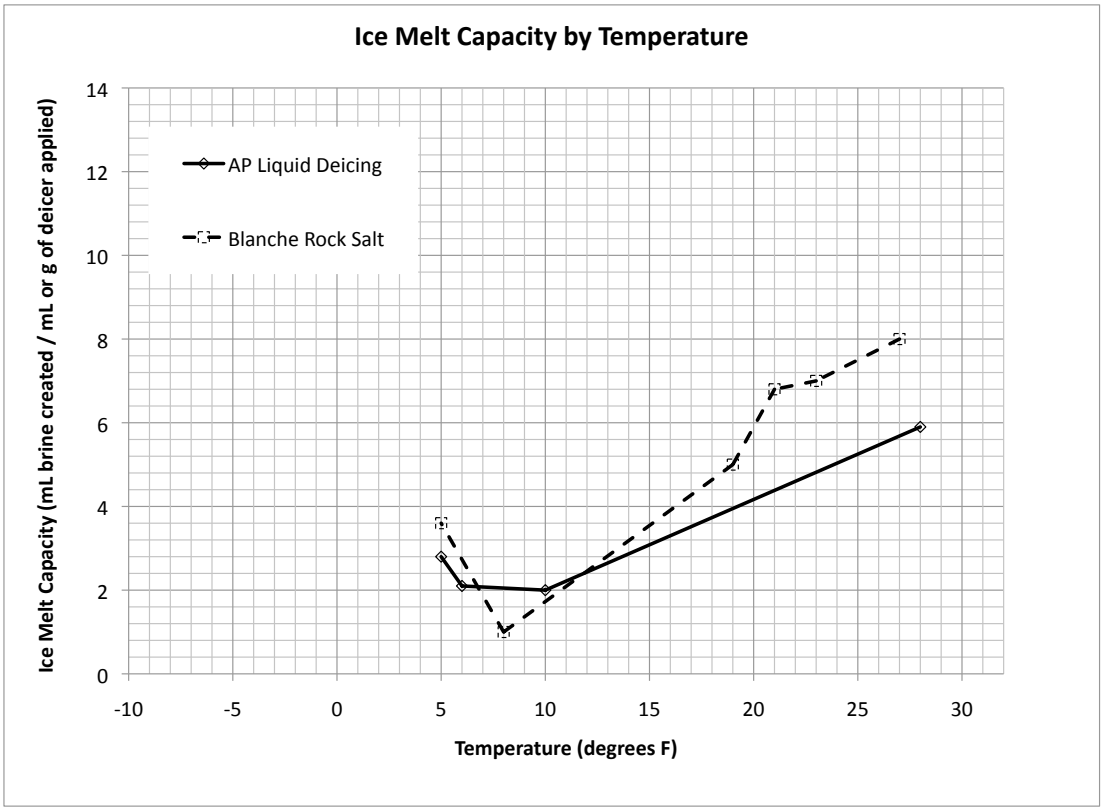


Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

Best Fit Analysis from JMP

| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AP Liquid Deicing | MgCl + Carb | | -2 | 28 | 1 | mL | 7 | 2 | | 2.25 | 4.75 | 5.9 |
| AP Liquid Deicing | MgCl + Carb | | -2 | 28 | 3 | mL | 16.5 | | | | | |
| AP Liquid Deicing | MgCl + Carb | | -12.5 | 10 | 1 | mL | 2 | 2 | | 0.00 | 0.00 | 2.0 |
| AP Liquid Deicing | MgCl + Carb | broke | -12.5 | 10 | 3 | mL | - | | | | | |
| AP Liquid Deicing | MgCl + Carb | | -14.5 | 6 | 1 | mL | 1.75 | 2 | | -0.75 | 2.50 | 2.1 |
| AP Liquid Deicing | MgCl + Carb | | -14.5 | 6 | 3 | mL | 6.75 | | | | | |
| AP Liquid Deicing | MgCl + Carb | | -15 | 5 | 1 | mL | 0 | 2 | | -5.50 | 5.50 | 2.8 |
| AP Liquid Deicing | MgCl + Carb | | -15 | 5 | 3 | mL | 11 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |

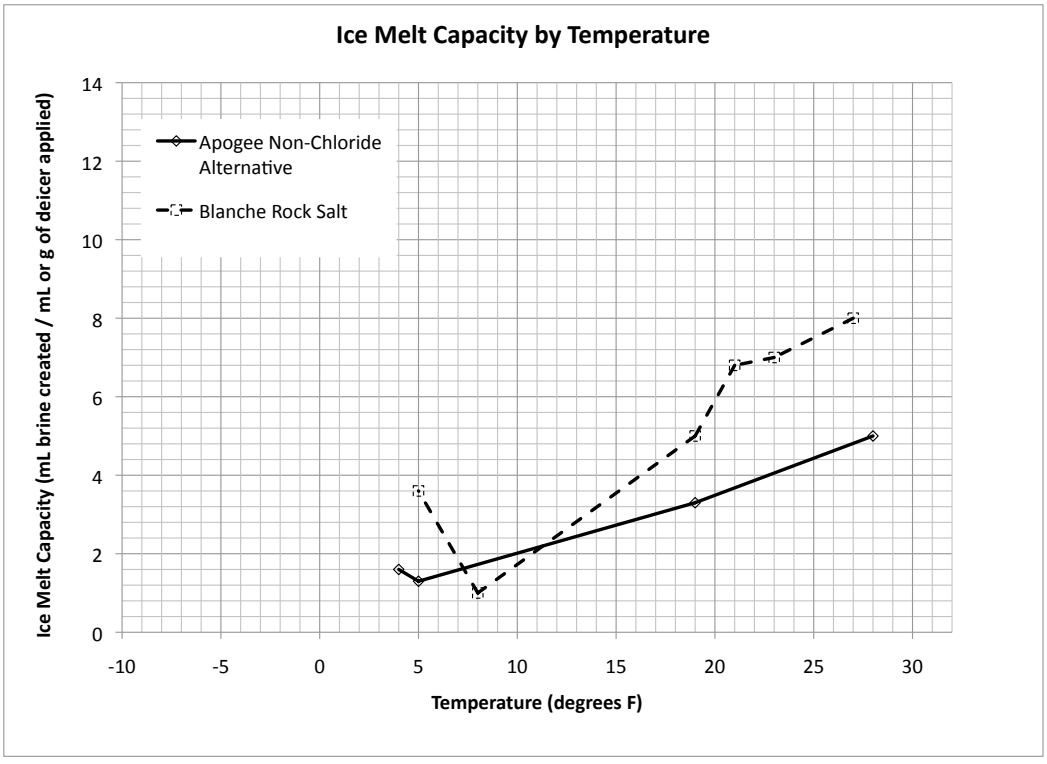


Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

Best Fit Analysis from JMP

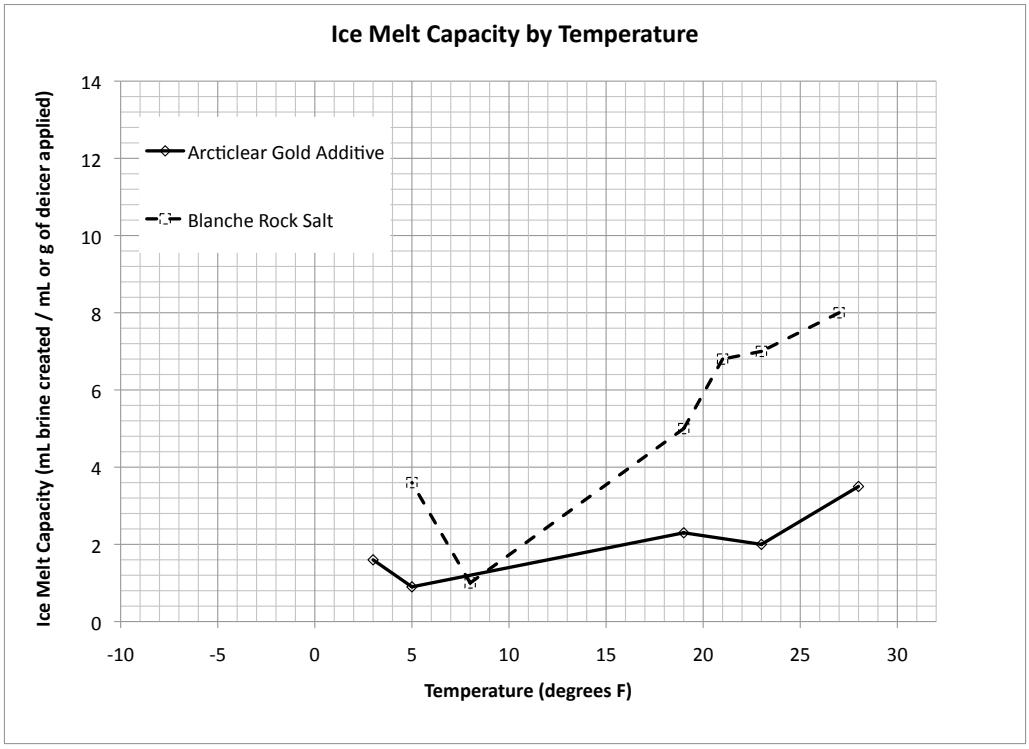
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Apogee Non-Choride Alt. | Alternative | | -2 | 28 | 1 | mL | 5 | 2 | | 0.00 | 5.00 | 5.0 |
| Apogee Non-Choride Alt. | Alternative | | -2 | 28 | 3 | mL | 15 | | | | | |
| Apogee Non-Choride Alt. | Alternative | | -7 | 19 | 1 | mL | 2.9 | 4 | 0.98 | 0.38 | 3.08 | 3.3 |
| Apogee Non-Choride Alt. | Alternative | | -7 | 19 | 1 | mL | 4 | | | | | |
| Apogee Non-Choride Alt. | Alternative | | -7 | 19 | 3 | mL | 10 | | | | | |
| Apogee Non-Choride Alt. | Alternative | | -7 | 19 | 3 | mL | 9.2 | | | | | |
| Apogee Non-Choride Alt. | Alternative | | -15 | 5 | 1 | mL | 1.5 | 4 | 0.97 | -0.31 | 1.44 | 1.3 |
| Apogee Non-Choride Alt. | Alternative | | -15 | 5 | 1 | mL | 0.75 | | | | | |
| Apogee Non-Choride Alt. | Alternative | | -15 | 5 | 3 | mL | 4 | | | | | |
| Apogee Non-Choride Alt. | Alternative | | -15 | 5 | 3 | mL | 4 | | | | | |
| Apogee Non-Choride Alt. | Alternative | | -15.5 | 4 | 1 | mL | 1.5 | 2 | | -0.25 | 1.75 | 1.6 |
| Apogee Non-Choride Alt. | Alternative | | -15.5 | 4 | 3 | mL | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

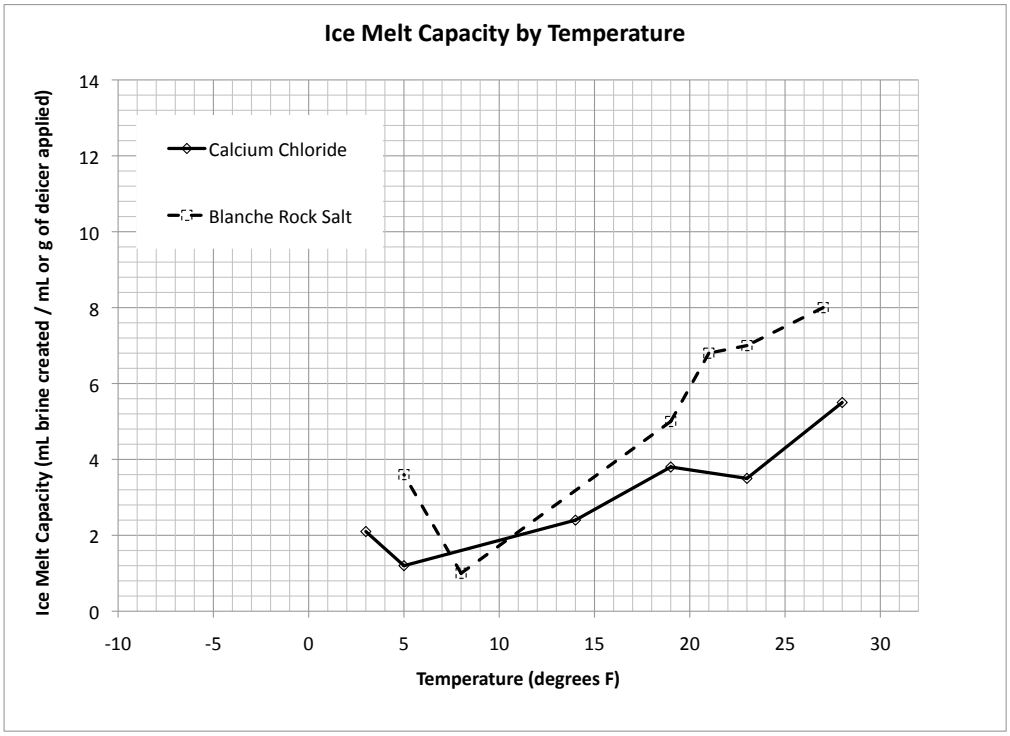
| | | | | | | | | | Best Fit Analysis from JMP | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
| Arcticlear Gold Additive | MgCl + Carb | | -2 | 28 | 1 | mL | 4 | 2 | | 1.00 | 3.00 | 3.5 |
| Arcticlear Gold Additive | MgCl + Carb | | -2 | 28 | 3 | mL | 10 | | | | | |
| Arcticlear Gold Additive | MgCl + Carb | | -5 | 23 | 1 | mL | 2 | 2 | | 0.00 | 2.00 | 2.0 |
| Arcticlear Gold Additive | MgCl + Carb | | -5 | 23 | 3 | mL | 6 | | | | | |
| Arcticlear Gold Additive | MgCl + Carb | | -7 | 19 | 1 | mL | 2 | 4 | 0.97 | 0.38 | 2.13 | 2.3 |
| Arcticlear Gold Additive | MgCl + Carb | | -7 | 19 | 1 | mL | 3 | | | | | |
| Arcticlear Gold Additive | MgCl + Carb | | -7 | 19 | 3 | mL | 7 | | | | | |
| Arcticlear Gold Additive | MgCl + Carb | | -7 | 19 | 3 | mL | 6.5 | | | | | |
| Arcticlear Gold Additive | MgCl + Carb | | -15 | 5 | 1 | mL | 1 | 4 | 0.71 | -0.75 | 1.25 | 0.9 |
| Arcticlear Gold Additive | MgCl + Carb | | -15 | 5 | 1 | mL | 0 | | | | | |
| Arcticlear Gold Additive | MgCl + Carb | | -15 | 5 | 3 | mL | 2 | | | | | |
| Arcticlear Gold Additive | MgCl + Carb | | -15 | 5 | 3 | mL | 4 | | | | | |
| Arcticlear Gold Additive | MgCl + Carb | | -16 | 3 | 1 | mL | 1.75 | 2 | | 0.38 | 1.38 | 1.6 |
| Arcticlear Gold Additive | MgCl + Carb | | -16 | 3 | 3 | mL | 4.5 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | Best Fit Analysis from JMP $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CaCl | CaCl | | -2 | 28 | 1 | mL | 5 | 2 | | -1.00 | 6.00 | 5.5 |
| CaCl | CaCl | | -2 | 28 | 3 | mL | 17 | | | | | |
| CaCl | CaCl | | -5 | 23 | 1 | mL | 3 | 2 | | -1.00 | 4.00 | 3.5 |
| CaCl | CaCl | | -5 | 23 | 3 | mL | 11 | | | | | |
| CaCl | CaCl | | -7 | 19 | 1 | mL | 2.2 | 4 | 0.63 | 2.35 | 2.65 | 3.8 |
| CaCl | CaCl | | -7 | 19 | 1 | mL | 7.8 | | | | | |
| CaCl | CaCl | | -7 | 19 | 3 | mL | 11 | | | | | |
| CaCl | CaCl | | -7 | 19 | 3 | mL | 9.6 | | | | | |
| CaCl | CaCl | | -10 | 14 | 1 | mL | 2.4 | 2 | | 0.00 | 2.40 | 2.4 |
| CaCl | CaCl | | -10 | 14 | 3 | mL | 7.2 | | | | | |
| CaCl | CaCl | | -15 | 5 | 1 | mL | 1.5 | 3 | 0.96 | 0.13 | 1.13 | 1.2 |
| CaCl | CaCl | | -15 | 5 | 1 | mL | 1 | | | | | |
| CaCl | CaCl | | -15 | 5 | 3 | mL | 3.5 | | | | | |
| CaCl | CaCl | broke | -15 | 5 | 3 | mL | - | | | | | |
| CaCl | CaCl | | -16 | 3 | 1 | mL | 2.5 | 2 | | 0.75 | 1.75 | 2.1 |
| CaCl | CaCl | | -16 | 3 | 3 | mL | 6 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |

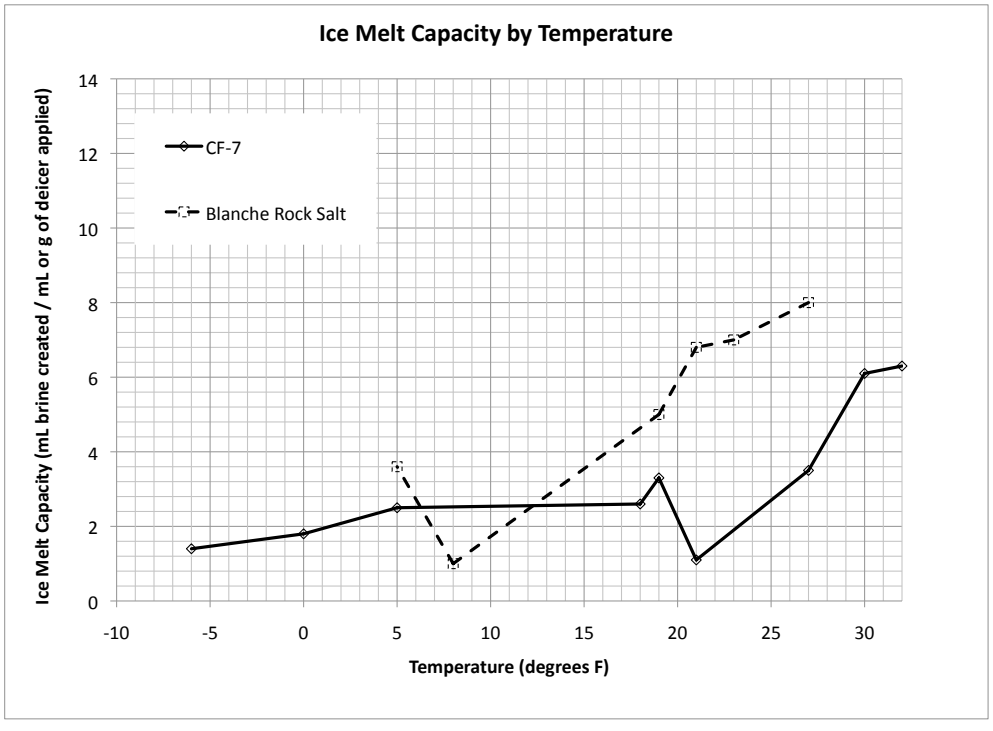


Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

Best Fit Analysis from JMP

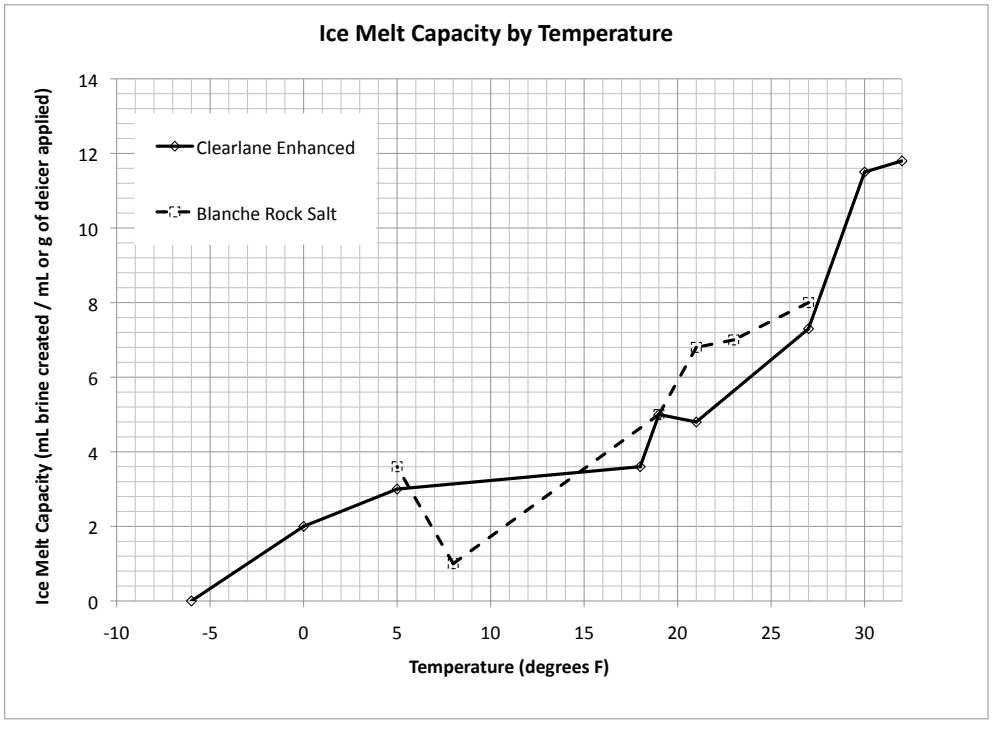
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CF-7 | Acetate | | 0 | 32 | 1 | mL | 7 | 2 | | 1.50 | 5.50 | 6.3 |
| CF-7 | Acetate | | 0 | 32 | 3 | mL | 18 | | | | | |
| CF-7 | Acetate | | -1 | 30 | 1 | mL | 6 | 2 | | -0.25 | 6.25 | 6.1 |
| CF-7 | Acetate | | -1 | 30 | 3 | mL | 18.5 | | | | | |
| CF-7 | Acetate | | -3 | 27 | 1 | mL | 3 | 2 | | -1.00 | 4.00 | 3.5 |
| CF-7 | Acetate | | -3 | 27 | 3 | mL | 11 | | | | | |
| CF-7 | Acetate | | -6 | 21 | 1 | mL | 1 | 2 | | -0.25 | 1.25 | 1.1 |
| CF-7 | Acetate | | -6 | 21 | 3 | mL | 3.5 | | | | | |
| CF-7 | Acetate | | -7 | 19 | 1 | mL | 4 | 2 | | 1.50 | 2.50 | 3.3 |
| CF-7 | Acetate | | -7 | 19 | 3 | mL | 9 | | | | | |
| CF-7 | Acetate | | -8 | 18 | 1 | mL | 2.5 | 2 | | -0.25 | 2.75 | 2.6 |
| CF-7 | Acetate | | -8 | 18 | 3 | mL | 8 | | | | | |
| CF-7 | Acetate | | -15 | 5 | 1 | mL | 2 | 2 | | -1.00 | 3.00 | 2.5 |
| CF-7 | Acetate | | -15 | 5 | 3 | mL | 8 | | | | | |
| CF-7 | Acetate | | -17.6 | 0 | 1 | mL | 2 | 2 | | 0.50 | 1.50 | 1.8 |
| CF-7 | Acetate | | -17.6 | 0 | 3 | mL | 5 | | | | | |
| CF-7 | Acetate | Frozen | -21 | -6 | 1 | mL | 0 | 2 | | -2.75 | 2.75 | 1.4 |
| CF-7 | Acetate | | -21 | -6 | 3 | mL | 5.5 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

| | | | | | | | | | Best Fit Analysis from JMP | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
| Clearlane Enhanced | NaCl + MgCl | | 0 | 32 | 1 | g | 14 | 2 | | 4.50 | 9.50 | 11.8 |
| Clearlane Enhanced | NaCl + MgCl | | 0 | 32 | 3 | g | 33 | | | | | |
| Clearlane Enhanced | NaCl + MgCl | | -1 | 30 | 1 | g | 14 | 2 | | 5.00 | 9.00 | 11.5 |
| Clearlane Enhanced | NaCl + MgCl | | -1 | 30 | 3 | g | 32 | | | | | |
| Clearlane Enhanced | NaCl + MgCl | | -3 | 27 | 1 | g | 9 | 2 | | 3.50 | 5.50 | 7.3 |
| Clearlane Enhanced | NaCl + MgCl | | -3 | 27 | 3 | g | 20 | | | | | |
| Clearlane Enhanced | NaCl + MgCl | | -6 | 21 | 1 | g | 4.5 | 2 | | -0.50 | 5.00 | 4.8 |
| Clearlane Enhanced | NaCl + MgCl | | -6 | 21 | 3 | g | 14.5 | | | | | |
| Clearlane Enhanced | NaCl + MgCl | | -7 | 19 | 1 | g | 4 | 2 | | -2.00 | 6.00 | 5.0 |
| Clearlane Enhanced | NaCl + MgCl | | -7 | 19 | 3 | g | 16 | | | | | |
| Clearlane Enhanced | NaCl + MgCl | | -8 | 18 | 1 | g | 3 | 2 | | -1.25 | 4.25 | 3.6 |
| Clearlane Enhanced | NaCl + MgCl | | -8 | 18 | 3 | g | 11.5 | | | | | |
| Clearlane Enhanced | NaCl + MgCl | | -15 | 5 | 1 | g | 3 | 2 | | 0.00 | 3.00 | 3.0 |
| Clearlane Enhanced | NaCl + MgCl | | -15 | 5 | 3 | g | 9 | | | | | |
| Clearlane Enhanced | NaCl + MgCl | | -17.6 | 0 | 1 | g | 3 | 2 | | 2.00 | 1.00 | 2.0 |
| Clearlane Enhanced | NaCl + MgCl | | -17.6 | 0 | 3 | g | 5 | | | | | |
| Clearlane Enhanced | NaCl + MgCl | Frozen | -21 | -6 | 1 | g | 0 | 2 | | 0.00 | 0.00 | 0.0 |
| Clearlane Enhanced | NaCl + MgCl | Frozen | -21 | -6 | 3 | g | 0 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |

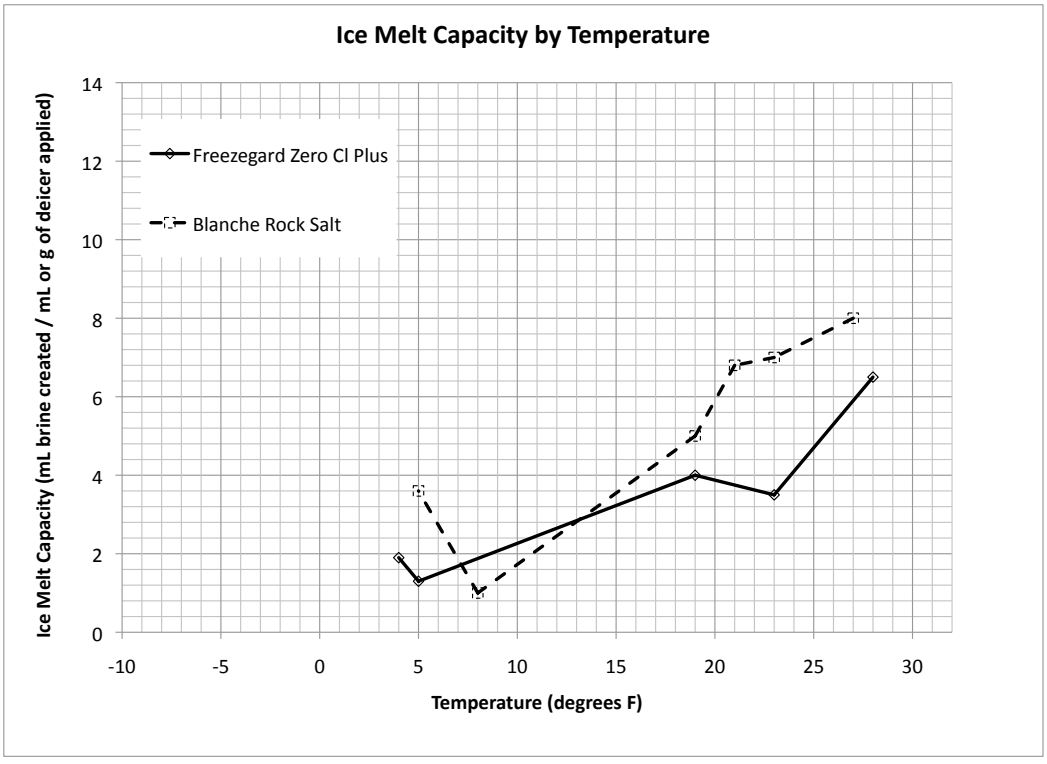


Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

Best Fit Analysis from JMP

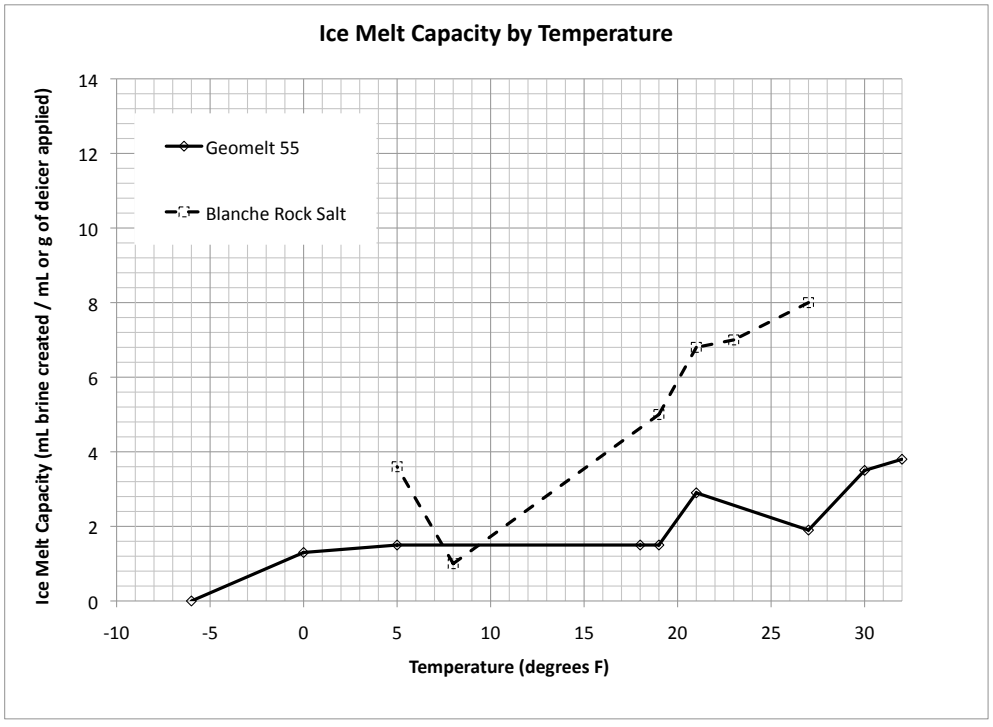
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Freezegard Zero Cl Plus | MgCl + Carb | | -2 | 28 | 1 | mL | 8 | 2 | | 3.00 | 5.00 | 6.5 |
| Freezegard Zero Cl Plus | MgCl + Carb | | -2 | 28 | 3 | mL | 18 | | | | | |
| Freezegard Zero Cl Plus | MgCl + Carb | | -5 | 23 | 1 | mL | 4 | 2 | | 1.00 | 3.00 | 3.5 |
| Freezegard Zero Cl Plus | MgCl + Carb | | -5 | 23 | 3 | mL | 10 | | | | | |
| Freezegard Zero Cl Plus | MgCl + Carb | | -7 | 19 | 1 | mL | 2.2 | 4 | 0.9 | -0.85 | 4.45 | 4.0 |
| Freezegard Zero Cl Plus | MgCl + Carb | | -7 | 19 | 1 | mL | 5 | | | | | |
| Freezegard Zero Cl Plus | MgCl + Carb | | -7 | 19 | 3 | mL | 14 | | | | | |
| Freezegard Zero Cl Plus | MgCl + Carb | | -7 | 19 | 3 | mL | 11 | | | | | |
| Freezegard Zero Cl Plus | MgCl + Carb | | -15 | 5 | 1 | mL | 1 | 2 | | -0.63 | 1.63 | 1.3 |
| Freezegard Zero Cl Plus | MgCl + Carb | | -15 | 5 | 3 | mL | 4.25 | | | | | |
| Freezegard Zero Cl Plus | MgCl + Carb | | -15.5 | 4 | 1 | mL | 1.5 | 2 | | -0.75 | 2.25 | 1.9 |
| Freezegard Zero Cl Plus | MgCl + Carb | | -15.5 | 4 | 3 | mL | 6 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

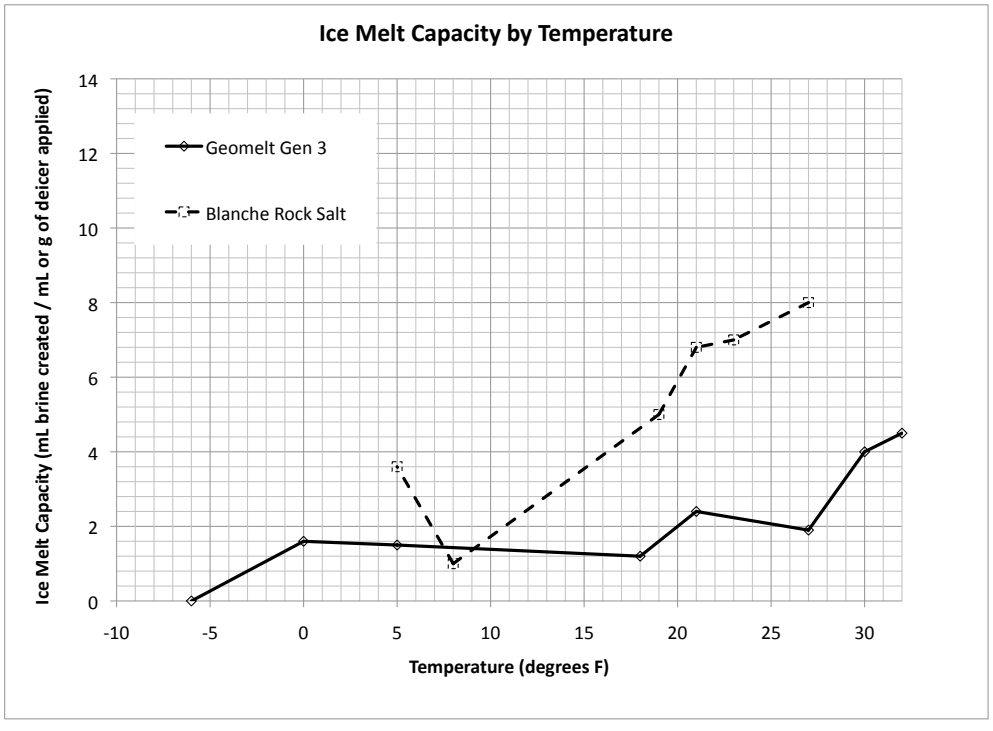
| | | | | | | | | | Best Fit Analysis from JMP | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
| Geomelt 55 | Carb | | 0 | 32 | 1 | mL | 4 | 2 | | 0.50 | 3.50 | 3.8 |
| Geomelt 55 | Carb | | 0 | 32 | 3 | mL | 11 | | | | | |
| Geomelt 55 | Carb | | -1 | 30 | 1 | mL | 4 | 2 | | 1.00 | 3.00 | 3.5 |
| Geomelt 55 | Carb | | -1 | 30 | 3 | mL | 10 | | | | | |
| Geomelt 55 | Carb | | -3 | 27 | 1 | mL | 2.5 | 2 | | 1.25 | 1.25 | 1.9 |
| Geomelt 55 | Carb | | -3 | 27 | 3 | mL | 5 | | | | | |
| Geomelt 55 | Carb | | -6 | 21 | 1 | mL | 2.5 | 2 | | -0.75 | 3.25 | 2.9 |
| Geomelt 55 | Carb | | -6 | 21 | 3 | mL | 9 | | | | | |
| Geomelt 55 | Carb | | -7 | 19 | 1 | mL | 1 | 2 | | -1.00 | 2.00 | 1.5 |
| Geomelt 55 | Carb | | -7 | 19 | 3 | mL | 5 | | | | | |
| Geomelt 55 | Carb | | -8 | 18 | 1 | mL | 2 | 2 | | 1.00 | 1.00 | 1.5 |
| Geomelt 55 | Carb | | -8 | 18 | 3 | mL | 4 | | | | | |
| Geomelt 55 | Carb | | -15 | 5 | 1 | mL | 2 | 2 | | 1.00 | 1.00 | 1.5 |
| Geomelt 55 | Carb | | -15 | 5 | 3 | mL | 4 | | | | | |
| Geomelt 55 | Carb | | -17.6 | 0 | 1 | mL | 1 | 2 | | -0.50 | 1.50 | 1.3 |
| Geomelt 55 | Carb | | -17.6 | 0 | 3 | mL | 4 | | | | | |
| Geomelt 55 | Carb | Frozen | -21 | -6 | 1 | mL | 0 | 2 | | 0.00 | 0.00 | 0.0 |
| Geomelt 55 | Carb | Frozen | -21 | -6 | 3 | mL | 0 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

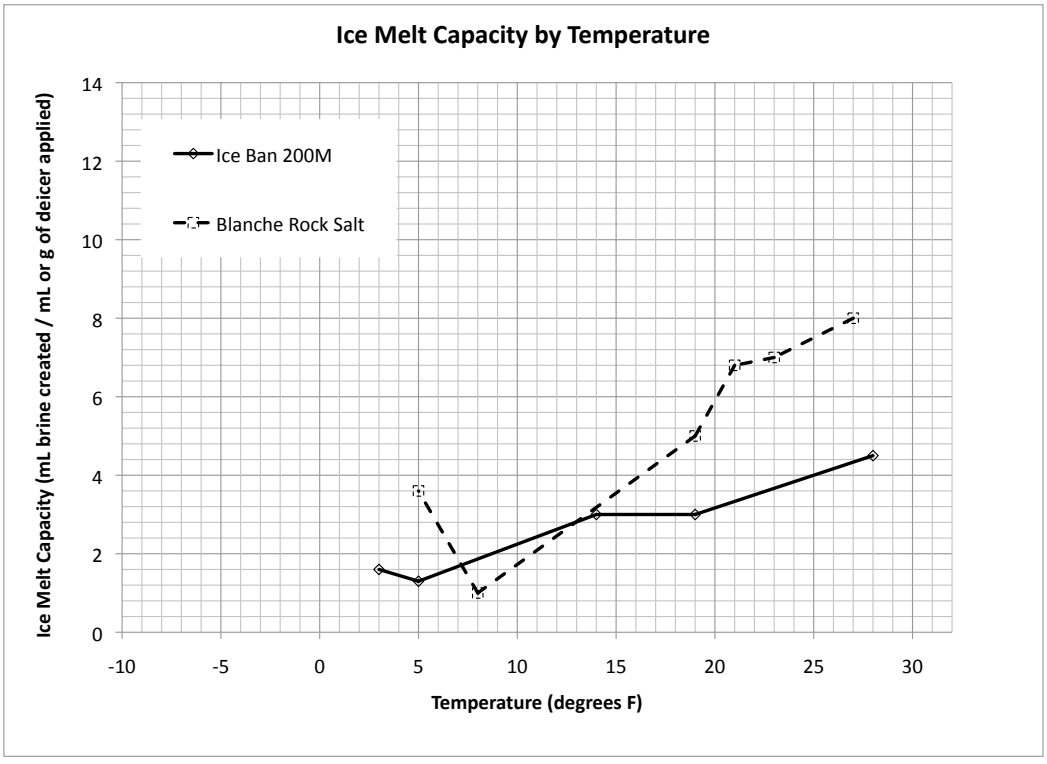
| | | | | | | | | | Best Fit Analysis from JMP | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
| Geomelt Gen 3 | NaCl + Carb | | 0 | 32 | 1 | mL | 5 | 2 | | 1.00 | 4.00 | 4.5 |
| Geomelt Gen 3 | NaCl + Carb | | 0 | 32 | 3 | mL | 13 | | | | | |
| Geomelt Gen 3 | NaCl + Carb | | -1 | 30 | 1 | mL | 4 | 2 | | 0.00 | 4.00 | 4.0 |
| Geomelt Gen 3 | NaCl + Carb | | -1 | 30 | 3 | mL | 12 | | | | | |
| Geomelt Gen 3 | NaCl + Carb | | -3 | 27 | 1 | mL | 2 | 2 | | 0.25 | 1.75 | 1.9 |
| Geomelt Gen 3 | NaCl + Carb | | -3 | 27 | 3 | mL | 5.5 | | | | | |
| Geomelt Gen 3 | NaCl + Carb | | -6 | 21 | 1 | mL | 2 | 2 | | -0.75 | 2.75 | 2.4 |
| Geomelt Gen 3 | NaCl + Carb | | -6 | 21 | 3 | mL | 7.5 | | | | | |
| Geomelt Gen 3 | NaCl + Carb | | -8 | 18 | 1 | mL | 1 | 4 | 0.98 | -0.38 | 1.38 | 1.2 |
| Geomelt Gen 3 | NaCl + Carb | | -8 | 18 | 1 | mL | 1 | | | | | |
| Geomelt Gen 3 | NaCl + Carb | | -8 | 18 | 3 | mL | 3.5 | | | | | |
| Geomelt Gen 3 | NaCl + Carb | | -8 | 18 | 3 | mL | 4 | | | | | |
| Geomelt Gen 3 | NaCl + Carb | | -15 | 5 | 1 | mL | 1 | 2 | | -1.00 | 2.00 | 1.5 |
| Geomelt Gen 3 | NaCl + Carb | | -15 | 5 | 3 | mL | 5 | | | | | |
| Geomelt Gen 3 | NaCl + Carb | | -17.6 | 0 | 1 | mL | 1.5 | 2 | | -0.25 | 1.75 | 1.6 |
| Geomelt Gen 3 | NaCl + Carb | | -17.6 | 0 | 3 | mL | 5 | | | | | |
| Geomelt Gen 3 | NaCl + Carb | Frozen | -21 | -6 | 1 | mL | 0 | 2 | | 0.00 | 0.00 | 0.0 |
| Geomelt Gen 3 | NaCl + Carb | Frozen | -21 | -6 | 3 | mL | 0 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

| | | | | | | | | | Best Fit Analysis from JMP | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
| Ice Ban 200M | MgCl + Carb | | -2 | 28 | 1 | mL | 4 | 2 | | -1.00 | 5.00 | 4.5 |
| Ice Ban 200M | MgCl + Carb | | -2 | 28 | 3 | mL | 14 | | | | | |
| Ice Ban 200M | MgCl + Carb | | -7 | 19 | 1 | mL | 2.8 | 4 | 1 | -0.40 | 3.20 | 3.0 |
| Ice Ban 200M | MgCl + Carb | | -7 | 19 | 1 | mL | 2.8 | | | | | |
| Ice Ban 200M | MgCl + Carb | | -7 | 19 | 3 | mL | 9 | | | | | |
| Ice Ban 200M | MgCl + Carb | | -7 | 19 | 3 | mL | 9.4 | | | | | |
| Ice Ban 200M | MgCl + Carb | | -10 | 14 | 1 | mL | 2.2 | 2 | | -1.50 | 3.70 | 3.0 |
| Ice Ban 200M | MgCl + Carb | | -10 | 14 | 3 | mL | 9.6 | | | | | |
| Ice Ban 200M | MgCl + Carb | | -15 | 5 | 1 | mL | 1 | 2 | | -0.50 | 1.50 | 1.3 |
| Ice Ban 200M | MgCl + Carb | | -15 | 5 | 3 | mL | 4 | | | | | |
| Ice Ban 200M | MgCl + Carb | | -16 | 3 | 1 | mL | 1.5 | 2 | | -0.25 | 1.75 | 1.6 |
| Ice Ban 200M | MgCl + Carb | | -16 | 3 | 3 | mL | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |

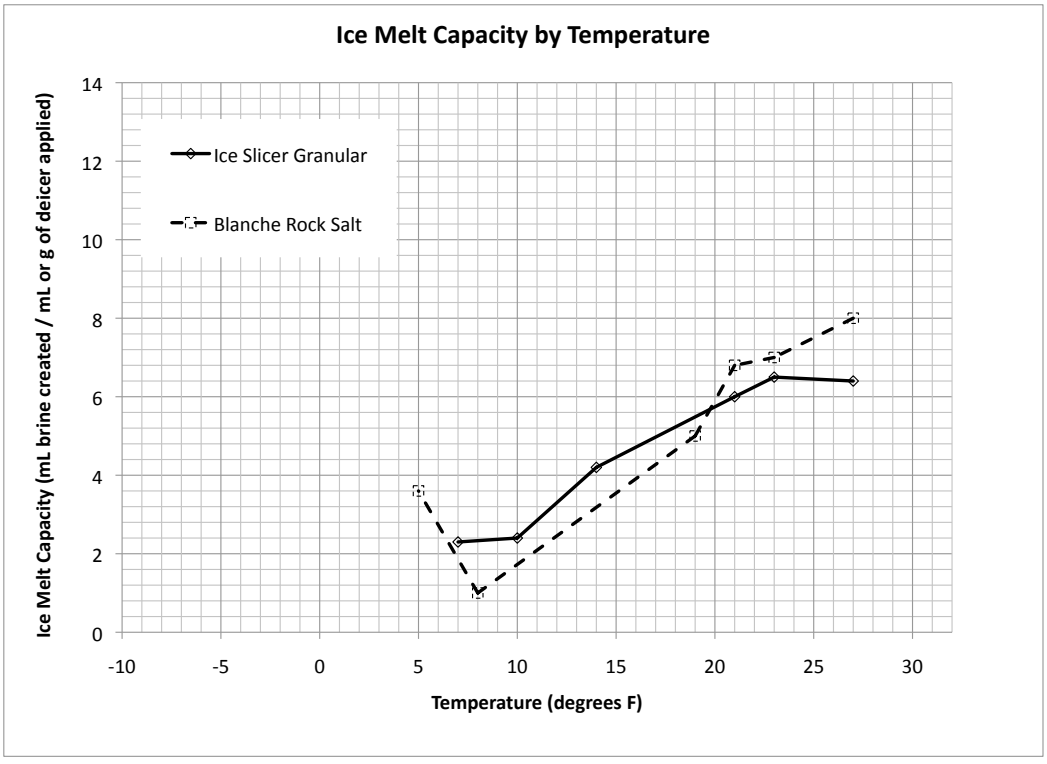


Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

Best Fit Analysis from JMP

| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ice Slicer Granular | NaCl + MgCl + KCl | | -3 | 27 | 1 | g | 7.4 | 2 | | 2.10 | 5.30 | 6.4 |
| Ice Slicer Granular | NaCl + MgCl + KCl | | -3 | 27 | 3 | g | 18 | | | | | |
| Ice Slicer Granular | NaCl + MgCl + KCl | | -5 | 23 | 1 | g | 7 | 2 | | 1.00 | 6.00 | 6.5 |
| Ice Slicer Granular | NaCl + MgCl + KCl | | -5 | 23 | 3 | g | 19 | | | | | |
| Ice Slicer Granular | NaCl + MgCl + KCl | 2 reapplies | -6 | 21 | 1 | g | 8 | 2 | | 4.00 | 4.00 | 6.0 |
| Ice Slicer Granular | NaCl + MgCl + KCl | 2 reapplies | -6 | 21 | 3 | g | 16 | | | | | |
| Ice Slicer Granular | NaCl + MgCl + KCl | | -10 | 14 | 1 | g | 4.2 | 2 | | 0.05 | 4.15 | 4.2 |
| Ice Slicer Granular | NaCl + MgCl + KCl | | -10 | 14 | 3 | g | 12.5 | | | | | |
| Ice Slicer Granular | NaCl + MgCl + KCl | | -12.5 | 10 | 1 | g | 1.75 | 2 | | -1.25 | 3.00 | 2.4 |
| Ice Slicer Granular | NaCl + MgCl + KCl | | -12.5 | 10 | 3 | g | 7.75 | | | | | |
| Ice Slicer Granular | NaCl + MgCl + KCl | | -14 | 7 | 1 | g | 2.75 | 2 | | 1.00 | 1.75 | 2.3 |
| Ice Slicer Granular | NaCl + MgCl + KCl | | -14 | 7 | 3 | g | 6.25 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |

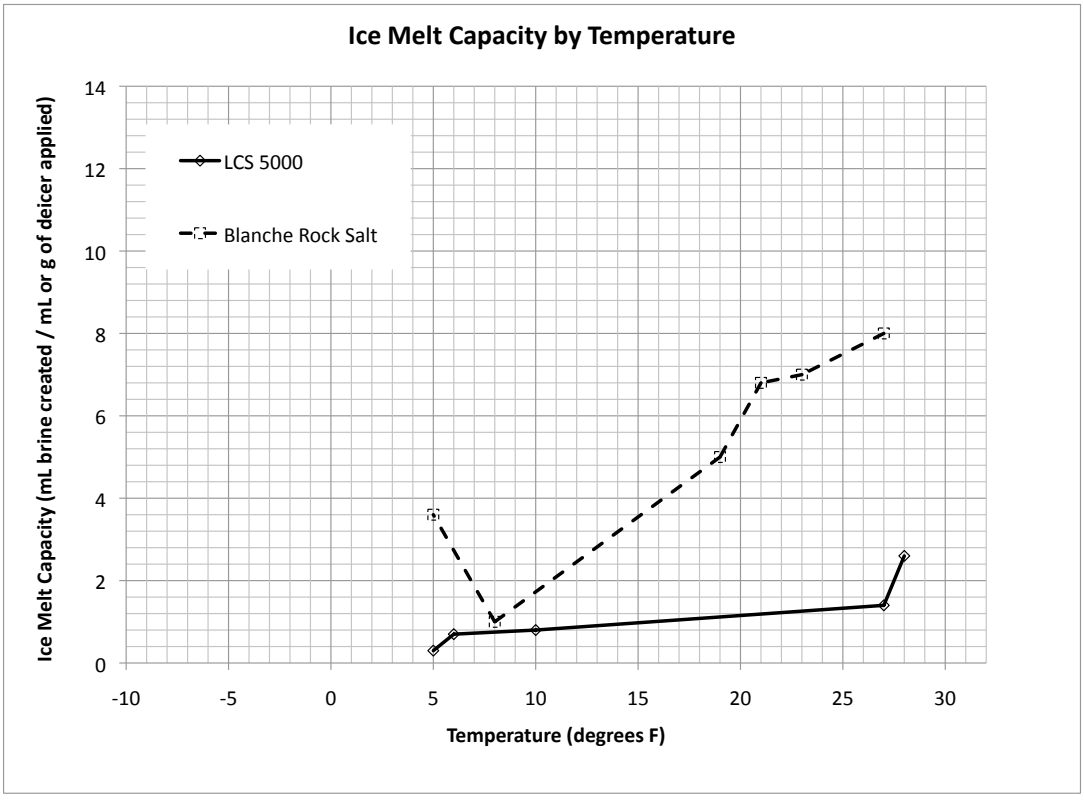


Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

Best Fit Analysis from JMP

| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LCS 5000 | Carb | | -2 | 28 | 1 | mL | 2.5 | 2 | | -0.25 | 2.75 | 2.6 |
| LCS 5000 | Carb | | -2 | 28 | 3 | mL | 8 | | | | | |
| LCS 5000 | Carb | | -3 | 27 | 1 | mL | 1.8 | 2 | | 0.80 | 1.00 | 1.4 |
| LCS 5000 | Carb | | -3 | 27 | 3 | mL | 3.8 | | | | | |
| LCS 5000 | Carb | | -12.5 | 10 | 1 | mL | 0.5 | 2 | | -0.50 | 1.00 | 0.8 |
| LCS 5000 | Carb | | -12.5 | 10 | 3 | mL | 2.5 | | | | | |
| LCS 5000 | Carb | | -14.5 | 6 | 1 | mL | 0.5 | 2 | | -0.38 | 0.88 | 0.7 |
| LCS 5000 | Carb | | -14.5 | 6 | 3 | mL | 2.25 | | | | | |
| LCS 5000 | Carb | | -15 | 5 | 1 | mL | 0 | 2 | | -0.50 | 0.50 | 0.3 |
| LCS 5000 | Carb | | -15 | 5 | 3 | mL | 1 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |

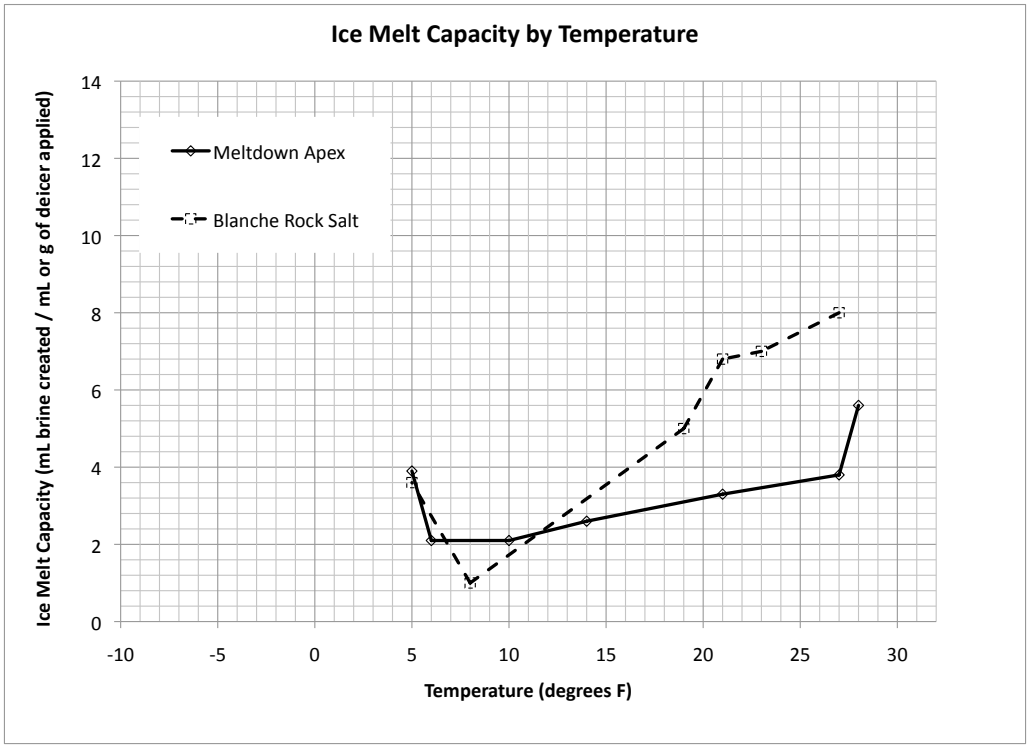


Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

Best Fit Analysis from JMP

| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Meltdown APEX | MgCl + Carb | | -2 | 28 | 1 | mL | 6 | 2 | | 0.75 | 5.25 | 5.6 |
| Meltdown APEX | MgCl + Carb | | -2 | 28 | 3 | mL | 16.5 | | | | | |
| Meltdown APEX | MgCl + Carb | | -3 | 27 | 1 | mL | 4 | 2 | | 0.50 | 3.50 | 3.8 |
| Meltdown APEX | MgCl + Carb | | -3 | 27 | 3 | mL | 11 | | | | | |
| Meltdown APEX | MgCl + Carb | 2 reapplies | -6 | 21 | 1 | mL | 3 | 2 | | -0.50 | 3.50 | 3.3 |
| Meltdown APEX | MgCl + Carb | 2 reapplies | -6 | 21 | 3 | mL | 10 | | | | | |
| Meltdown APEX | MgCl + Carb | | -10 | 14 | 1 | mL | 2.4 | 2 | | -0.40 | 2.80 | 2.6 |
| Meltdown APEX | MgCl + Carb | | -10 | 14 | 3 | mL | 8 | | | | | |
| Meltdown APEX | MgCl + Carb | | -12.5 | 10 | 1 | mL | 1.75 | 2 | | -0.75 | 2.50 | 2.1 |
| Meltdown APEX | MgCl + Carb | | -12.5 | 10 | 3 | mL | 6.75 | | | | | |
| Meltdown APEX | MgCl + Carb | | -14.5 | 6 | 1 | mL | 1.5 | 2 | | -1.25 | 2.75 | 2.1 |
| Meltdown APEX | MgCl + Carb | | -14.5 | 6 | 3 | mL | 7 | | | | | |
| Meltdown APEX | MgCl + Carb | | -15 | 5 | 1 | mL | 4 | 2 | | 0.25 | 3.75 | 3.9 |
| Meltdown APEX | MgCl + Carb | | -15 | 5 | 3 | mL | 11.5 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |

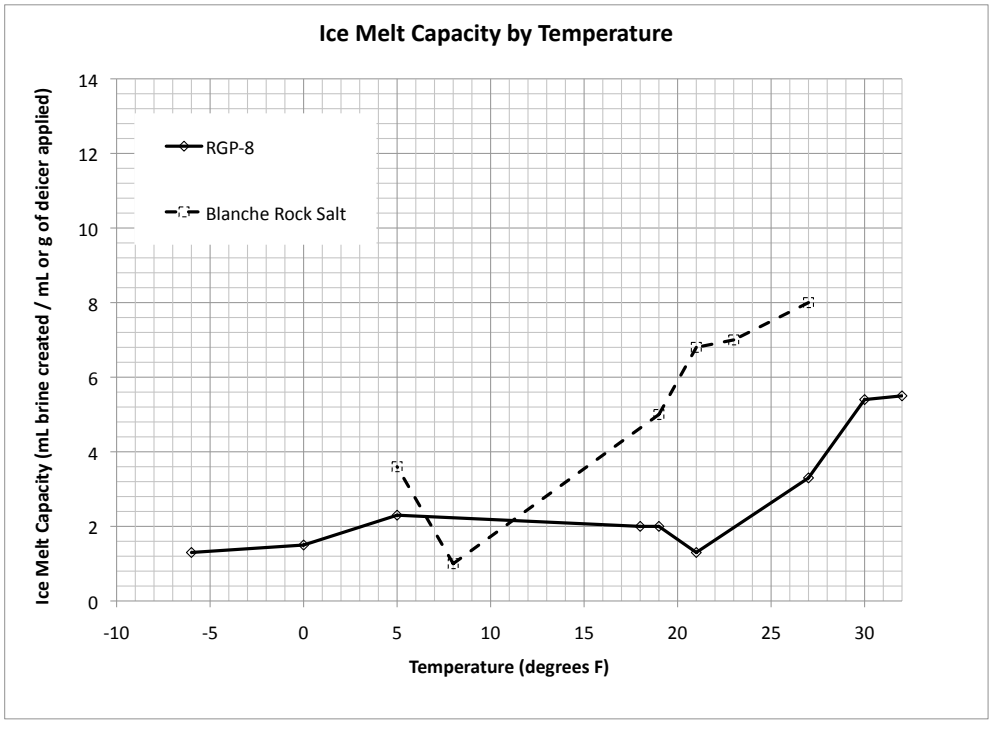


Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

Best Fit Analysis from JMP

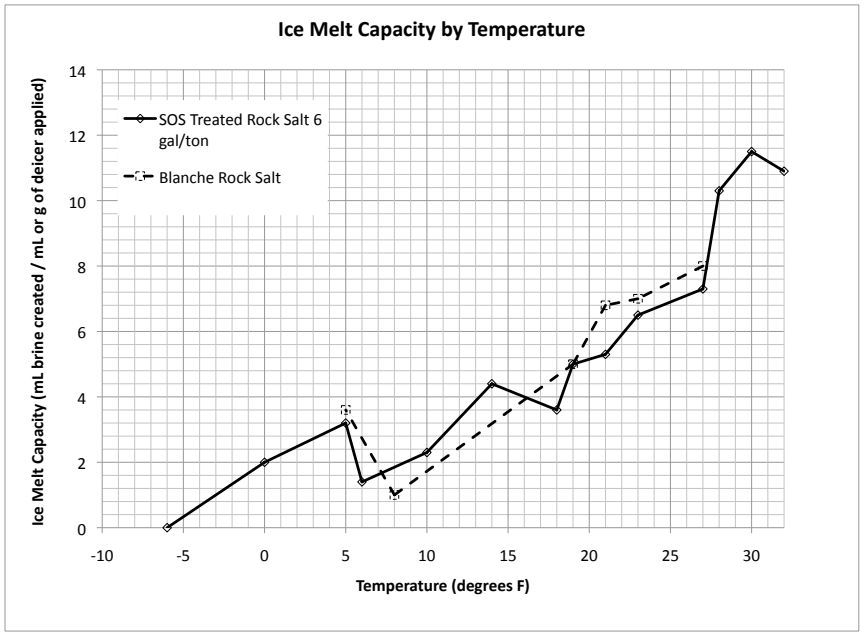
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RGP-8 | Carb | | 0 | 32 | 1 | mL | 6 | 2 | | 1.00 | 5.00 | 5.5 |
| RGP-8 | Carb | | 0 | 32 | 3 | mL | 16 | | | | | |
| RGP-8 | Carb | | -1 | 30 | 1 | mL | 5 | 2 | | -0.75 | 5.75 | 5.4 |
| RGP-8 | Carb | | -1 | 30 | 3 | mL | 16.5 | | | | | |
| RGP-8 | Carb | | -3 | 27 | 1 | mL | 3 | 2 | | -0.50 | 3.50 | 3.3 |
| RGP-8 | Carb | | -3 | 27 | 3 | mL | 10 | | | | | |
| RGP-8 | Carb | | -6 | 21 | 1 | mL | 1 | 2 | | -0.50 | 1.50 | 1.3 |
| RGP-8 | Carb | | -6 | 21 | 3 | mL | 4 | | | | | |
| RGP-8 | Carb | | -7 | 19 | 1 | mL | 1 | 2 | | -2.00 | 3.00 | 2.0 |
| RGP-8 | Carb | | -7 | 19 | 3 | mL | 7 | | | | | |
| RGP-8 | Carb | | -8 | 18 | 1 | mL | 2 | 2 | | 0.00 | 2.00 | 2.0 |
| RGP-8 | Carb | | -8 | 18 | 3 | mL | 6 | | | | | |
| RGP-8 | Carb | | -15 | 5 | 1 | mL | 2 | 2 | | -0.50 | 2.50 | 2.3 |
| RGP-8 | Carb | | -15 | 5 | 3 | mL | 7 | | | | | |
| RGP-8 | Carb | | -17.6 | 0 | 1 | mL | 1 | 2 | | -1.00 | 2.00 | 1.5 |
| RGP-8 | Carb | | -17.6 | 0 | 3 | mL | 5 | | | | | |
| RGP-8 | Carb | | -21 | -6 | 1 | mL | 0 | 2 | | -2.50 | 2.50 | 1.3 |
| RGP-8 | Carb | | -21 | -6 | 3 | mL | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

| | | | | | | | | | Best Fit Analysis from JMP | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | 0 | 32 | 1 | g | 13 | 2 | | 4.25 | 8.75 | 10.9 |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | 0 | 32 | 3 | g | 30.5 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -1 | 30 | 1 | g | 13 | 2 | | 3.00 | 10.00 | 11.5 |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -1 | 30 | 3 | g | 33 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -2 | 28 | 1 | g | 12 | 2 | | 3.50 | 8.50 | 10.3 |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -2 | 28 | 3 | g | 29 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -3 | 27 | 1 | g | 7 | 2 | | -0.50 | 7.50 | 7.3 |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -3 | 27 | 3 | g | 22 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -5 | 23 | 1 | g | 7 | 2 | | 1.00 | 6.00 | 6.5 |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -5 | 23 | 3 | g | 19 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | 2 reapplies | -6 | 21 | 1 | g | 6.8 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -6 | 21 | 1 | g | 4.5 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | 2 reapplies | -6 | 21 | 3 | g | 18 | 4 | 0.86 | 0.73 | 4.93 | 5.3 |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -6 | 21 | 3 | g | 13 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -7 | 19 | 1 | g | 5 | 1 | | 0.00 | 5.00 | 5.0 |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | Broke | -7 | 19 | 3 | g | | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -8 | 18 | 1 | g | 2.5 | 2 | | -2.25 | 4.75 | 3.6 |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -8 | 18 | 3 | g | 12 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -10 | 14 | 1 | g | 5.2 | 2 | | 1.55 | 3.65 | 4.4 |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -10 | 14 | 3 | g | 12.5 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -12.5 | 10 | 1 | g | 3 | 2 | | 1.50 | 1.50 | 2.3 |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -12.5 | 10 | 3 | g | 6 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -14.5 | 6 | 1 | g | 1.25 | 2 | | -0.38 | 1.63 | 1.4 |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -14.5 | 6 | 3 | g | 4.5 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -15 | 5 | 1 | g | 1.5 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -15 | 5 | 1 | g | 3 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -15 | 5 | 3 | g | 10 | 4 | 0.98 | -1.88 | 4.13 | 3.2 |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -15 | 5 | 3 | g | 11 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -17.6 | 0 | 1 | g | 2 | 2 | | 0.00 | 2.00 | 2.0 |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | | -17.6 | 0 | 3 | g | 6 | | | | | |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | Frozen | -21 | -6 | 1 | g | 0 | 2 | | 0.00 | 0.00 | 0.0 |
| SOS Treated Salt 6gal/ton | NaCl + MgCl | Frozen | -21 | -6 | 3 | g | 0 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |

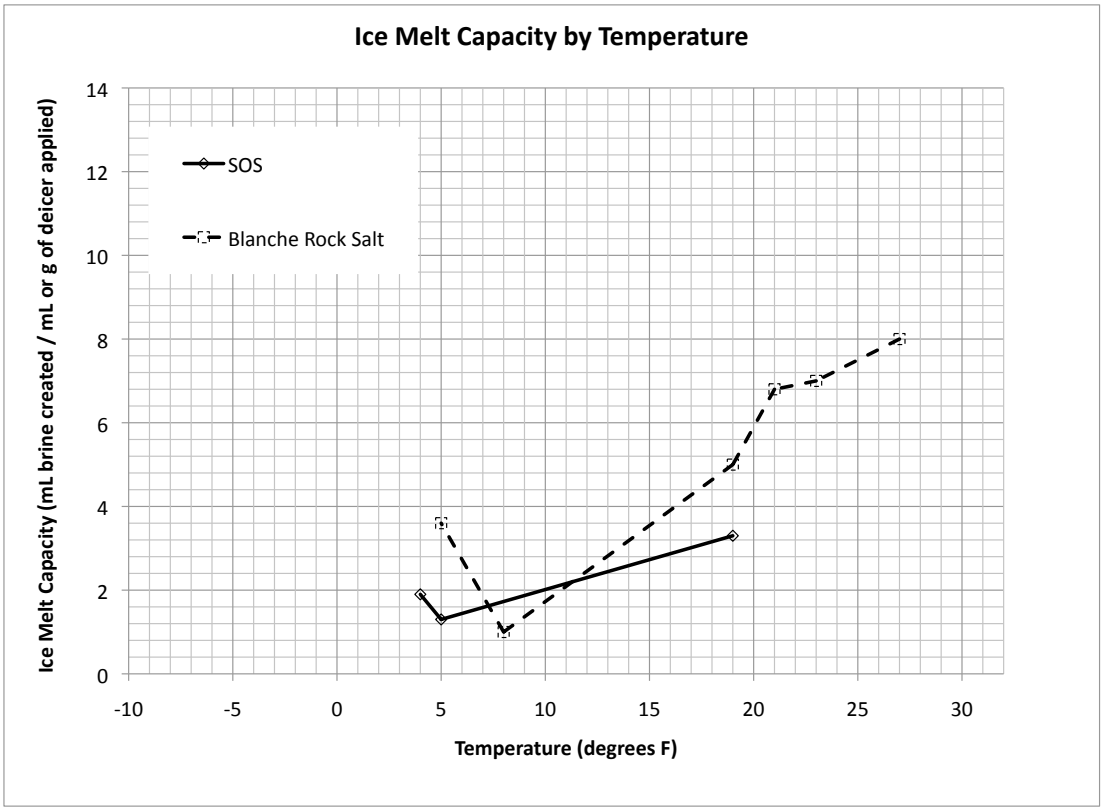


Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

Best Fit Analysis from JMP

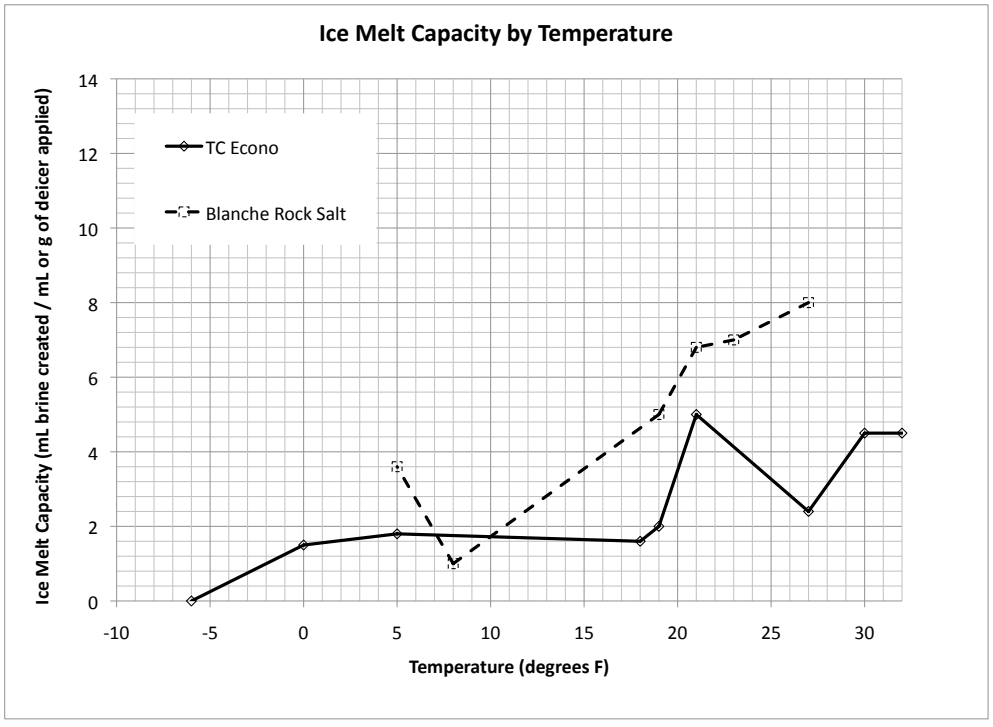
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOS | MgCl | | -7 | 19 | 1 | mL | 3.2 | 4 | 0.94 | 1.55 | 2.55 | 3.3 |
| SOS | MgCl | | -7 | 19 | 1 | mL | 5 | | | | | |
| SOS | MgCl | | -7 | 19 | 3 | mL | 9.2 | | | | | |
| SOS | MgCl | | -7 | 19 | 3 | mL | 9.2 | | | | | |
| SOS | MgCl | | -15 | 5 | 1 | mL | 1 | 2 | | -0.50 | 1.50 | 1.3 |
| SOS | MgCl | | -15 | 5 | 3 | mL | 4 | | | | | |
| SOS | MgCl | | -15.5 | 4 | 1 | mL | 2.5 | 2 | | 1.25 | 1.25 | 1.9 |
| SOS | MgCl | | -15.5 | 4 | 3 | mL | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

| | | | | | | | | | Best Fit Analysis from JMP | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
| TC Econo | NaCl + CaCl | | 0 | 32 | 1 | mL | 5 | 2 | | 1.00 | 4.00 | 4.5 |
| TC Econo | NaCl + CaCl | | 0 | 32 | 3 | mL | 13 | | | | | |
| TC Econo | NaCl + CaCl | | -1 | 30 | 1 | mL | 5 | 2 | | 1.00 | 4.00 | 4.5 |
| TC Econo | NaCl + CaCl | | -1 | 30 | 3 | mL | 13 | | | | | |
| TC Econo | NaCl + CaCl | | -3 | 27 | 1 | mL | 2.5 | 2 | | 0.25 | 2.25 | 2.4 |
| TC Econo | NaCl + CaCl | | -3 | 27 | 3 | mL | 7 | | | | | |
| TC Econo | NaCl + CaCl | | -6 | 21 | 1 | mL | 4.5 | 2 | | -1.00 | 5.50 | 5.0 |
| TC Econo | NaCl + CaCl | | -6 | 21 | 3 | mL | 15.5 | | | | | |
| TC Econo | NaCl + CaCl | | -7 | 19 | 1 | mL | 2 | 2 | | 0.00 | 2.00 | 2.0 |
| TC Econo | NaCl + CaCl | | -7 | 19 | 3 | mL | 6 | | | | | |
| TC Econo | NaCl + CaCl | | -8 | 18 | 1 | mL | 2 | 2 | | 0.75 | 1.25 | 1.6 |
| TC Econo | NaCl + CaCl | | -8 | 18 | 3 | mL | 4.5 | | | | | |
| TC Econo | NaCl + CaCl | | -15 | 5 | 1 | mL | 2 | 2 | | 0.50 | 1.50 | 1.8 |
| TC Econo | NaCl + CaCl | | -15 | 5 | 3 | mL | 5 | | | | | |
| TC Econo | NaCl + CaCl | | -17.6 | 0 | 1 | mL | 2 | 2 | | 1.00 | 1.00 | 1.5 |
| TC Econo | NaCl + CaCl | | -17.6 | 0 | 3 | mL | 4 | | | | | |
| TC Econo | NaCl + CaCl | Frozen | -21 | -6 | 1 | mL | 0 | 2 | | 0.00 | 0.00 | 0.0 |
| TC Econo | NaCl + CaCl | Frozen | -21 | -6 | 3 | mL | 0 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |

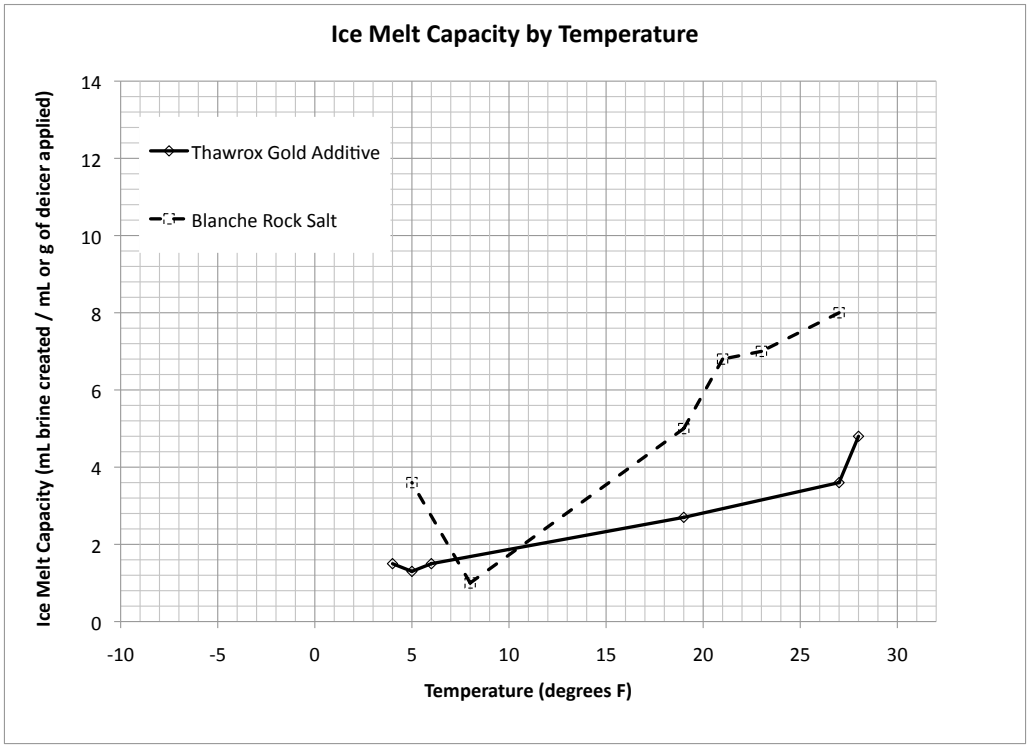


Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

Best Fit Analysis from JMP

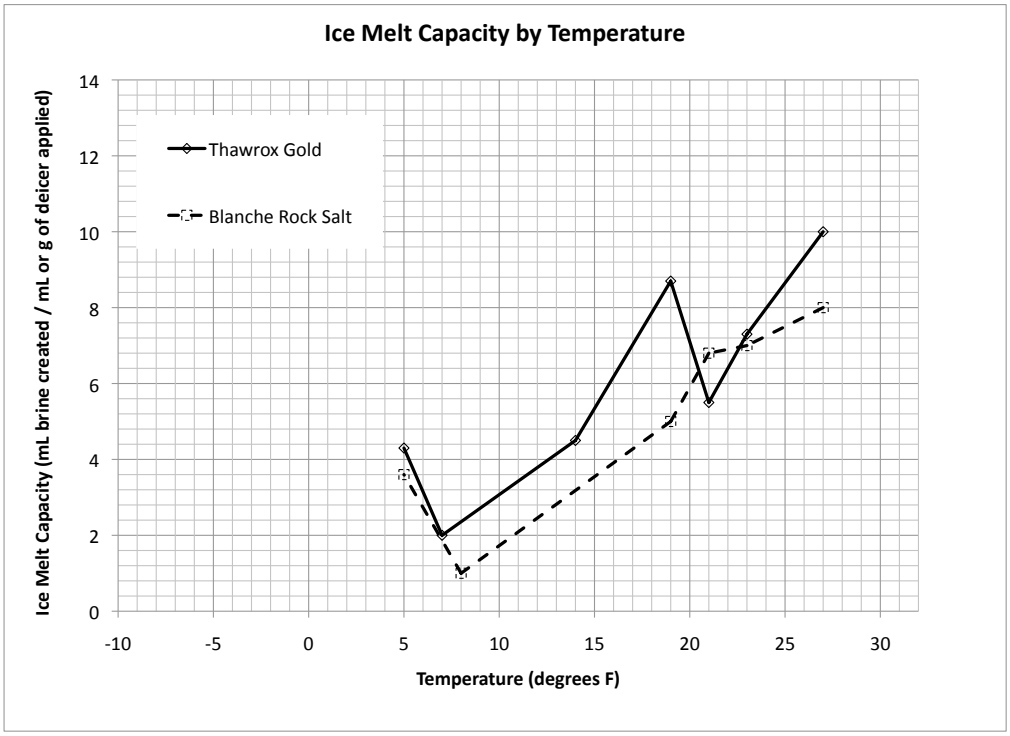
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thawrox Gold Additive | MgCl | | -2 | 28 | 1 | mL | 5 | 2 | | 0.50 | 4.50 | 4.8 |
| Thawrox Gold Additive | MgCl | | -2 | 28 | 3 | mL | 14 | | | | | |
| Thawrox Gold Additive | MgCl | | -3 | 27 | 1 | mL | 2.4 | 2 | | -2.40 | 4.80 | 3.6 |
| Thawrox Gold Additive | MgCl | | -3 | 27 | 3 | mL | 12 | | | | | |
| Thawrox Gold Additive | MgCl | | -7 | 19 | 1 | mL | 2.8 | 4 | 0.02 | 4.65 | 0.35 | 2.7 |
| Thawrox Gold Additive | MgCl | | -7 | 19 | 1 | mL | 7.2 | | | | | |
| Thawrox Gold Additive | MgCl | | -7 | 19 | 3 | mL | 2.8 | | | | | |
| Thawrox Gold Additive | MgCl | | -7 | 19 | 3 | mL | 8.6 | | | | | |
| Thawrox Gold Additive | MgCl | | -14.5 | 6 | 1 | mL | 1 | 2 | | -1.00 | 2.00 | 1.5 |
| Thawrox Gold Additive | MgCl | | -14.5 | 6 | 3 | mL | 5 | | | | | |
| Thawrox Gold Additive | MgCl | | -15 | 5 | 1 | mL | 1 | 2 | | -0.50 | 1.50 | 1.3 |
| Thawrox Gold Additive | MgCl | | -15 | 5 | 3 | mL | 4 | | | | | |
| Thawrox Gold Additive | MgCl | | -15.5 | 4 | 1 | mL | 1 | 2 | | -1.00 | 2.00 | 1.5 |
| Thawrox Gold Additive | MgCl | | -15.5 | 4 | 3 | mL | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

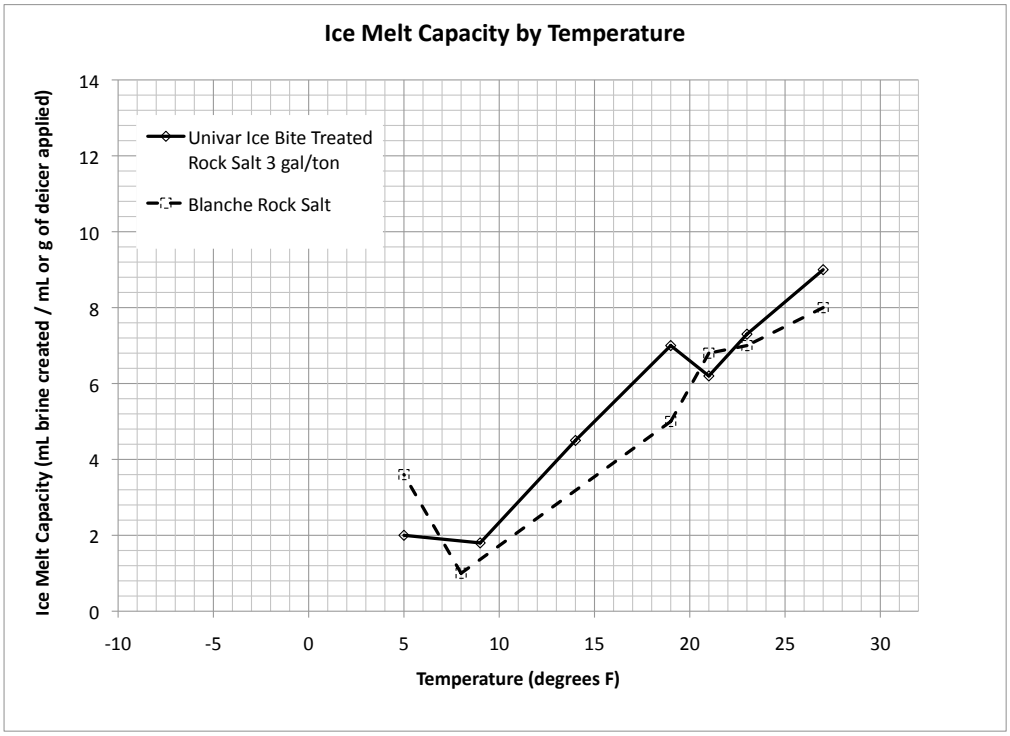
| | | | | | | | | | Best Fit Analysis from JMP | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
| Thawrox Gold | NaCl + MgCl | | -3 | 27 | 1 | g | 10 | 2 | | 0.00 | 10.00 | 10.0 |
| Thawrox Gold | NaCl + MgCl | | -3 | 27 | 3 | g | 30 | | | | | |
| Thawrox Gold | NaCl + MgCl | | -5 | 23 | 1 | g | 6 | 2 | | -2.50 | 8.50 | 7.3 |
| Thawrox Gold | NaCl + MgCl | | -5 | 23 | 3 | g | 23 | | | | | |
| Thawrox Gold | NaCl + MgCl | 2 reapplies | -6 | 21 | 1 | g | 5.6 | 2 | | 0.15 | 5.45 | 5.5 |
| Thawrox Gold | NaCl + MgCl | 2 reapplies | -6 | 21 | 3 | g | 16.5 | | | | | |
| Thawrox Gold | NaCl + MgCl | | -7 | 19 | 1 | g | 6.8 | 2 | | 0.20 | 8.60 | 8.7 |
| Thawrox Gold | NaCl + MgCl | | -7 | 19 | 3 | g | 20 | | | | | |
| Thawrox Gold | NaCl + MgCl | | -10 | 14 | 1 | g | 4.8 | 2 | | 0.70 | 4.10 | 4.5 |
| Thawrox Gold | NaCl + MgCl | | -10 | 14 | 3 | g | 13 | | | | | |
| Thawrox Gold | NaCl + MgCl | | -14 | 7 | 1 | g | 2 | 2 | | 0.00 | 2.00 | 2.0 |
| Thawrox Gold | NaCl + MgCl | | -14 | 7 | 3 | g | 6 | | | | | |
| Thawrox Gold | NaCl + MgCl | | -15 | 5 | 1 | g | 5.5 | | | | | |
| Thawrox Gold | NaCl + MgCl | | -15 | 5 | 1 | g | 1.75 | | | | | |
| Thawrox Gold | NaCl + MgCl | | -15 | 5 | 3 | g | 20 | 4 | 0.53 | -1.38 | 5.00 | 4.3 |
| Thawrox Gold | NaCl + MgCl | | -15 | 5 | 3 | g | 7.25 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

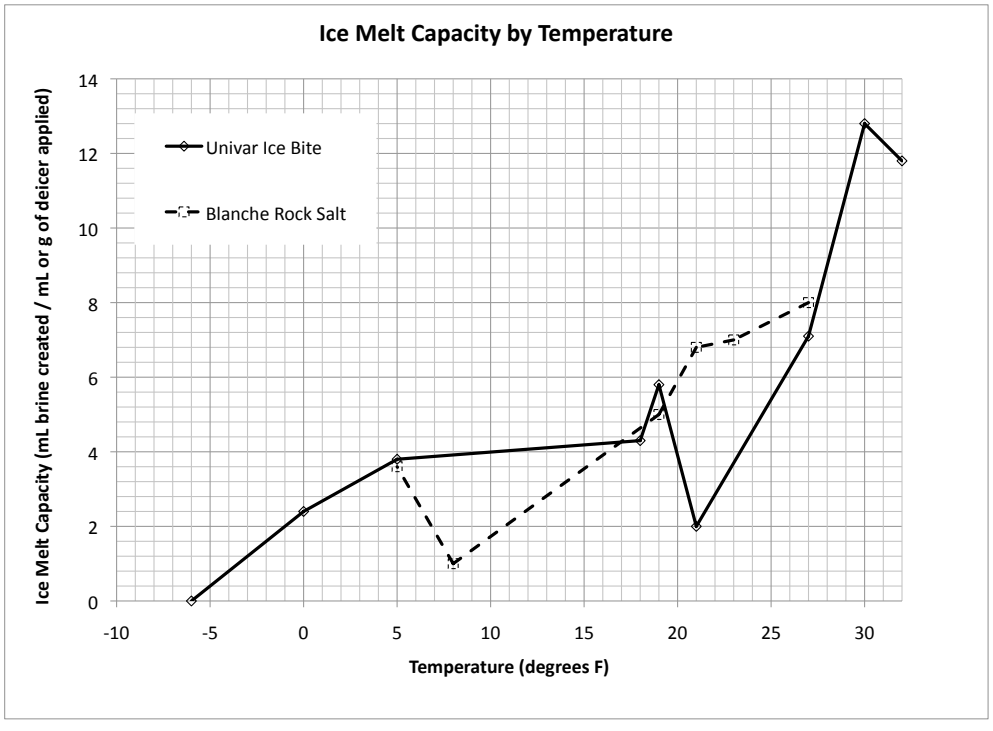
| | | | | | | | | | Best Fit Analysis from JMP | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
| Univar Ice Bite 3gal/ton | NaCl + Carb | | -3 | 27 | 1 | g | 9.8 | 2 | | 1.70 | 8.10 | 9.0 |
| Univar Ice Bite 3gal/ton | NaCl + Carb | | -3 | 27 | 3 | g | 26 | | | | | |
| Univar Ice Bite 3gal/ton | NaCl + Carb | | -5 | 23 | 1 | g | 8 | 2 | | 1.50 | 6.50 | 7.3 |
| Univar Ice Bite 3gal/ton | NaCl + Carb | | -5 | 23 | 3 | g | 21 | | | | | |
| Univar Ice Bite 3gal/ton | NaCl + Carb | 2 reapplies | -6 | 21 | 1 | g | 5.6 | 2 | | -1.10 | 6.70 | 6.2 |
| Univar Ice Bite 3gal/ton | NaCl + Carb | 2 reapplies | -6 | 21 | 3 | g | 19 | | | | | |
| Univar Ice Bite 3gal/ton | NaCl + Carb | | -7 | 19 | 1 | g | 4.8 | 2 | | -4.30 | 9.10 | 7.0 |
| Univar Ice Bite 3gal/ton | NaCl + Carb | | -7 | 19 | 3 | g | 23 | | | | | |
| Univar Ice Bite 3gal/ton | NaCl + Carb | | -10 | 14 | 1 | g | 4.4 | 2 | | -0.15 | 4.55 | 4.5 |
| Univar Ice Bite 3gal/ton | NaCl + Carb | | -10 | 14 | 3 | g | 13.5 | | | | | |
| Univar Ice Bite 3gal/ton | NaCl + Carb | | -13 | 9 | 1 | g | 1.75 | 2 | | -0.13 | 1.88 | 1.8 |
| Univar Ice Bite 3gal/ton | NaCl + Carb | | -13 | 9 | 3 | g | 5.5 | | | | | |
| Univar Ice Bite 3gal/ton | NaCl + Carb | | -15 | 5 | 1 | g | 1.5 | | | | | |
| Univar Ice Bite 3gal/ton | NaCl + Carb | | -15 | 5 | 1 | g | 0.75 | | | | | |
| Univar Ice Bite 3gal/ton | NaCl + Carb | | -15 | 5 | 3 | g | 7 | 4 | 0.99 | -1.75 | 2.88 | 2.0 |
| Univar Ice Bite 3gal/ton | NaCl + Carb | | -15 | 5 | 3 | g | 6.75 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 28, 2011

| | | | | | | | | | Best Fit Analysis from JMP | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deicer | Base | Notes | Temp deg C | Temp deg F | Amount of Decier | units | Brine Created | n | $R^2$ if n more than 2 | Intercept | Slope | Average Ice Melt Capacity at Temperature (g ice / g or mL deicer) |
| Univar Ice Bite | Carb | | 0 | 32 | 1 | g | 15 | 2 | | 6.50 | 8.50 | 11.8 |
| Univar Ice Bite | Carb | | 0 | 32 | 3 | g | 32 | | | | | |
| Univar Ice Bite | Carb | | -1 | 30 | 1 | g | 14 | 2 | | 2.50 | 11.50 | 12.8 |
| Univar Ice Bite | Carb | | -1 | 30 | 3 | g | 37 | | | | | |
| Univar Ice Bite | Carb | | -3 | 27 | 1 | g | 7.5 | 2 | | 0.75 | 6.75 | 7.1 |
| Univar Ice Bite | Carb | | -3 | 27 | 3 | g | 21 | | | | | |
| Univar Ice Bite | Carb | | -6 | 21 | 1 | g | 2.5 | 2 | | 1.00 | 1.50 | 2.0 |
| Univar Ice Bite | Carb | | -6 | 21 | 3 | g | 5.5 | | | | | |
| Univar Ice Bite | Carb | | -7 | 19 | 1 | g | 5 | 2 | | -1.50 | 6.50 | 5.8 |
| Univar Ice Bite | Carb | | -7 | 19 | 3 | g | 18 | | | | | |
| Univar Ice Bite | Carb | | -8 | 18 | 1 | g | 4 | 2 | | -0.50 | 4.50 | 4.3 |
| Univar Ice Bite | Carb | | -8 | 18 | 3 | g | 13 | | | | | |
| Univar Ice Bite | Carb | | -15 | 5 | 1 | g | 3 | 2 | | -1.50 | 4.50 | 3.8 |
| Univar Ice Bite | Carb | | -15 | 5 | 3 | g | 12 | | | | | |
| Univar Ice Bite | Carb | | -17.6 | 0 | 1 | g | 3 | 2 | | 1.25 | 1.75 | 2.4 |
| Univar Ice Bite | Carb | | -17.6 | 0 | 3 | g | 6.5 | | | | | |
| Univar Ice Bite | Carb | Frozen | -21 | -6 | 1 | g | 0 | 2 | | 0.00 | 0.00 | 0.0 |
| Univar Ice Bite | Carb | Frozen | -21 | -6 | 3 | g | 0 | | | | | |
| Blanche Rock Salt | NaCl | | -3 | 27 | 1 | g | 11 | 2 | | 6.00 | 5.00 | 8.0 |
| Blanche Rock Salt | NaCl | 2 reapplies | -3 | 27 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | | -5 | 23 | 1 | g | 7 | 2 | | 0.00 | 7.00 | 7.0 |
| Blanche Rock Salt | NaCl | | -5 | 23 | 3 | g | 21 | | | | | |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 1 | g | 9.2 | 2 | | 4.80 | 4.40 | 6.8 |
| Blanche Rock Salt | NaCl | 2 reapplies | -6 | 21 | 3 | g | 18 | | | | | |
| Blanche Rock Salt | NaCl | | -7 | 19 | 1 | g | 5.8 | 2 | | 1.70 | 4.10 | 5.0 |
| Blanche Rock Salt | NaCl | | -7 | 19 | 3 | g | 14 | | | | | |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 1 | g | 1.5 | 2 | | 1.00 | 0.50 | 1.0 |
| Blanche Rock Salt | NaCl | | -13.5 | 8 | 3 | g | 2.5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 5 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 1 | g | 2 | | | | | |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 19 | 4 | 0.3 | -0.25 | 3.75 | 3.6 |
| Blanche Rock Salt | NaCl | | -15 | 5 | 3 | g | 3 | | | | | |

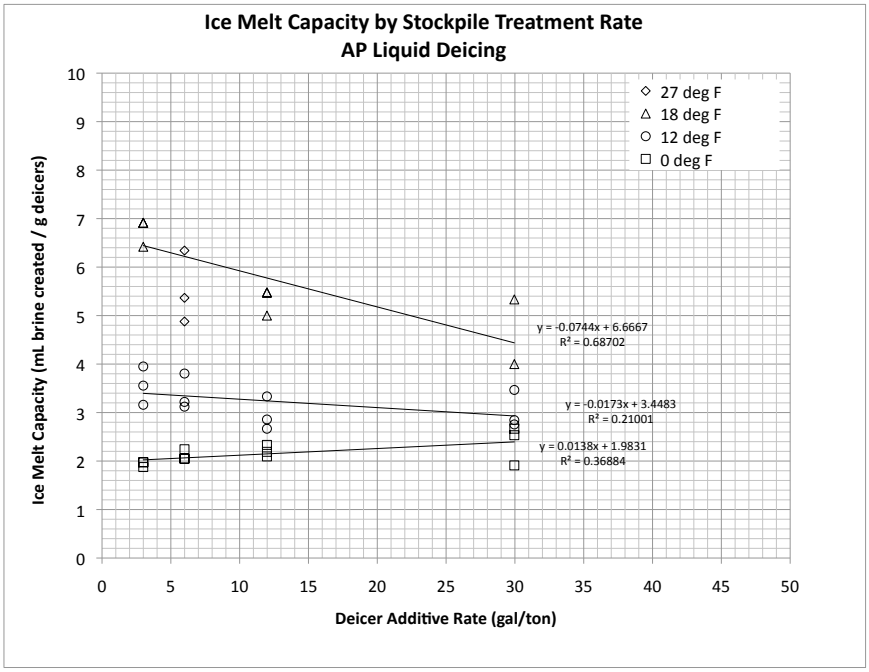


# Appendix C – Stockpile Treatment Analysis

Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

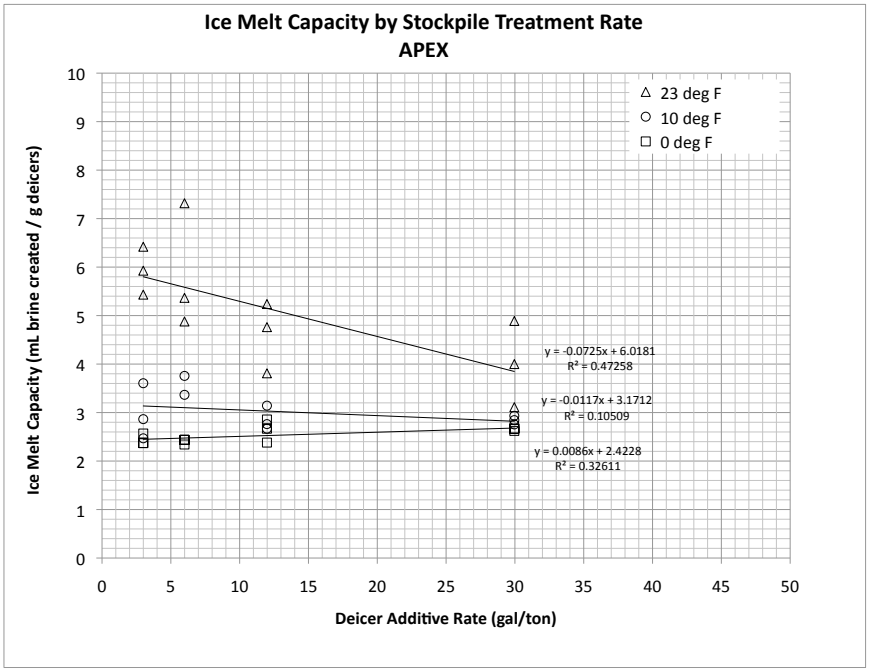
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 4 | 2.0 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 4 | 2.0 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 3.8 | 1.9 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 4.6 | 2.2 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 4.2 | 2.0 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 4.2 | 2.0 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 4.6 | 2.2 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 4.9 | 2.3 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 4.4 | 2.1 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 4.3 | 1.9 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 5.7 | 2.5 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 6 | 2.7 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 25 | -11 | 12 | 3.0 | 7.2 | 3.6 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 25 | -11 | 12 | 3.0 | 6.4 | 3.2 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 25 | -11 | 12 | 3.0 | 8 | 4.0 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 50 | -11 | 12 | 6.0 | 7.8 | 3.8 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 50 | -11 | 12 | 6.0 | 6.4 | 3.1 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 50 | -11 | 12 | 6.0 | 6.6 | 3.2 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 5.6 | 2.7 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 6 | 2.9 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 7 | 3.3 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 7.8 | 3.5 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 6.2 | 2.8 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 6.4 | 2.8 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 14 | 6.9 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 14 | 6.9 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 13 | 6.4 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 100 | -8 | 18 | 12.0 | 11.5 | 5.5 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 100 | -8 | 18 | 12.0 | 11.5 | 5.5 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 100 | -8 | 18 | 12.0 | 10.5 | 5.0 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 250 | -8 | 18 | 30.0 | 9 | 4.0 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 250 | -8 | 18 | 30.0 | 12 | 5.3 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 50 | -3 | 27 | 6.0 | 13 | 6.3 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 50 | -3 | 27 | 6.0 | 10 | 4.9 |
| AP Liquid DeIcing | Blanche Rock Salt | 2.0 | 50 | -3 | 27 | 6.0 | 11 | 5.4 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

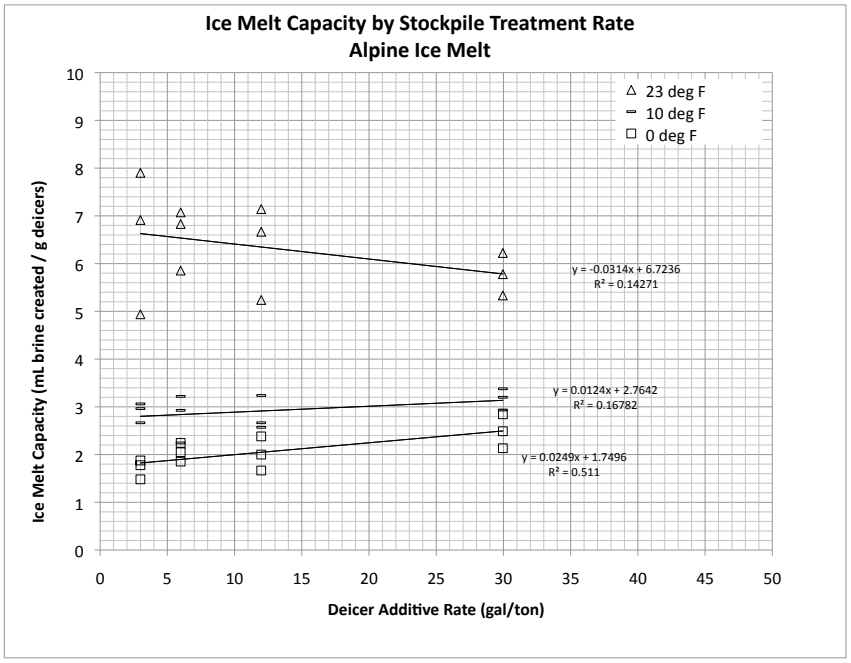
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| APEX | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 4.8 | 2.4 |
| APEX | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 4.8 | 2.4 |
| APEX | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 5.2 | 2.6 |
| APEX | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 5 | 2.4 |
| APEX | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 4.8 | 2.3 |
| APEX | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 5 | 2.4 |
| APEX | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 5.6 | 2.7 |
| APEX | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 5 | 2.4 |
| APEX | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 6 | 2.9 |
| APEX | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 6 | 2.7 |
| APEX | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 6 | 2.7 |
| APEX | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 5.9 | 2.6 |
| APEX | Blanche Rock Salt | 2.0 | 25 | -12 | 10 | 3.0 | 5.8 | 2.9 |
| APEX | Blanche Rock Salt | 2.0 | 25 | -12 | 10 | 3.0 | 5 | 2.5 |
| APEX | Blanche Rock Salt | 2.0 | 25 | -12 | 10 | 3.0 | 7.3 | 3.6 |
| APEX | Blanche Rock Salt | 2.0 | 50 | -12 | 10 | 6.0 | 6.9 | 3.4 |
| APEX | Blanche Rock Salt | 2.0 | 50 | -12 | 10 | 6.0 | 7.7 | 3.8 |
| APEX | Blanche Rock Salt | 2.0 | 100 | -12 | 10 | 12.0 | 5.8 | 2.8 |
| APEX | Blanche Rock Salt | 2.0 | 100 | -12 | 10 | 12.0 | 5.6 | 2.7 |
| APEX | Blanche Rock Salt | 2.0 | 100 | -12 | 10 | 12.0 | 6.6 | 3.1 |
| APEX | Blanche Rock Salt | 2.0 | 250 | -12 | 10 | 30.0 | 6.2 | 2.8 |
| APEX | Blanche Rock Salt | 2.0 | 250 | -12 | 10 | 30.0 | 6.4 | 2.8 |
| APEX | Blanche Rock Salt | 2.0 | 250 | -12 | 10 | 30.0 | 6.6 | 2.9 |
| APEX | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 12 | 5.9 |
| APEX | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 13 | 6.4 |
| APEX | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 11 | 5.4 |
| APEX | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 15 | 7.3 |
| APEX | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 10 | 4.9 |
| APEX | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 11 | 5.4 |
| APEX | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 10 | 4.8 |
| APEX | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 11 | 5.2 |
| APEX | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 8 | 3.8 |
| APEX | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 11 | 4.9 |
| APEX | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 9 | 4.0 |
| APEX | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 7 | 3.1 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

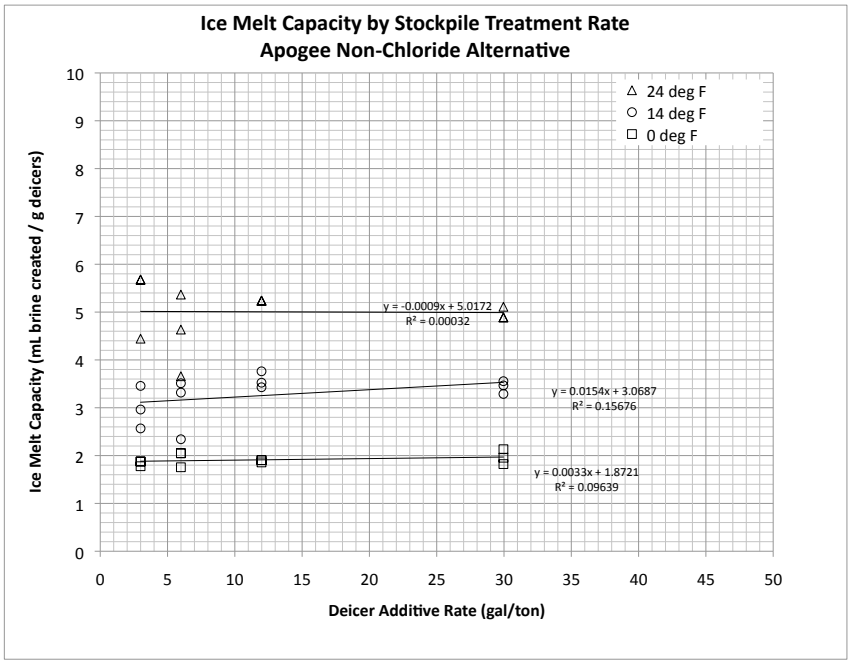
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 3.8 | 1.9 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 3.6 | 1.8 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 3 | 1.5 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 3.8 | 1.9 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 4.2 | 2.0 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 4.6 | 2.2 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 4.2 | 2.0 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 5 | 2.4 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 3.5 | 1.7 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 6.4 | 2.8 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 5.6 | 2.5 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 4.8 | 2.1 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 25 | -12 | 10 | 3.0 | 6 | 3.0 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 25 | -12 | 10 | 3.0 | 6.2 | 3.1 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 25 | -12 | 10 | 3.0 | 5.4 | 2.7 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 50 | -12 | 10 | 6.0 | 6 | 2.9 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 50 | -12 | 10 | 6.0 | 4.6 | 2.2 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 50 | -12 | 10 | 6.0 | 6.6 | 3.2 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 100 | -12 | 10 | 12.0 | 5.6 | 2.7 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 100 | -12 | 10 | 12.0 | 6.8 | 3.2 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 100 | -12 | 10 | 12.0 | 5.4 | 2.6 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 250 | -12 | 10 | 30.0 | 6.6 | 2.9 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 250 | -12 | 10 | 30.0 | 7.2 | 3.2 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 250 | -12 | 10 | 30.0 | 7.6 | 3.4 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 16 | 7.9 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 10 | 4.9 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 14 | 6.9 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 14.5 | 7.1 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 14 | 6.8 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 12 | 5.9 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 15 | 7.1 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 14 | 6.7 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 11 | 5.2 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 14 | 6.2 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 13 | 5.8 |
| Alpine Ice Melt | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 12 | 5.3 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

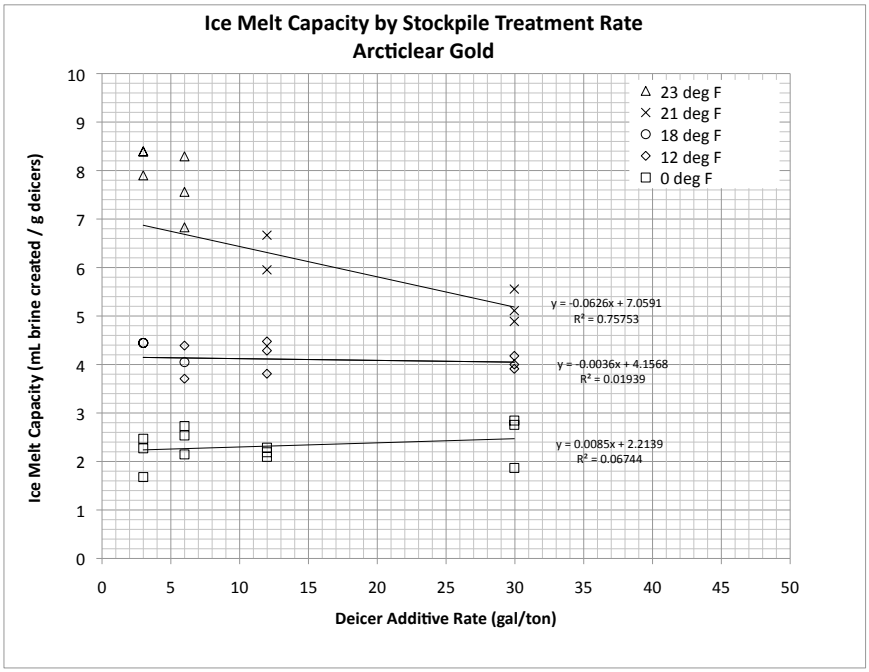
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 25 | -17.7 | 0 | 3.0 | 3.6 | 1.8 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 25 | -17.7 | 0 | 3.0 | 3.8 | 1.9 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 25 | -17.7 | 0 | 3.0 | 3.8 | 1.9 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 50 | -17.7 | 0 | 6.0 | 3.6 | 1.8 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 50 | -17.7 | 0 | 6.0 | 4.2 | 2.0 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 50 | -17.7 | 0 | 6.0 | 4.2 | 2.0 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 100 | -17.7 | 0 | 12.0 | 4 | 1.9 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 100 | -17.7 | 0 | 12.0 | 3.9 | 1.9 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 100 | -17.7 | 0 | 12.0 | 4 | 1.9 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 250 | -17.7 | 0 | 30.0 | 4.1 | 1.8 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 250 | -17.7 | 0 | 30.0 | 4.4 | 2.0 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 250 | -17.7 | 0 | 30.0 | 4.8 | 2.1 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 25 | -10 | 14 | 3.0 | 6 | 3.0 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 25 | -10 | 14 | 3.0 | 5.2 | 2.6 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 25 | -10 | 14 | 3.0 | 7 | 3.5 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 50 | -10 | 14 | 6.0 | 4.8 | 2.3 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 50 | -10 | 14 | 6.0 | 6.8 | 3.3 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 50 | -10 | 14 | 6.0 | 7.2 | 3.5 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 100 | -10 | 14 | 12.0 | 7.4 | 3.5 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 100 | -10 | 14 | 12.0 | 7.9 | 3.8 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 100 | -10 | 14 | 12.0 | 7.2 | 3.4 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 250 | -10 | 14 | 30.0 | 7.4 | 3.3 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 250 | -10 | 14 | 30.0 | 8 | 3.6 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 250 | -10 | 14 | 30.0 | 7.8 | 3.5 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 25 | -4.5 | 24 | 3.0 | 11.5 | 5.7 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 25 | -4.5 | 24 | 3.0 | 9 | 4.4 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 25 | -4.5 | 24 | 3.0 | 11.5 | 5.7 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 50 | -4.5 | 24 | 6.0 | 11 | 5.4 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 50 | -4.5 | 24 | 6.0 | 7.5 | 3.7 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 50 | -4.5 | 24 | 6.0 | 9.5 | 4.6 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 100 | -4.5 | 24 | 12.0 | 11 | 5.2 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 100 | -4.5 | 24 | 12.0 | 11 | 5.2 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 100 | -4.5 | 24 | 12.0 | 11 | 5.2 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 250 | -4.5 | 24 | 30.0 | 11.5 | 5.1 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 250 | -4.5 | 24 | 30.0 | 11 | 4.9 |
| Apogee Non-Choride Alt | Blanche Rock Salt | 2.0 | 250 | -4.5 | 24 | 30.0 | 11 | 4.9 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

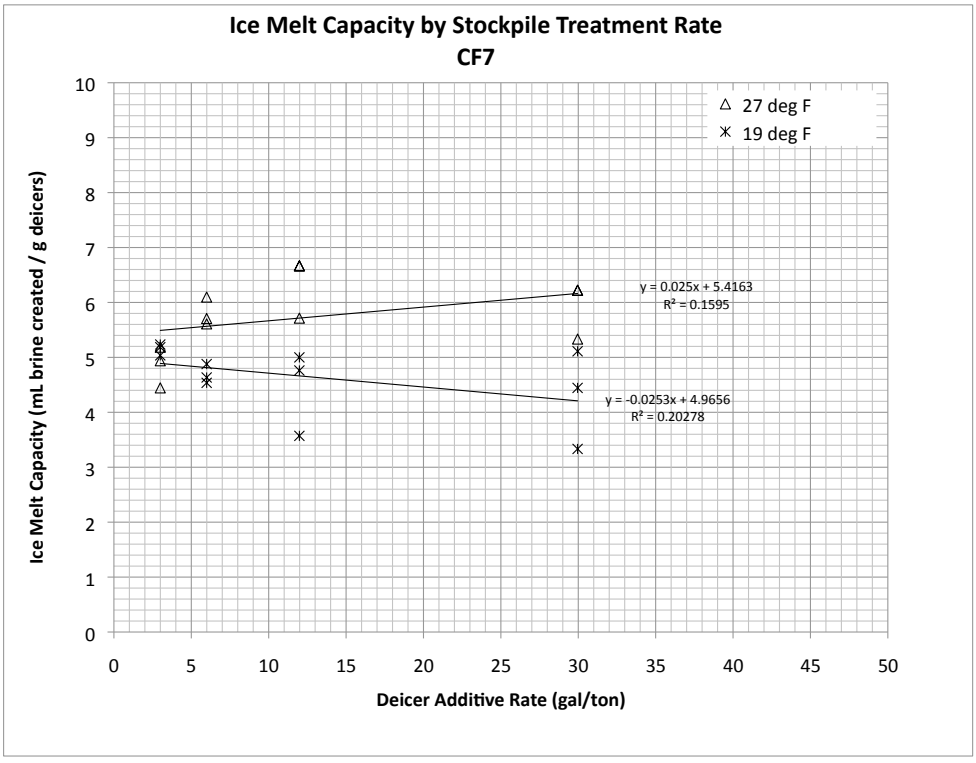
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 3.4 | 1.7 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 4.6 | 2.3 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 5 | 2.5 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 4.4 | 2.1 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 5.2 | 2.5 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 5.6 | 2.7 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 4.8 | 2.3 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 4.4 | 2.1 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 4.6 | 2.2 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 4.2 | 1.9 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 6.2 | 2.8 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 6.4 | 2.8 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 50 | -11 | 12 | 6.0 | 7.6 | 3.7 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 50 | -11 | 12 | 6.0 | 9 | 4.4 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 9 | 4.3 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 8 | 3.8 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 9.4 | 4.5 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 8.8 | 3.9 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 9.4 | 4.2 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 9 | 4.0 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 9 | 4.4 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 9 | 4.4 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 9 | 4.4 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 50 | -8 | 18 | 6.0 | 8.3 | 4.0 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 100 | -6 | 21 | 12.0 | 14 | 6.7 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 100 | -6 | 21 | 12.0 | 12.5 | 6.0 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 250 | -6 | 21 | 30.0 | 11 | 4.9 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 250 | -6 | 21 | 30.0 | 12.5 | 5.6 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 250 | -6 | 21 | 30.0 | 11.5 | 5.1 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 17 | 8.4 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 16 | 7.9 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 17 | 8.4 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 17 | 8.3 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 14 | 6.8 |
| Articlear Gold Additive | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 15.5 | 7.6 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

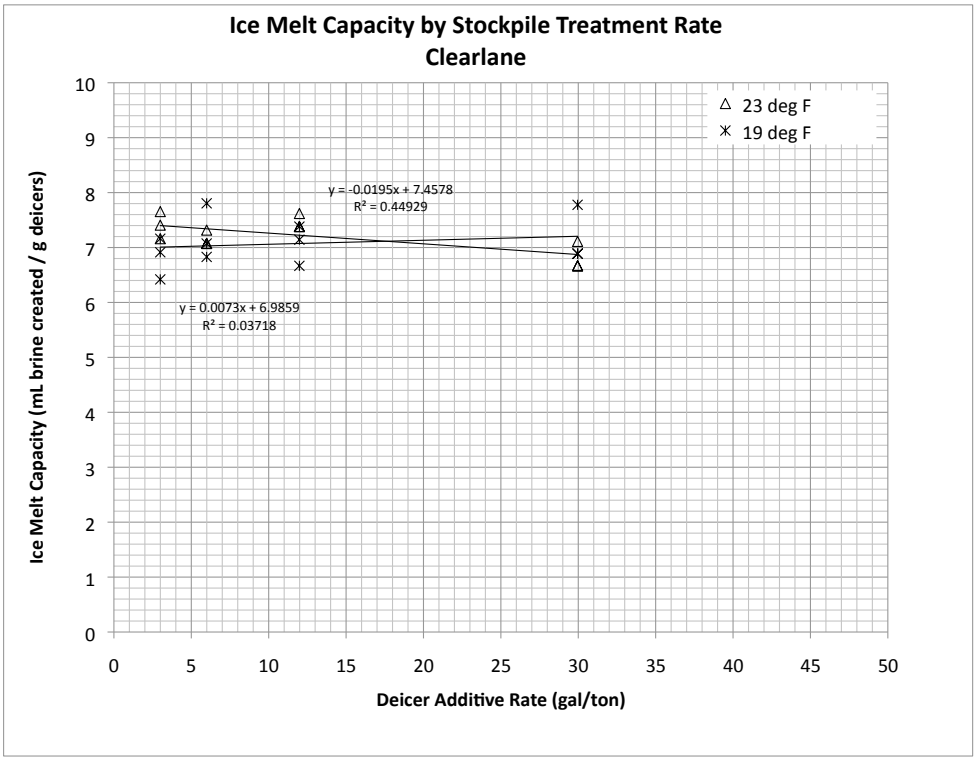
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| CF 7 | Blanche Rock Salt | 2.0 | 250 | -3 | 27 | 30.0 | 12 | 5.3 |
| CF 7 | Blanche Rock Salt | 2.0 | 250 | -3 | 27 | 30.0 | 14 | 6.2 |
| CF 7 | Blanche Rock Salt | 2.0 | 250 | -3 | 27 | 30.0 | 14 | 6.2 |
| CF 7 | Blanche Rock Salt | 2.0 | 100 | -3 | 27 | 12.0 | 12 | 5.7 |
| CF 7 | Blanche Rock Salt | 2.0 | 100 | -3 | 27 | 12.0 | 14 | 6.7 |
| CF 7 | Blanche Rock Salt | 2.0 | 100 | -3 | 27 | 12.0 | 14 | 6.7 |
| CF 7 | Blanche Rock Salt | 2.0 | 50 | -3 | 27 | 6.0 | 11.7 | 5.7 |
| CF 7 | Blanche Rock Salt | 2.0 | 50 | -3 | 27 | 6.0 | 11.5 | 5.6 |
| CF 7 | Blanche Rock Salt | 2.0 | 50 | -3 | 27 | 6.0 | 12.5 | 6.1 |
| CF 7 | Blanche Rock Salt | 2.0 | 25 | -3 | 27 | 3.0 | 10.5 | 5.2 |
| CF 7 | Blanche Rock Salt | 2.0 | 25 | -3 | 27 | 3.0 | 10 | 4.9 |
| CF 7 | Blanche Rock Salt | 2.0 | 25 | -3 | 27 | 3.0 | 9 | 4.4 |
| CF 7 | Blanche Rock Salt | 2.0 | 250 | -7 | 19 | 30.0 | 7.5 | 3.3 |
| CF 7 | Blanche Rock Salt | 2.0 | 250 | -7 | 19 | 30.0 | 11.5 | 5.1 |
| CF 7 | Blanche Rock Salt | 2.0 | 250 | -7 | 19 | 30.0 | 10 | 4.4 |
| CF 7 | Blanche Rock Salt | 2.0 | 100 | -7 | 19 | 12.0 | 10.5 | 5.0 |
| CF 7 | Blanche Rock Salt | 2.0 | 100 | -7 | 19 | 12.0 | 7.5 | 3.6 |
| CF 7 | Blanche Rock Salt | 2.0 | 100 | -7 | 19 | 12.0 | 10 | 4.8 |
| CF 7 | Blanche Rock Salt | 2.0 | 50 | -7 | 19 | 6.0 | 9.5 | 4.6 |
| CF 7 | Blanche Rock Salt | 2.0 | 50 | -7 | 19 | 6.0 | 9.3 | 4.5 |
| CF 7 | Blanche Rock Salt | 2.0 | 50 | -7 | 19 | 6.0 | 10 | 4.9 |
| CF 7 | Blanche Rock Salt | 2.0 | 25 | -7 | 19 | 3.0 | 10.5 | 5.2 |
| CF 7 | Blanche Rock Salt | 2.0 | 25 | -7 | 19 | 3.0 | 10.2 | 5.0 |
| CF 7 | Blanche Rock Salt | 2.0 | 25 | -7 | 19 | 3.0 | 10.6 | 5.2 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

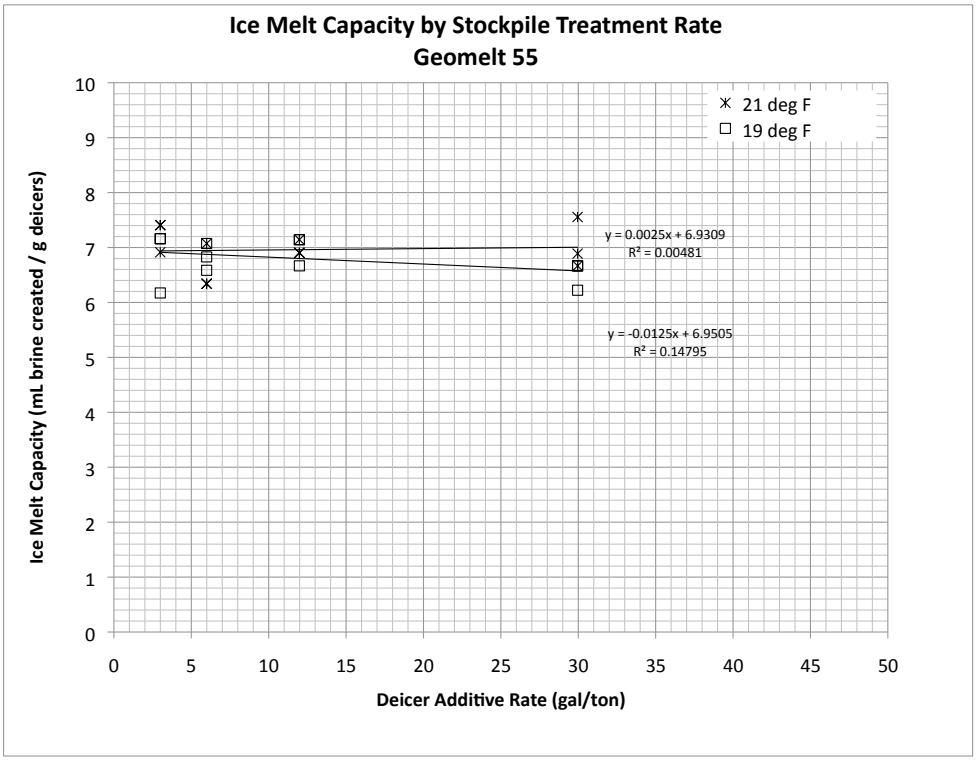
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| Clearlane | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 15.5 | 7.7 |
| Clearlane | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 15 | 7.4 |
| Clearlane | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 14.5 | 7.2 |
| Clearlane | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 14.5 | 7.1 |
| Clearlane | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 14.5 | 7.1 |
| Clearlane | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 15 | 7.3 |
| Clearlane | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 15.5 | 7.4 |
| Clearlane | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 16 | 7.6 |
| Clearlane | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 15.5 | 7.4 |
| Clearlane | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 15 | 6.7 |
| Clearlane | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 15 | 6.7 |
| Clearlane | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 16 | 7.1 |
| Clearlane | Blanche Rock Salt | 2.0 | 25 | -7 | 19 | 3.0 | 14 | 6.9 |
| Clearlane | Blanche Rock Salt | 2.0 | 25 | -7 | 19 | 3.0 | 14.5 | 7.2 |
| Clearlane | Blanche Rock Salt | 2.0 | 25 | -7 | 19 | 3.0 | 13 | 6.4 |
| Clearlane | Blanche Rock Salt | 2.0 | 50 | -7 | 19 | 6.0 | 14.5 | 7.1 |
| Clearlane | Blanche Rock Salt | 2.0 | 50 | -7 | 19 | 6.0 | 14 | 6.8 |
| Clearlane | Blanche Rock Salt | 2.0 | 50 | -7 | 19 | 6.0 | 16 | 7.8 |
| Clearlane | Blanche Rock Salt | 2.0 | 100 | -7 | 19 | 12.0 | 15.5 | 7.4 |
| Clearlane | Blanche Rock Salt | 2.0 | 100 | -7 | 19 | 12.0 | 14 | 6.7 |
| Clearlane | Blanche Rock Salt | 2.0 | 100 | -7 | 19 | 12.0 | 15 | 7.1 |
| Clearlane | Blanche Rock Salt | 2.0 | 250 | -7 | 19 | 30.0 | 15.5 | 6.9 |
| Clearlane | Blanche Rock Salt | 2.0 | 250 | -7 | 19 | 30.0 | 17.5 | 7.8 |
| Clearlane | Blanche Rock Salt | 2.0 | 250 | -7 | 19 | 30.0 | 15.5 | 6.9 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

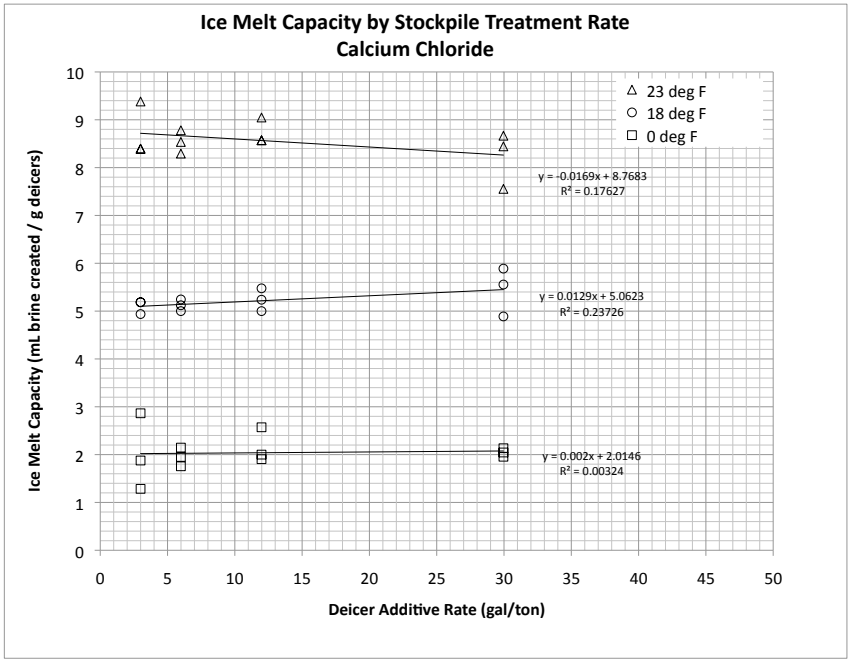
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| Geomelt 55 | Blanche Rock Salt | 2.0 | 25 | -6 | 21 | 3.0 | 15 | 7.4 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 25 | -6 | 21 | 3.0 | 15 | 7.4 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 25 | -6 | 21 | 3.0 | 14 | 6.9 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 50 | -6 | 21 | 6.0 | 13 | 6.3 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 50 | -6 | 21 | 6.0 | 14.5 | 7.1 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 50 | -6 | 21 | 6.0 | 13 | 6.3 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 100 | -6 | 21 | 12.0 | 15 | 7.1 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 100 | -6 | 21 | 12.0 | 14.5 | 6.9 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 100 | -6 | 21 | 12.0 | 14.5 | 6.9 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 250 | -6 | 21 | 30.0 | 17 | 7.6 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 250 | -6 | 21 | 30.0 | 15.5 | 6.9 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 250 | -6 | 21 | 30.0 | 15 | 6.7 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 25 | -7 | 19 | 3.0 | 12.5 | 6.2 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 25 | -7 | 19 | 3.0 | 14.5 | 7.2 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 25 | -7 | 19 | 3.0 | 14.5 | 7.2 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 50 | -7 | 19 | 6.0 | 13.5 | 6.6 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 50 | -7 | 19 | 6.0 | 14.5 | 7.1 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 50 | -7 | 19 | 6.0 | 14 | 6.8 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 100 | -7 | 19 | 12.0 | 15 | 7.1 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 100 | -7 | 19 | 12.0 | 15 | 7.1 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 100 | -7 | 19 | 12.0 | 14 | 6.7 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 250 | -7 | 19 | 30.0 | 14 | 6.2 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 250 | -7 | 19 | 30.0 | 15 | 6.7 |
| Geomelt 55 | Blanche Rock Salt | 2.0 | 250 | -7 | 19 | 30.0 | 15 | 6.7 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

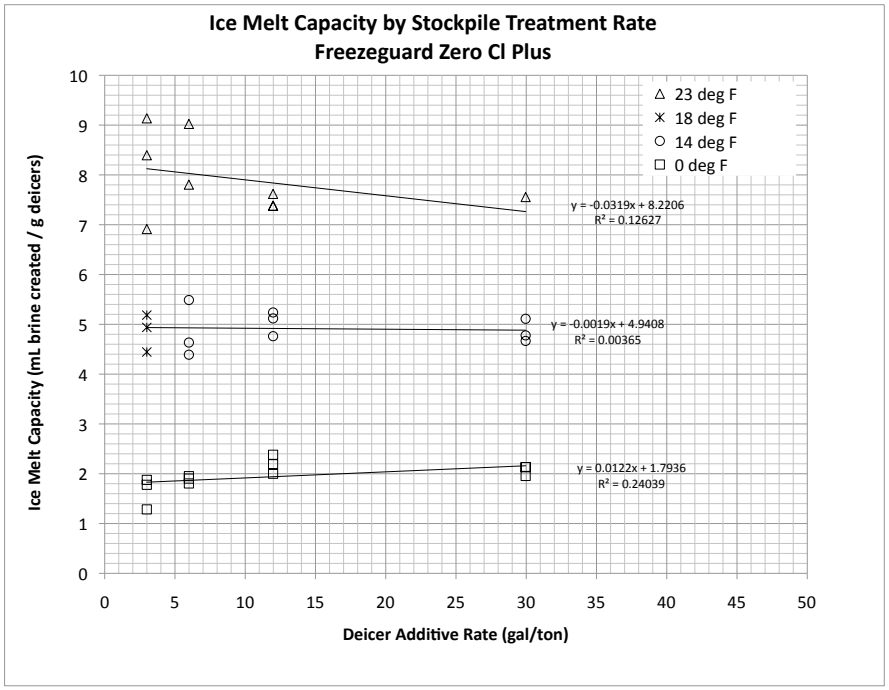
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| Calcium Chloride | Blanche Rock Salt | 2.0 | 25 | -17.7 | 0 | 3.0 | 5.8 | 2.9 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 25 | -17.7 | 0 | 3.0 | 2.6 | 1.3 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 25 | -17.7 | 0 | 3.0 | 3.8 | 1.9 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 50 | -17.7 | 0 | 6.0 | 4.4 | 2.1 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 50 | -17.7 | 0 | 6.0 | 4 | 2.0 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 50 | -17.7 | 0 | 6.0 | 3.6 | 1.8 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 100 | -17.7 | 0 | 12.0 | 4.2 | 2.0 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 100 | -17.7 | 0 | 12.0 | 5.4 | 2.6 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 100 | -17.7 | 0 | 12.0 | 4 | 1.9 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 250 | -17.7 | 0 | 30.0 | 4.6 | 2.0 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 250 | -17.7 | 0 | 30.0 | 4.4 | 2.0 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 250 | -17.7 | 0 | 30.0 | 4.8 | 2.1 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 10 | 4.9 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 10.5 | 5.2 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 10.5 | 5.2 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 50 | -8 | 18 | 6.0 | 10.75 | 5.2 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 50 | -8 | 18 | 6.0 | 10.5 | 5.1 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 50 | -8 | 18 | 6.0 | 10.25 | 5.0 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 100 | -8 | 18 | 12.0 | 11.5 | 5.5 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 100 | -8 | 18 | 12.0 | 10.5 | 5.0 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 100 | -8 | 18 | 12.0 | 11 | 5.2 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 250 | -8 | 18 | 30.0 | 12.5 | 5.6 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 250 | -8 | 18 | 30.0 | 11 | 4.9 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 250 | -8 | 18 | 30.0 | 13.25 | 5.9 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 19 | 9.4 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 17 | 8.4 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 17 | 8.4 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 17.5 | 8.5 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 18 | 8.8 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 17 | 8.3 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 18 | 8.6 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 19 | 9.0 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 18 | 8.6 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 19.5 | 8.7 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 19 | 8.4 |
| Calcium Chloride | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 17 | 7.6 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

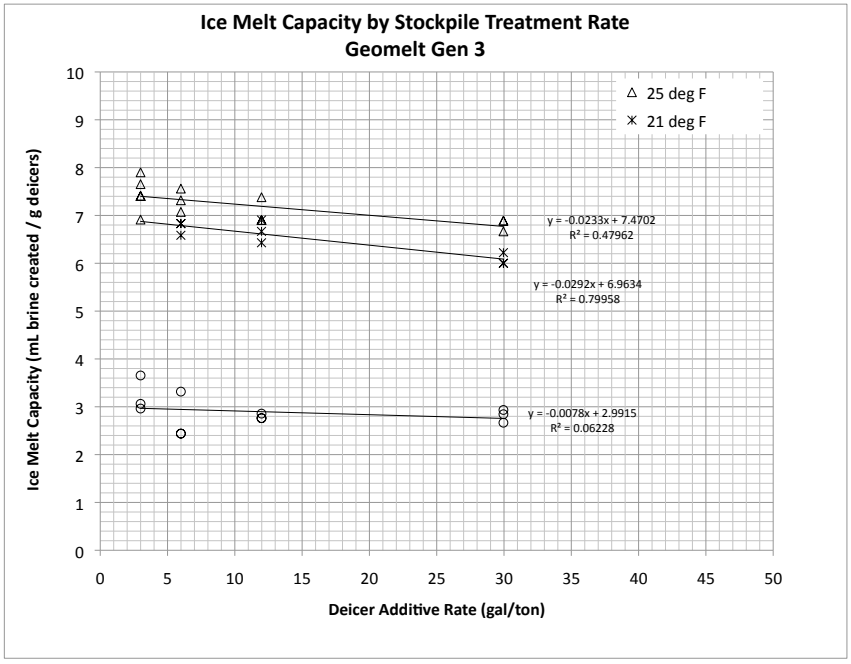
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 25 | -17.7 | 0 | 3.0 | 3.6 | 1.8 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 25 | -17.7 | 0 | 3.0 | 3.8 | 1.9 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 25 | -17.7 | 0 | 3.0 | 2.6 | 1.3 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 50 | -17.7 | 0 | 6.0 | 3.7 | 1.8 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 50 | -17.7 | 0 | 6.0 | 3.9 | 1.9 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 50 | -17.7 | 0 | 6.0 | 4 | 2.0 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 100 | -17.7 | 0 | 12.0 | 5 | 2.4 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 100 | -17.7 | 0 | 12.0 | 4.6 | 2.2 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 100 | -17.7 | 0 | 12.0 | 4.2 | 2.0 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 250 | -17.7 | 0 | 30.0 | 4.8 | 2.1 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 250 | -17.7 | 0 | 30.0 | 4.8 | 2.1 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 250 | -17.7 | 0 | 30.0 | 4.4 | 2.0 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 50 | -10 | 14 | 6.0 | 9 | 4.4 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 50 | -10 | 14 | 6.0 | 9.5 | 4.6 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 50 | -10 | 14 | 6.0 | 11.25 | 5.5 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 100 | -10 | 14 | 12.0 | 11 | 5.2 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 100 | -10 | 14 | 12.0 | 10.75 | 5.1 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 100 | -10 | 14 | 12.0 | 10 | 4.8 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 250 | -10 | 14 | 30.0 | 11.5 | 5.1 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 250 | -10 | 14 | 30.0 | 10.75 | 4.8 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 250 | -10 | 14 | 30.0 | 10.5 | 4.7 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 9 | 4.4 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 10.5 | 5.2 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 10 | 4.9 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 18.5 | 9.1 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 14 | 6.9 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 17 | 8.4 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 16 | 7.8 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 18.5 | 9.0 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 15.5 | 7.4 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 15.5 | 7.4 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 16 | 7.6 |
| Freezeguard Zero Cl Plus | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 17 | 7.6 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

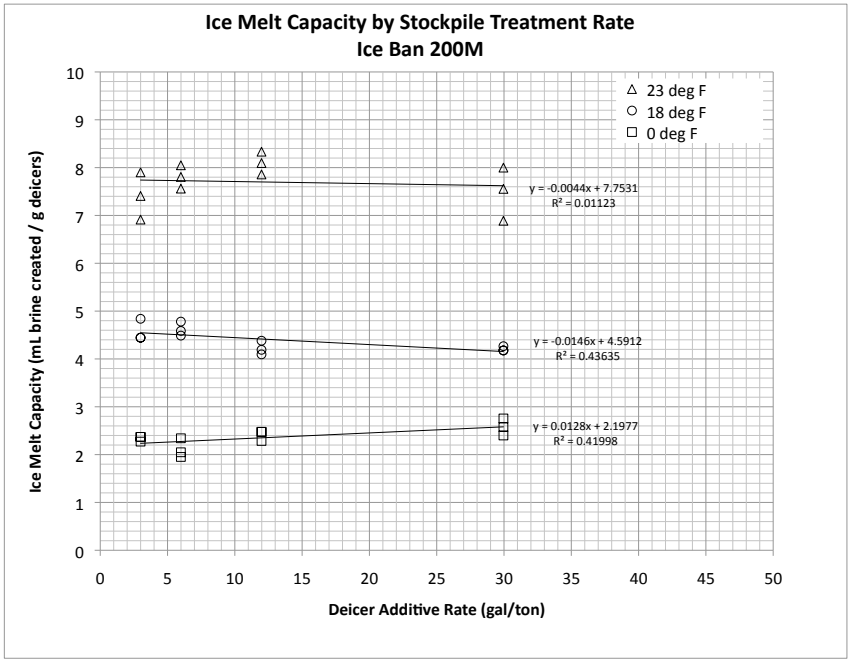
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 25 | -4 | 25 | 3.0 | 16 | 7.9 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 25 | -4 | 25 | 3.0 | 15 | 7.4 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 25 | -4 | 25 | 3.0 | 15 | 7.4 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 25 | -4 | 25 | 3.0 | 14 | 6.9 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 25 | -4 | 25 | 3.0 | 15 | 7.4 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 25 | -4 | 25 | 3.0 | 15.5 | 7.7 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 50 | -4 | 25 | 6.0 | 14.5 | 7.1 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 50 | -4 | 25 | 6.0 | 15 | 7.3 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 50 | -4 | 25 | 6.0 | 15.5 | 7.6 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 100 | -4 | 25 | 12.0 | 14.5 | 6.9 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 100 | -4 | 25 | 12.0 | 14.5 | 6.9 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 100 | -4 | 25 | 12.0 | 15.5 | 7.4 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 250 | -4 | 25 | 30.0 | 15 | 6.7 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 250 | -4 | 25 | 30.0 | 15.5 | 6.9 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 250 | -4 | 25 | 30.0 | 15.5 | 6.9 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 50 | -6 | 21 | 6.0 | 14 | 6.8 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 50 | -6 | 21 | 6.0 | 14 | 6.8 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 50 | -6 | 21 | 6.0 | 13.5 | 6.6 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 100 | -6 | 21 | 12.0 | 14.5 | 6.9 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 100 | -6 | 21 | 12.0 | 14 | 6.7 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 100 | -6 | 21 | 12.0 | 13.5 | 6.4 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 250 | -6 | 21 | 30.0 | 13.5 | 6.0 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 250 | -6 | 21 | 30.0 | 13.5 | 6.0 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 250 | -6 | 21 | 30.0 | 14 | 6.2 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 25 | -15 | 5 | 3.0 | 6 | 3.0 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 25 | -15 | 5 | 3.0 | 6.2 | 3.1 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 25 | -15 | 5 | 3.0 | 7.4 | 3.7 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 50 | -15 | 5 | 6.0 | 5 | 2.4 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 50 | -15 | 5 | 6.0 | 5 | 2.4 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 50 | -15 | 5 | 6.0 | 6.8 | 3.3 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 100 | -15 | 5 | 12.0 | 5.8 | 2.8 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 100 | -15 | 5 | 12.0 | 6 | 2.9 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 100 | -15 | 5 | 12.0 | 5.8 | 2.8 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 250 | -15 | 5 | 30.0 | 6 | 2.7 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 250 | -15 | 5 | 30.0 | 6.4 | 2.8 |
| Geomelt Gen 3 | Blanche Rock Salt | 2.0 | 250 | -15 | 5 | 30.0 | 6.6 | 2.9 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

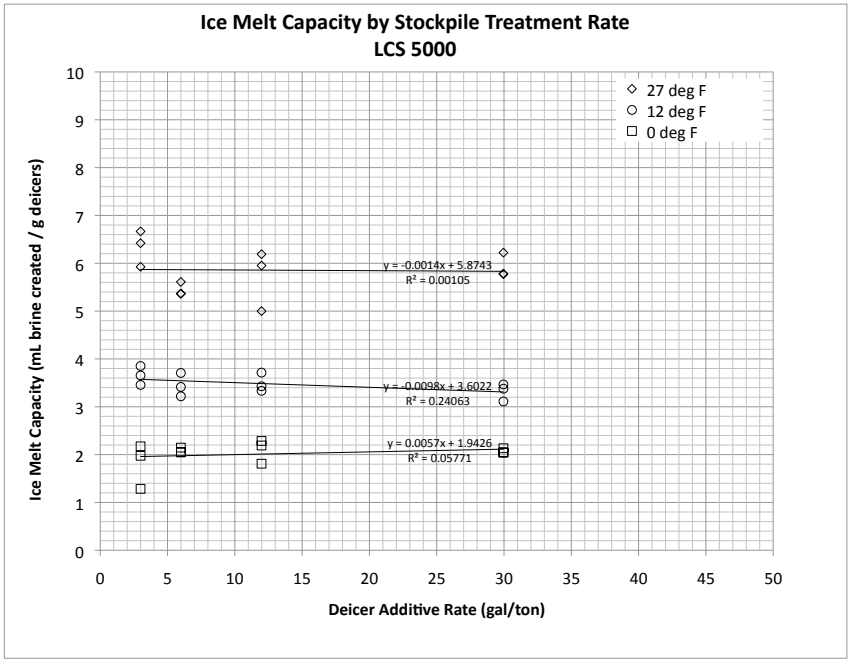
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 25 | -17.9 | 0 | 3.0 | 4.6 | 2.3 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 25 | -17.9 | 0 | 3.0 | 4.8 | 2.4 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 25 | -17.9 | 0 | 3.0 | 4.8 | 2.4 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 50 | -17.9 | 0 | 6.0 | 4.2 | 2.0 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 50 | -17.9 | 0 | 6.0 | 4.8 | 2.3 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 50 | -17.9 | 0 | 6.0 | 4 | 2.0 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 100 | -17.9 | 0 | 12.0 | 5.2 | 2.5 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 100 | -17.9 | 0 | 12.0 | 5.2 | 2.5 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 100 | -17.9 | 0 | 12.0 | 4.8 | 2.3 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 250 | -17.9 | 0 | 30.0 | 5.4 | 2.4 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 250 | -17.9 | 0 | 30.0 | 6.2 | 2.8 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 250 | -17.9 | 0 | 30.0 | 5.8 | 2.6 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 9 | 4.4 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 9 | 4.4 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 9.8 | 4.8 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 50 | -8 | 18 | 6.0 | 9.2 | 4.5 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 50 | -8 | 18 | 6.0 | 9.4 | 4.6 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 50 | -8 | 18 | 6.0 | 9.8 | 4.8 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 100 | -8 | 18 | 12.0 | 8.8 | 4.2 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 100 | -8 | 18 | 12.0 | 9.2 | 4.4 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 100 | -8 | 18 | 12.0 | 8.6 | 4.1 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 250 | -8 | 18 | 30.0 | 9.6 | 4.3 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 250 | -8 | 18 | 30.0 | 9.4 | 4.2 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 250 | -8 | 18 | 30.0 | 9.4 | 4.2 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 14 | 6.9 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 15 | 7.4 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 25 | -5 | 23 | 3.0 | 16 | 7.9 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 15.5 | 7.6 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 16.5 | 8.0 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 50 | -5 | 23 | 6.0 | 16 | 7.8 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 16.5 | 7.9 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 17 | 8.1 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 100 | -5 | 23 | 12.0 | 17.5 | 8.3 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 15.5 | 6.9 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 17 | 7.6 |
| Ice Ban 200M | Blanche Rock Salt | 2.0 | 250 | -5 | 23 | 30.0 | 18 | 8.0 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

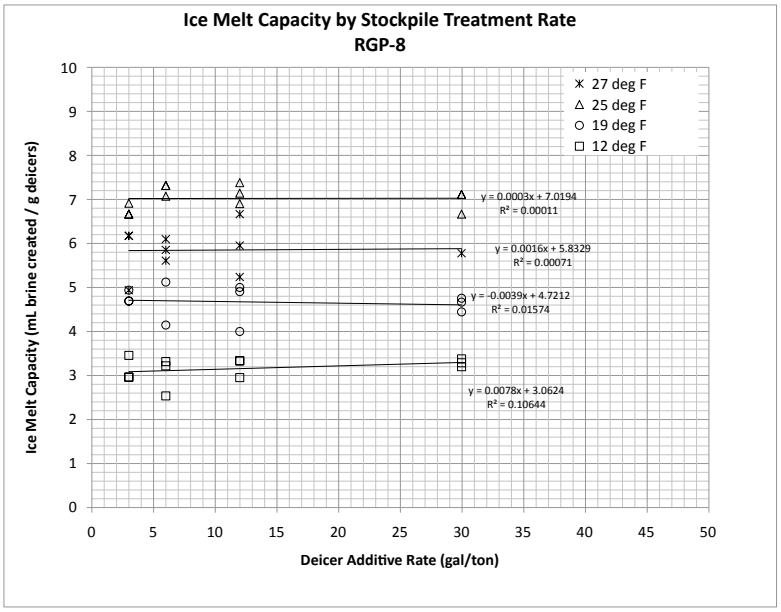
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| LCS 5000 | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 4.4 | 2.2 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 4 | 2.0 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 2.6 | 1.3 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 4.4 | 2.1 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 4.2 | 2.0 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 4.2 | 2.0 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 4.8 | 2.3 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 4.6 | 2.2 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 3.8 | 1.8 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 4.6 | 2.0 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 4.8 | 2.1 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 4.6 | 2.0 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 25 | -11 | 12 | 3.0 | 7.4 | 3.7 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 25 | -11 | 12 | 3.0 | 7 | 3.5 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 25 | -11 | 12 | 3.0 | 7.8 | 3.9 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 50 | -11 | 12 | 6.0 | 7.6 | 3.7 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 50 | -11 | 12 | 6.0 | 6.6 | 3.2 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 50 | -11 | 12 | 6.0 | 7 | 3.4 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 7.8 | 3.7 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 7.2 | 3.4 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 7 | 3.3 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 7 | 3.1 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 7.8 | 3.5 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 7.6 | 3.4 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 25 | -3 | 27 | 3.0 | 12 | 5.9 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 25 | -3 | 27 | 3.0 | 13.5 | 6.7 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 25 | -3 | 27 | 3.0 | 13 | 6.4 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 50 | -3 | 27 | 6.0 | 11 | 5.4 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 50 | -3 | 27 | 6.0 | 11.5 | 5.6 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 50 | -3 | 27 | 6.0 | 11 | 5.4 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 100 | -3 | 27 | 12.0 | 13 | 6.2 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 100 | -3 | 27 | 12.0 | 10.5 | 5.0 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 100 | -3 | 27 | 12.0 | 12.5 | 6.0 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 250 | -3 | 27 | 30.0 | 14 | 6.2 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 250 | -3 | 27 | 30.0 | 13 | 5.8 |
| LCS 5000 | Blanche Rock Salt | 2.0 | 250 | -3 | 27 | 30.0 | 13 | 5.8 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

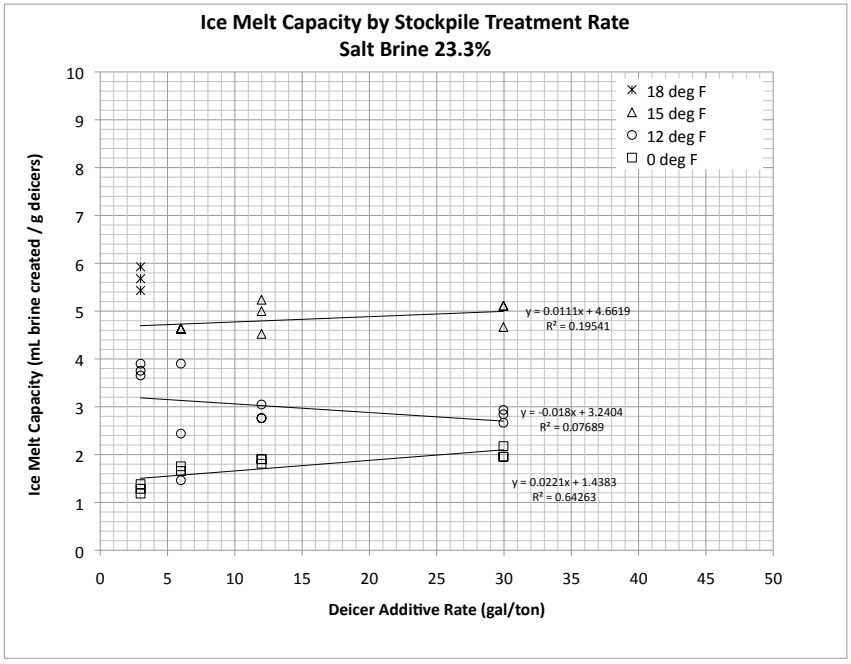
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| RGP-8 | Blanche Rock Salt | 2.0 | 250 | -3 | 27 | 30.0 | 13 | 5.8 |
| RGP-8 | Blanche Rock Salt | 2.0 | 100 | -3 | 27 | 12.0 | 11 | 5.2 |
| RGP-8 | Blanche Rock Salt | 2.0 | 100 | -3 | 27 | 12.0 | 12.5 | 6.0 |
| RGP-8 | Blanche Rock Salt | 2.0 | 100 | -3 | 27 | 12.0 | 14 | 6.7 |
| RGP-8 | Blanche Rock Salt | 2.0 | 50 | -3 | 27 | 6.0 | 11.5 | 5.6 |
| RGP-8 | Blanche Rock Salt | 2.0 | 50 | -3 | 27 | 6.0 | 12 | 5.9 |
| RGP-8 | Blanche Rock Salt | 2.0 | 50 | -3 | 27 | 6.0 | 12.5 | 6.1 |
| RGP-8 | Blanche Rock Salt | 2.0 | 25 | -3 | 27 | 3.0 | 10 | 4.9 |
| RGP-8 | Blanche Rock Salt | 2.0 | 25 | -3 | 27 | 3.0 | 12.5 | 6.2 |
| RGP-8 | Blanche Rock Salt | 2.0 | 25 | -3 | 27 | 3.0 | 12.5 | 6.2 |
| RGP-8 | Blanche Rock Salt | 2.0 | 25 | -4 | 25 | 3.0 | 13.5 | 6.7 |
| RGP-8 | Blanche Rock Salt | 2.0 | 25 | -4 | 25 | 3.0 | 13.5 | 6.7 |
| RGP-8 | Blanche Rock Salt | 2.0 | 25 | -4 | 25 | 3.0 | 14 | 6.9 |
| RGP-8 | Blanche Rock Salt | 2.0 | 50 | -4 | 25 | 6.0 | 15 | 7.3 |
| RGP-8 | Blanche Rock Salt | 2.0 | 50 | -4 | 25 | 6.0 | 15 | 7.3 |
| RGP-8 | Blanche Rock Salt | 2.0 | 50 | -4 | 25 | 6.0 | 14.5 | 7.1 |
| RGP-8 | Blanche Rock Salt | 2.0 | 100 | -4 | 25 | 12.0 | 14.5 | 6.9 |
| RGP-8 | Blanche Rock Salt | 2.0 | 100 | -4 | 25 | 12.0 | 15.5 | 7.4 |
| RGP-8 | Blanche Rock Salt | 2.0 | 100 | -4 | 25 | 12.0 | 15 | 7.1 |
| RGP-8 | Blanche Rock Salt | 2.0 | 250 | -4 | 25 | 30.0 | 16 | 7.1 |
| RGP-8 | Blanche Rock Salt | 2.0 | 250 | -4 | 25 | 30.0 | 16 | 7.1 |
| RGP-8 | Blanche Rock Salt | 2.0 | 250 | -4 | 25 | 30.0 | 15 | 6.7 |
| RGP-8 | Blanche Rock Salt | 2.0 | 250 | -7 | 19 | 30.0 | 10.7 | 4.8 |
| RGP-8 | Blanche Rock Salt | 2.0 | 250 | -7 | 19 | 30.0 | 10.5 | 4.7 |
| RGP-8 | Blanche Rock Salt | 2.0 | 250 | -7 | 19 | 30.0 | 10 | 4.4 |
| RGP-8 | Blanche Rock Salt | 2.0 | 100 | -7 | 19 | 12.0 | 8.4 | 4.0 |
| RGP-8 | Blanche Rock Salt | 2.0 | 100 | -7 | 19 | 12.0 | 10.5 | 5.0 |
| RGP-8 | Blanche Rock Salt | 2.0 | 100 | -7 | 19 | 12.0 | 10.3 | 4.9 |
| RGP-8 | Blanche Rock Salt | 2.0 | 50 | -7 | 19 | 6.0 | 10.5 | 5.1 |
| RGP-8 | Blanche Rock Salt | 2.0 | 50 | -7 | 19 | 6.0 | 8.5 | 4.1 |
| RGP-8 | Blanche Rock Salt | 2.0 | 25 | -7 | 19 | 3.0 | 10 | 4.9 |
| RGP-8 | Blanche Rock Salt | 2.0 | 25 | -7 | 19 | 3.0 | 9.5 | 4.7 |
| RGP-8 | Blanche Rock Salt | 2.0 | 25 | -7 | 19 | 3.0 | 9.5 | 4.7 |
| RGP-8 | Blanche Rock Salt | 2.0 | 25 | -11 | 12 | 3.0 | 6 | 3.0 |
| RGP-8 | Blanche Rock Salt | 2.0 | 25 | -11 | 12 | 3.0 | 7 | 3.5 |
| RGP-8 | Blanche Rock Salt | 2.0 | 25 | -11 | 12 | 3.0 | 6 | 3.0 |
| RGP-8 | Blanche Rock Salt | 2.0 | 50 | -11 | 12 | 6.0 | 6.6 | 3.2 |
| RGP-8 | Blanche Rock Salt | 2.0 | 50 | -11 | 12 | 6.0 | 6.8 | 3.3 |
| RGP-8 | Blanche Rock Salt | 2.0 | 50 | -11 | 12 | 6.0 | 5.2 | 2.5 |
| RGP-8 | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 7 | 3.3 |
| RGP-8 | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 6.2 | 3.0 |
| RGP-8 | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 7 | 3.3 |
| RGP-8 | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 7.6 | 3.4 |
| RGP-8 | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 7.2 | 3.2 |
| RGP-8 | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 7.4 | 3.3 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

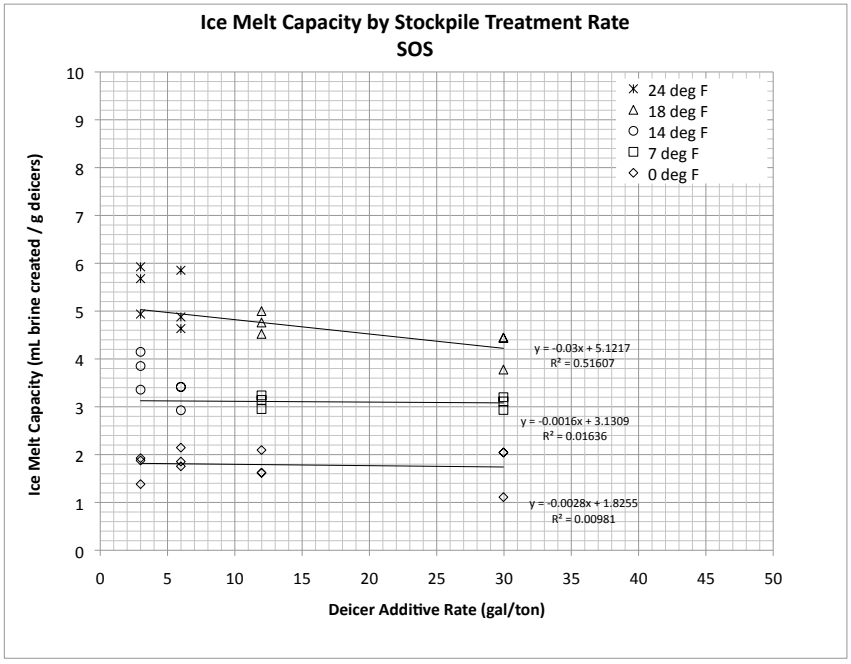
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 2.8 | 1.4 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 2.4 | 1.2 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 2.6 | 1.3 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 3.4 | 1.7 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 3.4 | 1.7 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 3.6 | 1.8 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 3.8 | 1.8 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 4 | 1.9 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 4 | 1.9 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 4.4 | 2.0 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 4.9 | 2.2 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 4.4 | 2.0 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 25 | -11 | 12 | 3.0 | 7.6 | 3.8 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 25 | -11 | 12 | 3.0 | 7.9 | 3.9 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 25 | -11 | 12 | 3.0 | 7.4 | 3.7 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 50 | -11 | 12 | 6.0 | 8 | 3.9 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 50 | -11 | 12 | 6.0 | 5 | 2.4 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 50 | -11 | 12 | 6.0 | 3 | 1.5 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 5.8 | 2.8 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 5.8 | 2.8 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 100 | -11 | 12 | 12.0 | 6.4 | 3.0 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 6.6 | 2.9 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 6 | 2.7 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 250 | -11 | 12 | 30.0 | 6.4 | 2.8 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 50 | -9.5 | 15 | 6.0 | 9.5 | 4.6 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 50 | -9.5 | 15 | 6.0 | 9.5 | 4.6 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 50 | -9.5 | 15 | 6.0 | 9.5 | 4.6 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 100 | -9.5 | 15 | 12.0 | 9.5 | 4.5 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 100 | -9.5 | 15 | 12.0 | 10.5 | 5.0 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 100 | -9.5 | 15 | 12.0 | 11 | 5.2 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 250 | -9.5 | 15 | 30.0 | 11.5 | 5.1 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 250 | -9.5 | 15 | 30.0 | 11.5 | 5.1 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 250 | -9.5 | 15 | 30.0 | 10.5 | 4.7 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 11.5 | 5.7 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 12 | 5.9 |
| Salt Brine 23.3% | Blanche Rock Salt | 2.0 | 25 | -8 | 18 | 3.0 | 11 | 5.4 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

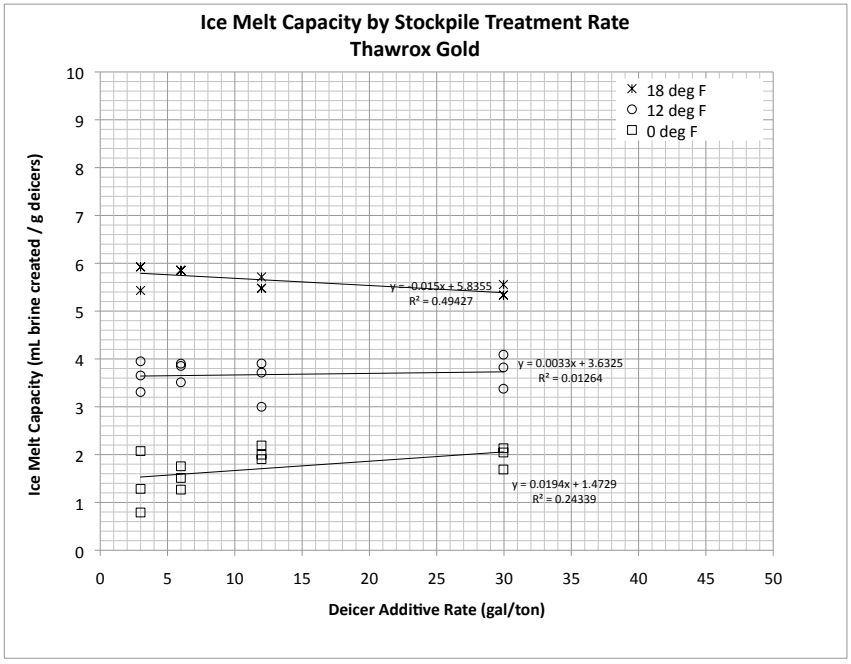
| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| SOS | Blanche Rock Salt | 2.0 | 25 | -4.5 | 24 | 3.0 | 11.5 | 5.7 |
| SOS | Blanche Rock Salt | 2.0 | 25 | -4.5 | 24 | 3.0 | 10 | 4.9 |
| SOS | Blanche Rock Salt | 2.0 | 25 | -4.5 | 24 | 3.0 | 12 | 5.9 |
| SOS | Blanche Rock Salt | 2.0 | 50 | -4.5 | 24 | 6.0 | 12 | 5.9 |
| SOS | Blanche Rock Salt | 2.0 | 50 | -4.5 | 24 | 6.0 | 10 | 4.9 |
| SOS | Blanche Rock Salt | 2.0 | 50 | -4.5 | 24 | 6.0 | 9.5 | 4.6 |
| SOS | Blanche Rock Salt | 2.0 | 100 | -8 | 18 | 12.0 | 9.5 | 4.5 |
| SOS | Blanche Rock Salt | 2.0 | 100 | -8 | 18 | 12.0 | 10.5 | 5.0 |
| SOS | Blanche Rock Salt | 2.0 | 100 | -8 | 18 | 12.0 | 10 | 4.8 |
| SOS | Blanche Rock Salt | 2.0 | 250 | -8 | 18 | 30.0 | 10 | 4.4 |
| SOS | Blanche Rock Salt | 2.0 | 250 | -8 | 18 | 30.0 | 10 | 4.4 |
| SOS | Blanche Rock Salt | 2.0 | 250 | -8 | 18 | 30.0 | 8.5 | 3.8 |
| SOS | Blanche Rock Salt | 2.0 | 25 | -10 | 14 | 3.0 | 7.8 | 3.9 |
| SOS | Blanche Rock Salt | 2.0 | 25 | -10 | 14 | 3.0 | 8.4 | 4.1 |
| SOS | Blanche Rock Salt | 2.0 | 25 | -10 | 14 | 3.0 | 6.8 | 3.4 |
| SOS | Blanche Rock Salt | 2.0 | 50 | -10 | 14 | 6.0 | 7 | 3.4 |
| SOS | Blanche Rock Salt | 2.0 | 50 | -10 | 14 | 6.0 | 7 | 3.4 |
| SOS | Blanche Rock Salt | 2.0 | 50 | -10 | 14 | 6.0 | 6 | 2.9 |
| SOS | Blanche Rock Salt | 2.0 | 100 | -14 | 7 | 12.0 | 6.2 | 3.0 |
| SOS | Blanche Rock Salt | 2.0 | 100 | -14 | 7 | 12.0 | 6.6 | 3.1 |
| SOS | Blanche Rock Salt | 2.0 | 100 | -14 | 7 | 12.0 | 6.8 | 3.2 |
| SOS | Blanche Rock Salt | 2.0 | 250 | -14 | 7 | 30.0 | 7.2 | 3.2 |
| SOS | Blanche Rock Salt | 2.0 | 250 | -14 | 7 | 30.0 | 7 | 3.1 |
| SOS | Blanche Rock Salt | 2.0 | 250 | -14 | 7 | 30.0 | 6.6 | 2.9 |
| SOS | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 2.8 | 1.4 |
| SOS | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 3.9 | 1.9 |
| SOS | Blanche Rock Salt | 2.0 | 25 | -17.8 | 0 | 3.0 | 3.8 | 1.9 |
| SOS | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 3.8 | 1.9 |
| SOS | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 4.4 | 2.1 |
| SOS | Blanche Rock Salt | 2.0 | 50 | -17.8 | 0 | 6.0 | 3.6 | 1.8 |
| SOS | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 3.4 | 1.6 |
| SOS | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 3.4 | 1.6 |
| SOS | Blanche Rock Salt | 2.0 | 100 | -17.8 | 0 | 12.0 | 4.4 | 2.1 |
| SOS | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 2.5 | 1.1 |
| SOS | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 4.6 | 2.0 |
| SOS | Blanche Rock Salt | 2.0 | 250 | -17.8 | 0 | 30.0 | 4.6 | 2.0 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

May 30, 2011

| Deicer Additive | Base Granular | Amount of Base Granular (g) | Amount of Additive Applied (uL) | Temp deg C | Temp deg F | Additive Applied in Gallons Per Ton | Brine Created | Ice Melt Capacity (mL brine created / g deicer applied) |
|---|---|---|---|---|---|---|---|---|
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 25 | -8 | 17.6 | 3.0 | 12 | 5.9 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 25 | -8 | 17.6 | 3.0 | 12 | 5.9 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 25 | -8 | 17.6 | 3.0 | 11 | 5.4 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 50 | -8 | 17.6 | 6.0 | 12 | 5.9 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 50 | -8 | 17.6 | 6.0 | 12 | 5.9 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 50 | -8 | 17.6 | 6.0 | 12 | 5.9 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 100 | -8 | 17.6 | 12.0 | 11.5 | 5.5 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 100 | -8 | 17.6 | 12.0 | 12 | 5.7 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 100 | -8 | 17.6 | 12.0 | 11.5 | 5.5 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 250 | -8 | 17.6 | 30.0 | 12 | 5.3 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 250 | -8 | 17.6 | 30.0 | 12 | 5.3 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 250 | -8 | 17.6 | 30.0 | 12.5 | 5.6 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 25 | -11 | 12.2 | 3.0 | 8 | 4.0 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 25 | -11 | 12.2 | 3.0 | 6.7 | 3.3 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 25 | -11 | 12.2 | 3.0 | 7.4 | 3.7 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 50 | -11 | 12.2 | 6.0 | 7.9 | 3.9 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 50 | -11 | 12.2 | 6.0 | 7.2 | 3.5 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 50 | -11 | 12.2 | 6.0 | 8 | 3.9 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 100 | -11 | 12.2 | 12.0 | 7.8 | 3.7 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 100 | -11 | 12.2 | 12.0 | 6.3 | 3.0 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 100 | -11 | 12.2 | 12.0 | 8.2 | 3.9 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 250 | -11 | 12.2 | 30.0 | 9.2 | 4.1 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 250 | -11 | 12.2 | 30.0 | 8.6 | 3.8 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 250 | -11 | 12.2 | 30.0 | 7.6 | 3.4 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 25 | -17.8 | -0.04 | 3.0 | 1.6 | 0.8 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 25 | -17.8 | -0.04 | 3.0 | 2.6 | 1.3 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 25 | -17.8 | -0.04 | 3.0 | 4.2 | 2.1 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 50 | -17.8 | -0.04 | 6.0 | 3.6 | 1.8 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 50 | -17.8 | -0.04 | 6.0 | 2.6 | 1.3 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 50 | -17.8 | -0.04 | 6.0 | 3.1 | 1.5 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 100 | -17.8 | -0.04 | 12.0 | 4.6 | 2.2 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 100 | -17.8 | -0.04 | 12.0 | 4 | 1.9 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 100 | -17.8 | -0.04 | 12.0 | 4.2 | 2.0 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 250 | -17.8 | -0.04 | 30.0 | 4.8 | 2.1 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 250 | -17.8 | -0.04 | 30.0 | 4.6 | 2.0 |
| Thawrax Gold Additive | Blanche Rock Salt | 2.0 | 250 | -17.8 | -0.04 | 30.0 | 3.8 | 1.7 |

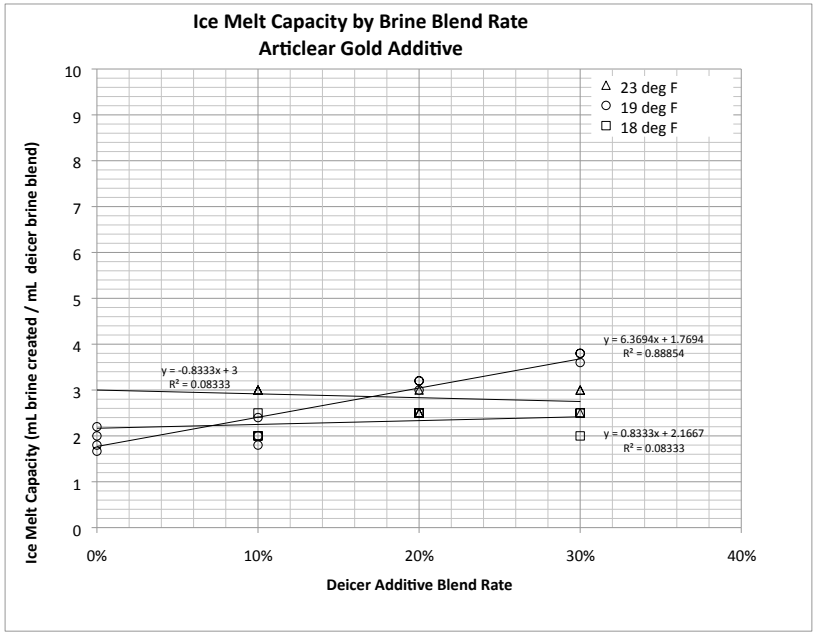


# Appendix D – Brine Blend Rate Analysis

Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

June 24, 2011

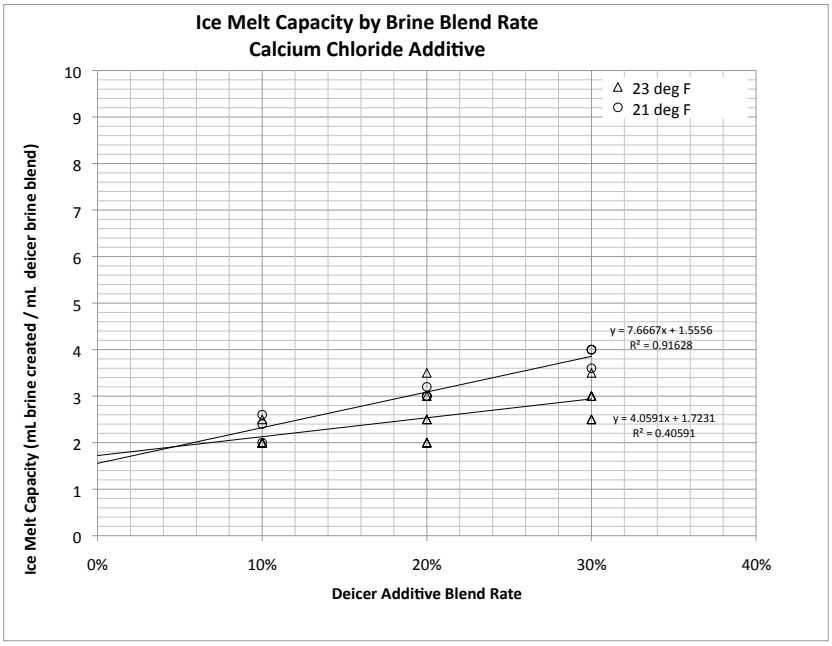
| Deicer Additive | Base Brine | Proportion of Base Brine | Proportion of Additive | Temp deg C | Temp deg F | Amount of Brine Blend Applied (mL) | Brine Created (mL) | Ice Melt Capacity (mL brine created / mL deicer brine blend applied) |
|---|---|---|---|---|---|---|---|---|
| Articlear Gold | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 3 | 3.0 |
| Articlear Gold | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 3 | 3.0 |
| Articlear Gold | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 3 | 3.0 |
| Articlear Gold | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 3 | 3.0 |
| Articlear Gold | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 2.5 | 2.5 |
| Articlear Gold | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 2.5 | 2.5 |
| Articlear Gold | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 3 | 3.0 |
| Articlear Gold | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 2.5 | 2.5 |
| Articlear Gold | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 3 | 3.0 |
| Articlear Gold | Salt (NaCl) Brine | 90% | 10% | -7 | 19 | 1.0 | 2 | 2.0 |
| Articlear Gold | Salt (NaCl) Brine | 90% | 10% | -7 | 19 | 1.0 | 1.8 | 1.8 |
| Articlear Gold | Salt (NaCl) Brine | 90% | 10% | -7 | 19 | 1.0 | 2.4 | 2.4 |
| Articlear Gold | Salt (NaCl) Brine | 80% | 20% | -7 | 19 | 1.0 | 3 | 3.0 |
| Articlear Gold | Salt (NaCl) Brine | 80% | 20% | -7 | 19 | 1.0 | 3.2 | 3.2 |
| Articlear Gold | Salt (NaCl) Brine | 80% | 20% | -7 | 19 | 1.0 | 3.2 | 3.2 |
| Articlear Gold | Salt (NaCl) Brine | 70% | 30% | -7 | 19 | 1.0 | 3.8 | 3.8 |
| Articlear Gold | Salt (NaCl) Brine | 70% | 30% | -7 | 19 | 1.0 | 3.8 | 3.8 |
| Articlear Gold | Salt (NaCl) Brine | 70% | 30% | -7 | 19 | 1.0 | 3.6 | 3.6 |
| Articlear Gold | Salt (NaCl) Brine | 90% | 10% | -8 | 18 | 1.0 | 2 | 2.0 |
| Articlear Gold | Salt (NaCl) Brine | 90% | 10% | -8 | 18 | 1.0 | 2.5 | 2.5 |
| Articlear Gold | Salt (NaCl) Brine | 90% | 10% | -8 | 18 | 1.0 | 2 | 2.0 |
| Articlear Gold | Salt (NaCl) Brine | 80% | 20% | -8 | 18 | 1.0 | 2.5 | 2.5 |
| Articlear Gold | Salt (NaCl) Brine | 80% | 20% | -8 | 18 | 1.0 | 2.5 | 2.5 |
| Articlear Gold | Salt (NaCl) Brine | 80% | 20% | -8 | 18 | 1.0 | 2.5 | 2.5 |
| Articlear Gold | Salt (NaCl) Brine | 70% | 30% | -8 | 18 | 1.0 | 2.5 | 2.5 |
| Articlear Gold | Salt (NaCl) Brine | 70% | 30% | -8 | 18 | 1.0 | 2 | 2.0 |
| Articlear Gold | Salt (NaCl) Brine | 70% | 30% | -8 | 18 | 1.0 | 2.5 | 2.5 |
| none | Salt (NaCl) Brine | 100% | 0% | -2 | 28 | 1.0 | 4.5 | 4.5 |
| none | Salt (NaCl) Brine | 100% | 0% | -2 | 28 | 3.0 | 12 | 4.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -3 | 27 | 1.0 | 3 | 3.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -3 | 27 | 3.0 | 9 | 3.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 1.0 | 1.8 | 1.8 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 3.0 | 6.6 | 2.2 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 1.0 | 2 | 2.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 3.0 | 5 | 1.7 |
| none | Salt (NaCl) Brine | 100% | 0% | -14 | 7 | 1.0 | 0.5 | 0.5 |
| none | Salt (NaCl) Brine | 100% | 0% | -14 | 7 | 3.0 | 3 | 1.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 3.0 | 7 | 2.3 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 1.0 | 1 | 1.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 3.0 | 3 | 1.0 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

June 24, 2011

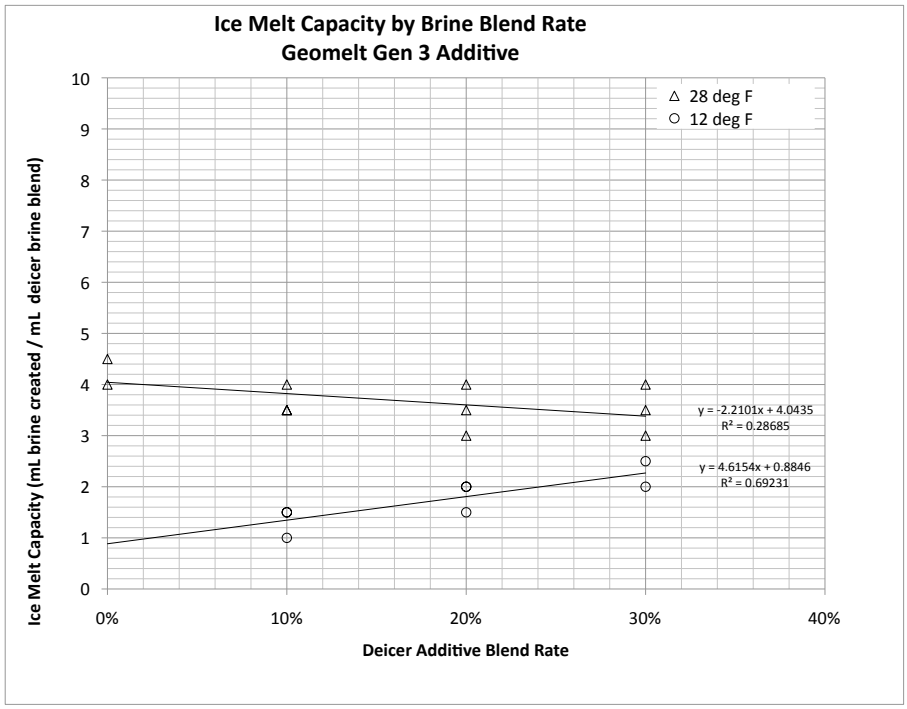
| Deicer Additive | Base Brine | Proportion of Base Brine | Proportion of Additive | Temp deg C | Temp deg F | Amount of Brine Blend Applied (mL) | Brine Created (mL) | Ice Melt Capacity (mL brine created / mL deicer brine blend applied) |
|---|---|---|---|---|---|---|---|---|
| CaCl | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 2 | 2.0 |
| CaCl | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 2 | 2.0 |
| CaCl | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 2 | 2.0 |
| CaCl | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 2 | 2.0 |
| CaCl | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 2.5 | 2.5 |
| CaCl | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 2 | 2.0 |
| CaCl | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 2.5 | 2.5 |
| CaCl | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 3 | 3.0 |
| CaCl | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 2.5 | 2.5 |
| CaCl | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 2 | 2.0 |
| CaCl | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 2.5 | 2.5 |
| CaCl | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 2.5 | 2.5 |
| CaCl | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 3 | 3.0 |
| CaCl | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 3.5 | 3.5 |
| CaCl | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 3 | 3.0 |
| CaCl | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 3.5 | 3.5 |
| CaCl | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 3 | 3.0 |
| CaCl | Salt (NaCl) Brine | 90% | 10% | -6 | 21 | 1.0 | 2 | 2.0 |
| CaCl | Salt (NaCl) Brine | 90% | 10% | -6 | 21 | 1.0 | 2.4 | 2.4 |
| CaCl | Salt (NaCl) Brine | 90% | 10% | -6 | 21 | 1.0 | 2.6 | 2.6 |
| CaCl | Salt (NaCl) Brine | 80% | 20% | -6 | 21 | 1.0 | 3 | 3.0 |
| CaCl | Salt (NaCl) Brine | 80% | 20% | -6 | 21 | 1.0 | 3.2 | 3.2 |
| CaCl | Salt (NaCl) Brine | 80% | 20% | -6 | 21 | 1.0 | 3 | 3.0 |
| CaCl | Salt (NaCl) Brine | 70% | 30% | -6 | 21 | 1.0 | 3.6 | 3.6 |
| CaCl | Salt (NaCl) Brine | 70% | 30% | -6 | 21 | 1.0 | 4 | 4.0 |
| CaCl | Salt (NaCl) Brine | 70% | 30% | -6 | 21 | 1.0 | 4 | 4.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -2 | 28 | 1.0 | 4.5 | 4.5 |
| none | Salt (NaCl) Brine | 100% | 0% | -2 | 28 | 3.0 | 12 | 4.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -3 | 27 | 1.0 | 3 | 3.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -3 | 27 | 3.0 | 9 | 3.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 1.0 | 1.8 | 1.8 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 3.0 | 6.6 | 2.2 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 1.0 | 2 | 2.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 3.0 | 5 | 1.7 |
| none | Salt (NaCl) Brine | 100% | 0% | -14 | 7 | 1.0 | 0.5 | 0.5 |
| none | Salt (NaCl) Brine | 100% | 0% | -14 | 7 | 3.0 | 3 | 1.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 3.0 | 7 | 2.3 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 1.0 | 1 | 1.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 3.0 | 3 | 1.0 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

June 24, 2011

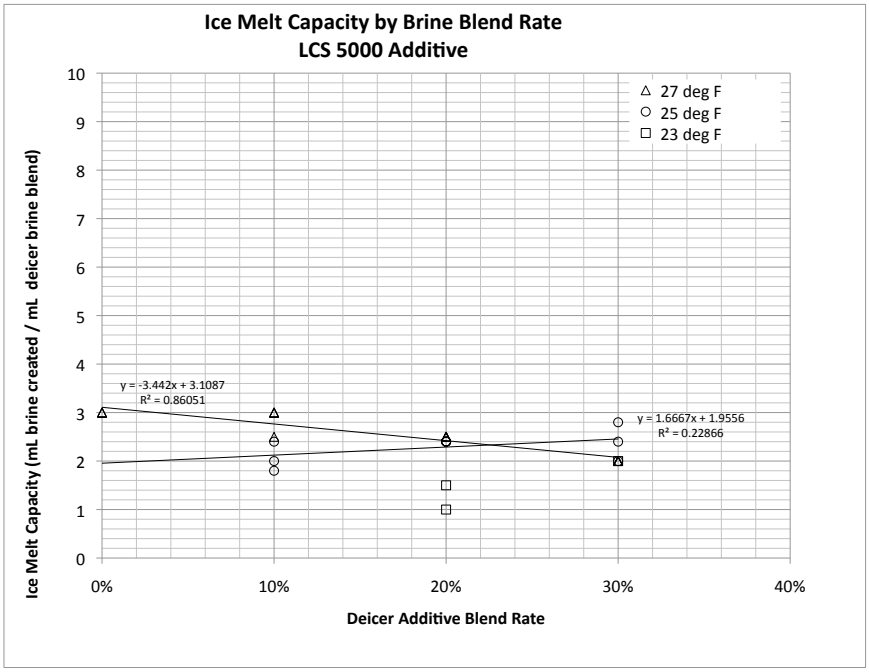
| Deicer Additive | Base Brine | Proportion of Base Brine | Proportion of Additive | Temp deg C | Temp deg F | Amount of Brine Blend Applied (mL) | Brine Created (mL) | Ice Melt Capacity (mL brine created / mL deicer brine blend applied) |
|---|---|---|---|---|---|---|---|---|
| Geomelt Gen 3 | Salt (NaCl) Brine | 90% | 10% | -2 | 28 | 1.0 | 3.5 | 3.5 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 90% | 10% | -2 | 28 | 1.0 | 3.5 | 3.5 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 90% | 10% | -2 | 28 | 1.0 | 4 | 4.0 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 80% | 20% | -2 | 28 | 1.0 | 3 | 3.0 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 80% | 20% | -2 | 28 | 1.0 | 4 | 4.0 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 80% | 20% | -2 | 28 | 1.0 | 3.5 | 3.5 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 70% | 30% | -2 | 28 | 1.0 | 3.5 | 3.5 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 70% | 30% | -2 | 28 | 1.0 | 4 | 4.0 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 70% | 30% | -2 | 28 | 1.0 | 3 | 3.0 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 90% | 10% | -11 | 12 | 1.0 | 1 | 1.0 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 90% | 10% | -11 | 12 | 1.0 | 1.5 | 1.5 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 90% | 10% | -11 | 12 | 1.0 | 1.5 | 1.5 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 80% | 20% | -11 | 12 | 1.0 | 1.5 | 1.5 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 80% | 20% | -11 | 12 | 1.0 | 2 | 2.0 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 80% | 20% | -11 | 12 | 1.0 | 2 | 2.0 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 70% | 30% | -11 | 12 | 1.0 | 2 | 2.0 |
| Geomelt Gen 3 | Salt (NaCl) Brine | 70% | 30% | -11 | 12 | 1.0 | 2.5 | 2.5 |
| none | Salt (NaCl) Brine | 100% | 0% | -2 | 28 | 1.0 | 4.5 | 4.5 |
| none | Salt (NaCl) Brine | 100% | 0% | -2 | 28 | 3.0 | 12 | 4.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -3 | 27 | 1.0 | 3 | 3.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -3 | 27 | 3.0 | 9 | 3.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 1.0 | 1.8 | 1.8 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 3.0 | 6.6 | 2.2 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 1.0 | 2 | 2.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 3.0 | 5 | 1.7 |
| none | Salt (NaCl) Brine | 100% | 0% | -14 | 7 | 1.0 | 0.5 | 0.5 |
| none | Salt (NaCl) Brine | 100% | 0% | -14 | 7 | 3.0 | 3 | 1.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 3.0 | 7 | 2.3 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 1.0 | 1 | 1.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 3.0 | 3 | 1.0 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

June 24, 2011

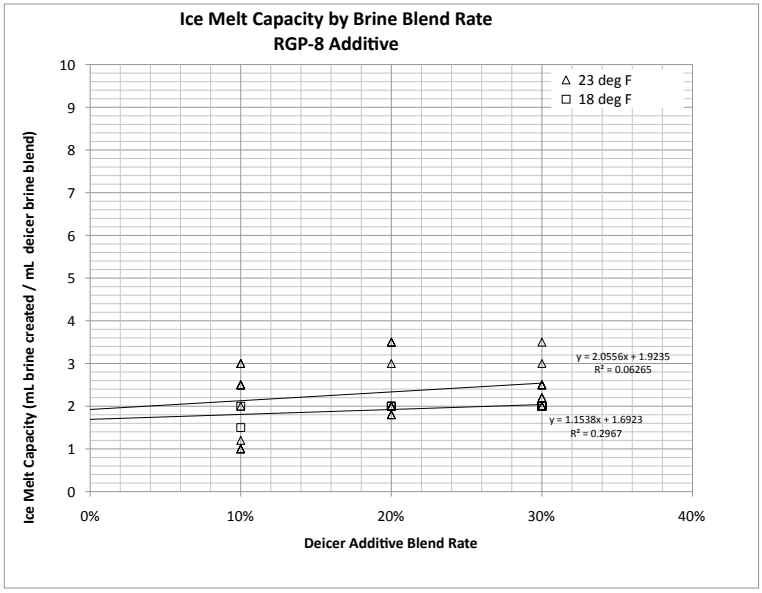
| Deicer Additive | Base Brine | Proportion of Base Brine | Proportion of Additive | Temp deg C | Temp deg F | Amount of Brine Blend Applied (mL) | Brine Created (mL) | Ice Melt Capacity (mL brine created / mL deicer brine blend applied) |
|---|---|---|---|---|---|---|---|---|
| LCS 5000 | Salt (NaCl) Brine | 90% | 10% | -3 | 27 | 1.0 | 3 | 3.0 |
| LCS 5000 | Salt (NaCl) Brine | 90% | 10% | -3 | 27 | 1.0 | 2.5 | 2.5 |
| LCS 5000 | Salt (NaCl) Brine | 90% | 10% | -3 | 27 | 1.0 | 3 | 3.0 |
| LCS 5000 | Salt (NaCl) Brine | 80% | 20% | -3 | 27 | 1.0 | 2.5 | 2.5 |
| LCS 5000 | Salt (NaCl) Brine | 80% | 20% | -3 | 27 | 1.0 | 2.5 | 2.5 |
| LCS 5000 | Salt (NaCl) Brine | 80% | 20% | -3 | 27 | 1.0 | 2.5 | 2.5 |
| LCS 5000 | Salt (NaCl) Brine | 70% | 30% | -3 | 27 | 1.0 | 2 | 2.0 |
| LCS 5000 | Salt (NaCl) Brine | 70% | 30% | -3 | 27 | 1.0 | 2 | 2.0 |
| LCS 5000 | Salt (NaCl) Brine | 70% | 30% | -3 | 27 | 1.0 | 2 | 2.0 |
| LCS 5000 | Salt (NaCl) Brine | 90% | 10% | -4 | 25 | 1.0 | 1.8 | 1.8 |
| LCS 5000 | Salt (NaCl) Brine | 90% | 10% | -4 | 25 | 1.0 | 2 | 2.0 |
| LCS 5000 | Salt (NaCl) Brine | 90% | 10% | -4 | 25 | 1.0 | 2.4 | 2.4 |
| LCS 5000 | Salt (NaCl) Brine | 80% | 20% | -4 | 25 | 1.0 | 2.4 | 2.4 |
| LCS 5000 | Salt (NaCl) Brine | 80% | 20% | -4 | 25 | 1.0 | 2.4 | 2.4 |
| LCS 5000 | Salt (NaCl) Brine | 80% | 20% | -4 | 25 | 1.0 | 2.4 | 2.4 |
| LCS 5000 | Salt (NaCl) Brine | 70% | 30% | -4 | 25 | 1.0 | 2 | 2.0 |
| LCS 5000 | Salt (NaCl) Brine | 70% | 30% | -4 | 25 | 1.0 | 2.4 | 2.4 |
| LCS 5000 | Salt (NaCl) Brine | 70% | 30% | -4 | 25 | 1.0 | 2.8 | 2.8 |
| LCS 5000 | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 1 | 1.0 |
| LCS 5000 | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 1.5 | 1.5 |
| LCS 5000 | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 2 | 2.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -2 | 28 | 1.0 | 4.5 | 4.5 |
| none | Salt (NaCl) Brine | 100% | 0% | -2 | 28 | 3.0 | 12 | 4.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -3 | 27 | 1.0 | 3 | 3.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -3 | 27 | 3.0 | 9 | 3.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 1.0 | 1.8 | 1.8 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 3.0 | 6.6 | 2.2 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 1.0 | 2 | 2.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 3.0 | 5 | 1.7 |
| none | Salt (NaCl) Brine | 100% | 0% | -14 | 7 | 1.0 | 0.5 | 0.5 |
| none | Salt (NaCl) Brine | 100% | 0% | -14 | 7 | 3.0 | 3 | 1.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 3.0 | 7 | 2.3 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 1.0 | 1 | 1.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 3.0 | 3 | 1.0 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

June 24, 2011

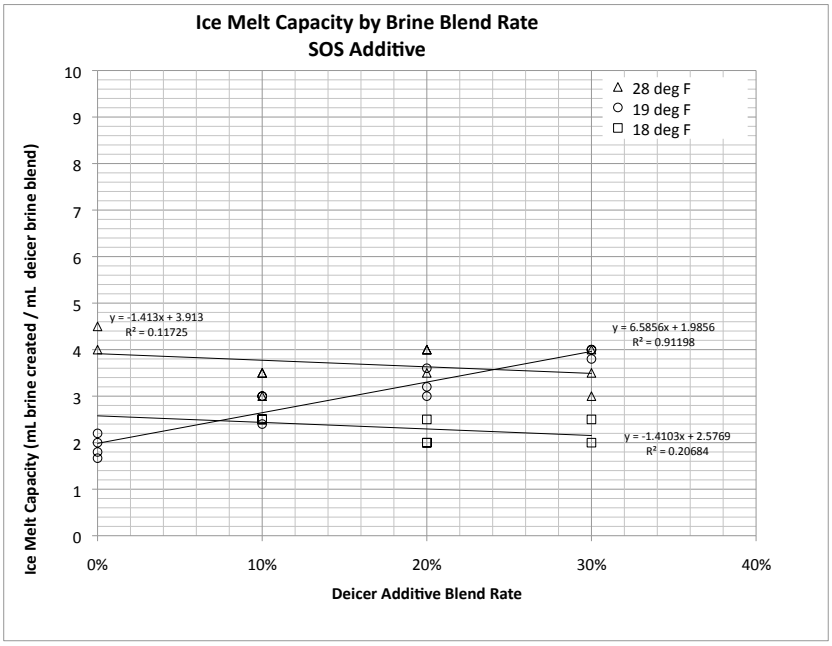
| Deicer Additive | Base Brine | Proportion of Base Brine | Proportion of Additive | Temp deg C | Temp deg F | Amount of Brine Blend Applied (mL) | Brine Created (mL) | Ice Melt Capacity (mL brine created / mL deicer brine blend applied) |
|---|---|---|---|---|---|---|---|---|
| RGP-8 | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 1 | 1.0 |
| RGP-8 | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 1 | 1.0 |
| RGP-8 | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 1.2 | 1.2 |
| RGP-8 | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 1.8 | 1.8 |
| RGP-8 | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 1.8 | 1.8 |
| RGP-8 | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 2 | 2.0 |
| RGP-8 | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 2.2 | 2.2 |
| RGP-8 | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 2 | 2.0 |
| RGP-8 | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 2.2 | 2.2 |
| RGP-8 | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 2.5 | 2.5 |
| RGP-8 | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 2 | 2.0 |
| RGP-8 | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 2.5 | 2.5 |
| RGP-8 | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 2 | 2.0 |
| RGP-8 | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 2 | 2.0 |
| RGP-8 | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 2 | 2.0 |
| RGP-8 | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 2.5 | 2.5 |
| RGP-8 | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 2.5 | 2.5 |
| RGP-8 | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 3 | 3.0 |
| RGP-8 | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 3 | 3.0 |
| RGP-8 | Salt (NaCl) Brine | 90% | 10% | -5 | 23 | 1.0 | 2.5 | 2.5 |
| RGP-8 | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 3.5 | 3.5 |
| RGP-8 | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 3 | 3.0 |
| RGP-8 | Salt (NaCl) Brine | 80% | 20% | -5 | 23 | 1.0 | 3.5 | 3.5 |
| RGP-8 | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 3 | 3.0 |
| RGP-8 | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 3.5 | 3.5 |
| RGP-8 | Salt (NaCl) Brine | 70% | 30% | -5 | 23 | 1.0 | 2.5 | 2.5 |
| RGP-8 | Salt (NaCl) Brine | 90% | 10% | -8 | 18 | 1.0 | 1.5 | 1.5 |
| RGP-8 | Salt (NaCl) Brine | 90% | 10% | -8 | 18 | 1.0 | 2 | 2.0 |
| RGP-8 | Salt (NaCl) Brine | 80% | 20% | -8 | 18 | 1.0 | 2 | 2.0 |
| RGP-8 | Salt (NaCl) Brine | 80% | 20% | -8 | 18 | 1.0 | 2 | 2.0 |
| RGP-8 | Salt (NaCl) Brine | 80% | 20% | -8 | 18 | 1.0 | 2 | 2.0 |
| RGP-8 | Salt (NaCl) Brine | 70% | 30% | -8 | 18 | 1.0 | 2 | 2.0 |
| RGP-8 | Salt (NaCl) Brine | 70% | 30% | -8 | 18 | 1.0 | 2 | 2.0 |
| RGP-8 | Salt (NaCl) Brine | 70% | 30% | -8 | 18 | 1.0 | 2 | 2.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -2 | 28 | 1.0 | 4.5 | 4.5 |
| none | Salt (NaCl) Brine | 100% | 0% | -2 | 28 | 3.0 | 12 | 4.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -3 | 27 | 1.0 | 3 | 3.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -3 | 27 | 3.0 | 9 | 3.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 1.0 | 1.8 | 1.8 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 3.0 | 6.6 | 2.2 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 1.0 | 2 | 2.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 3.0 | 5 | 1.7 |
| none | Salt (NaCl) Brine | 100% | 0% | -14 | 7 | 1.0 | 0.5 | 0.5 |
| none | Salt (NaCl) Brine | 100% | 0% | -14 | 7 | 3.0 | 3 | 1.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 3.0 | 7 | 2.3 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 1.0 | 1 | 1.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 3.0 | 3 | 1.0 |



Ice Melt Capacity Evaluation
Mn/DOT Salt Brine Blending
S. Druschel / MSU Mankato Civil Engineering

June 24, 2011

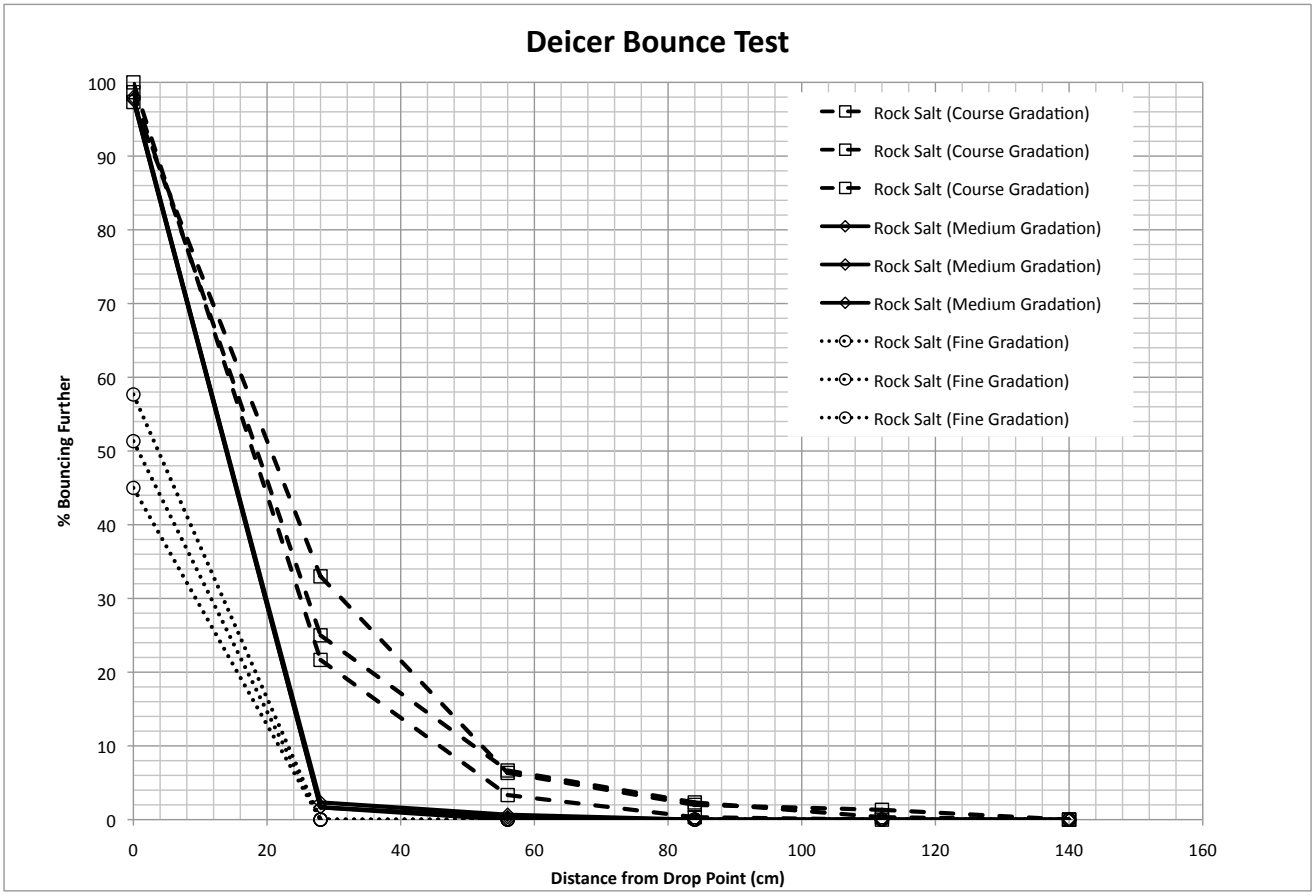
| Deicer Additive | Base Brine | Proportion of Base Brine | Proportion of Additive | Temp deg C | Temp deg F | Amount of Brine Blend Applied (mL) | Brine Created (mL) | Ice Melt Capacity (mL brine created / mL deicer brine blend applied) |
|---|---|---|---|---|---|---|---|---|
| SOS | Salt (NaCl) Brine | 90% | 10% | -2 | 28 | 1.0 | 3 | 3.0 |
| SOS | Salt (NaCl) Brine | 90% | 10% | -2 | 28 | 1.0 | 3.5 | 3.5 |
| SOS | Salt (NaCl) Brine | 90% | 10% | -2 | 28 | 1.0 | 3.5 | 3.5 |
| SOS | Salt (NaCl) Brine | 80% | 20% | -2 | 28 | 1.0 | 4 | 4.0 |
| SOS | Salt (NaCl) Brine | 80% | 20% | -2 | 28 | 1.0 | 3.5 | 3.5 |
| SOS | Salt (NaCl) Brine | 80% | 20% | -2 | 28 | 1.0 | 4 | 4.0 |
| SOS | Salt (NaCl) Brine | 70% | 30% | -2 | 28 | 1.0 | 3.5 | 3.5 |
| SOS | Salt (NaCl) Brine | 70% | 30% | -2 | 28 | 1.0 | 3 | 3.0 |
| SOS | Salt (NaCl) Brine | 70% | 30% | -2 | 28 | 1.0 | 4 | 4.0 |
| SOS | Salt (NaCl) Brine | 90% | 10% | -7 | 19 | 1.0 | 3 | 3.0 |
| SOS | Salt (NaCl) Brine | 90% | 10% | -7 | 19 | 1.0 | 2.4 | 2.4 |
| SOS | Salt (NaCl) Brine | 90% | 10% | -7 | 19 | 1.0 | 3 | 3.0 |
| SOS | Salt (NaCl) Brine | 80% | 20% | -7 | 19 | 1.0 | 3 | 3.0 |
| SOS | Salt (NaCl) Brine | 80% | 20% | -7 | 19 | 1.0 | 3.2 | 3.2 |
| SOS | Salt (NaCl) Brine | 80% | 20% | -7 | 19 | 1.0 | 3.6 | 3.6 |
| SOS | Salt (NaCl) Brine | 70% | 30% | -7 | 19 | 1.0 | 4 | 4.0 |
| SOS | Salt (NaCl) Brine | 70% | 30% | -7 | 19 | 1.0 | 3.8 | 3.8 |
| SOS | Salt (NaCl) Brine | 70% | 30% | -7 | 19 | 1.0 | 4 | 4.0 |
| SOS | Salt (NaCl) Brine | 90% | 10% | -8 | 18 | 1.0 | 2.5 | 2.5 |
| SOS | Salt (NaCl) Brine | 90% | 10% | -8 | 18 | 1.0 | 2.5 | 2.5 |
| SOS | Salt (NaCl) Brine | 90% | 10% | -8 | 18 | 1.0 | 2.5 | 2.5 |
| SOS | Salt (NaCl) Brine | 80% | 20% | -8 | 18 | 1.0 | 2 | 2.0 |
| SOS | Salt (NaCl) Brine | 80% | 20% | -8 | 18 | 1.0 | 2.5 | 2.5 |
| SOS | Salt (NaCl) Brine | 80% | 20% | -8 | 18 | 1.0 | 2 | 2.0 |
| SOS | Salt (NaCl) Brine | 70% | 30% | -8 | 18 | 1.0 | 2.5 | 2.5 |
| SOS | Salt (NaCl) Brine | 70% | 30% | -8 | 18 | 1.0 | 2 | 2.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -2 | 28 | 1.0 | 4.5 | 4.5 |
| none | Salt (NaCl) Brine | 100% | 0% | -2 | 28 | 3.0 | 12 | 4.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -3 | 27 | 1.0 | 3 | 3.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -3 | 27 | 3.0 | 9 | 3.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 1.0 | 1.8 | 1.8 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 3.0 | 6.6 | 2.2 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 1.0 | 2 | 2.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -7 | 19 | 3.0 | 5 | 1.7 |
| none | Salt (NaCl) Brine | 100% | 0% | -14 | 7 | 1.0 | 0.5 | 0.5 |
| none | Salt (NaCl) Brine | 100% | 0% | -14 | 7 | 3.0 | 3 | 1.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 3.0 | 7 | 2.3 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 1.0 | 1 | 1.0 |
| none | Salt (NaCl) Brine | 100% | 0% | -15 | 5 | 3.0 | 3 | 1.0 |



# Appendix E – Bounce Test Results

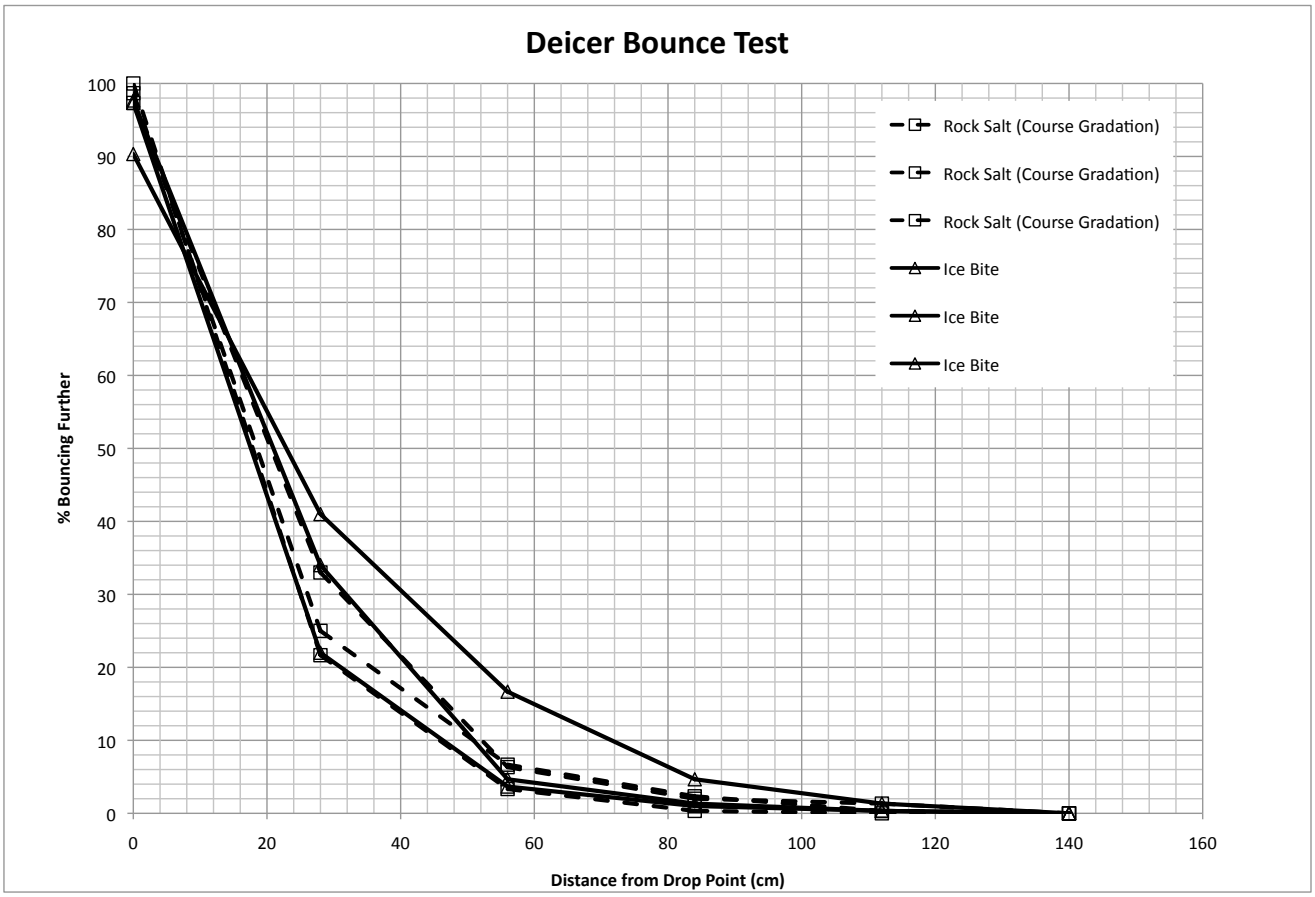
Bounce Test Results
MN/DOT Salt Brine Blending
S. Druschel, MSU Mankato Environmental Engineering
August 10, 2011

| Material | Test Replicate # | Sheet (numbered from drop location) | Distance (cm) | Mean Distance of Range (cm) | Total Mass (Sheet + Deicer) (g) | Net Mass (g) | % of total | Maximum Distance of Step | % Bouncing Beyond Maximum Distance |
|---|---|---|---|---|---|---|---|---|---|
| NaCl (4/10) | 1 | unkacctd | on plate | 0 | | | 0.00 | 0 | 100.00 |
| NaCl (4/10) | 1 | 1 | 0-28 | 14 | 32.5 | 23.5 | 78.33 | 28 | 21.67 |
| NaCl (4/10) | 1 | 2 | 28-56 | 42 | 14.5 | 5.5 | 18.33 | 56 | 3.33 |
| NaCl (4/10) | 1 | 3 | 56-84 | 70 | 9.9 | 0.9 | 3.00 | 84 | 0.33 |
| NaCl (4/10) | 1 | 4 | 84-112 | 98 | 9.1 | 0.1 | 0.33 | 112 | 0.00 |
| NaCl (4/10) | 1 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| NaCl (4/10) | 2 | unkacctd | on plate | 0 | | | 2.67 | 0 | 97.33 |
| NaCl (4/10) | 2 | 1 | 0-28 | 14 | 28.3 | 19.3 | 64.33 | 28 | 33.00 |
| NaCl (4/10) | 2 | 2 | 28-56 | 42 | 17.0 | 8.0 | 26.67 | 56 | 6.33 |
| NaCl (4/10) | 2 | 3 | 56-84 | 70 | 10.3 | 1.3 | 4.33 | 84 | 2.00 |
| NaCl (4/10) | 2 | 4 | 84-112 | 98 | 9.2 | 0.2 | 0.67 | 112 | 1.33 |
| NaCl (4/10) | 2 | 5 | 112-140 | 126 | 9.4 | 0.4 | 1.33 | 140 | 0.00 |
| NaCl (4/10) | 3 | unkacctd | on plate | 0 | | | 1.33 | 0 | 98.67 |
| NaCl (4/10) | 3 | 1 | 0-28 | 14 | 31.1 | 22.1 | 73.67 | 28 | 25.00 |
| NaCl (4/10) | 3 | 2 | 28-56 | 42 | 14.5 | 5.5 | 18.33 | 56 | 6.67 |
| NaCl (4/10) | 3 | 3 | 56-84 | 70 | 10.3 | 1.3 | 4.33 | 84 | 2.33 |
| NaCl (4/10) | 3 | 4 | 84-112 | 98 | 9.6 | 0.6 | 2.00 | 112 | 0.33 |
| NaCl (4/10) | 3 | 5 | 112-140 | 126 | 9.1 | 0.1 | 0.33 | 140 | 0.00 |
| NaCl (10/20) | 1 | unkacctd | on plate | 0 | | | 2.33 | 0 | 97.67 |
| NaCl (10/20) | 1 | 1 | 0-28 | 14 | 37.8 | 28.8 | 96.00 | 28 | 1.67 |
| NaCl (10/20) | 1 | 2 | 28-56 | 42 | 9.5 | 0.5 | 1.67 | 56 | 0.00 |
| NaCl (10/20) | 1 | 3 | 56-84 | 70 | 0.0 | 0.0 | 0.00 | 84 | 0.00 |
| NaCl (10/20) | 1 | 4 | 84-112 | 98 | 0.0 | 0.0 | 0.00 | 112 | 0.00 |
| NaCl (10/20) | 1 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| NaCl (10/20) | 2 | unkacctd | on plate | 0 | | | 2.00 | 0 | 98.00 |
| NaCl (10/20) | 2 | 1 | 0-28 | 14 | 37.9 | 28.9 | 96.33 | 28 | 1.67 |
| NaCl (10/20) | 2 | 2 | 28-56 | 42 | 9.4 | 0.4 | 1.33 | 56 | 0.33 |
| NaCl (10/20) | 2 | 3 | 56-84 | 70 | 9.1 | 0.1 | 0.33 | 84 | 0.00 |
| NaCl (10/20) | 2 | 4 | 84-112 | 98 | 0.0 | 0.0 | 0.00 | 112 | 0.00 |
| NaCl (10/20) | 2 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| NaCl (10/20) | 3 | unkacctd | on plate | 0 | | | 2.33 | 0 | 97.67 |
| NaCl (10/20) | 3 | 1 | 0-28 | 14 | 37.6 | 28.6 | 95.33 | 28 | 2.33 |
| NaCl (10/20) | 3 | 2 | 28-56 | 42 | 9.5 | 0.5 | 1.67 | 56 | 0.67 |
| NaCl (10/20) | 3 | 3 | 56-84 | 70 | 9.2 | 0.2 | 0.67 | 84 | 0.00 |
| NaCl (10/20) | 3 | 4 | 84-112 | 98 | 0.0 | 0.0 | 0.00 | 112 | 0.00 |
| NaCl (10/20) | 3 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| NaCl (/20) | 1 | unkacctd | on plate | 0 | | | 55.00 | 0 | 45.00 |
| NaCl (/20) | 1 | 1 | 0-28 | 14 | 22.5 | 13.5 | 45.00 | 28 | 0.00 |
| NaCl (/20) | 1 | 2 | 28-56 | 42 | 0.0 | 0.0 | 0.00 | 56 | 0.00 |
| NaCl (/20) | 1 | 3 | 56-84 | 70 | 0.0 | 0.0 | 0.00 | 84 | 0.00 |
| NaCl (/20) | 1 | 4 | 84-112 | 98 | 0.0 | 0.0 | 0.00 | 112 | 0.00 |
| NaCl (/20) | 1 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| NaCl (/20) | 2 | unkacctd | on plate | 0 | | | 48.67 | 0 | 51.33 |
| NaCl (/20) | 2 | 1 | 0-28 | 14 | 24.4 | 15.4 | 51.33 | 28 | 0.00 |
| NaCl (/20) | 2 | 2 | 28-56 | 42 | 0.0 | 0.0 | 0.00 | 56 | 0.00 |
| NaCl (/20) | 2 | 3 | 56-84 | 70 | 0.0 | 0.0 | 0.00 | 84 | 0.00 |
| NaCl (/20) | 2 | 4 | 84-112 | 98 | 0.0 | 0.0 | 0.00 | 112 | 0.00 |
| NaCl (/20) | 2 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| NaCl (/20) | 2 | unkacctd | on plate | 0 | | | 42.33 | 0 | 57.67 |
| NaCl (/20) | 3 | 1 | 0-28 | 14 | 26.3 | 17.3 | 57.67 | 28 | 0.00 |
| NaCl (/20) | 3 | 2 | 28-56 | 42 | 0.0 | 0.0 | 0.00 | 56 | 0.00 |
| NaCl (/20) | 3 | 3 | 56-84 | 70 | 0.0 | 0.0 | 0.00 | 84 | 0.00 |
| NaCl (/20) | 3 | 4 | 84-112 | 98 | 0.0 | 0.0 | 0.00 | 112 | 0.00 |
| NaCl (/20) | 3 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |


Deicer Bounce Test
% Bouncing Further
Distance from Drop Point (cm)
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
Rock Salt (Course Gradation)
Rock Salt (Course Gradation)
Rock Salt (Course Gradation)
Rock Salt (Medium Gradation)
Rock Salt (Medium Gradation)
Rock Salt (Medium Gradation)
Rock Salt (Fine Gradation)
Rock Salt (Fine Gradation)
Rock Salt (Fine Gradation)

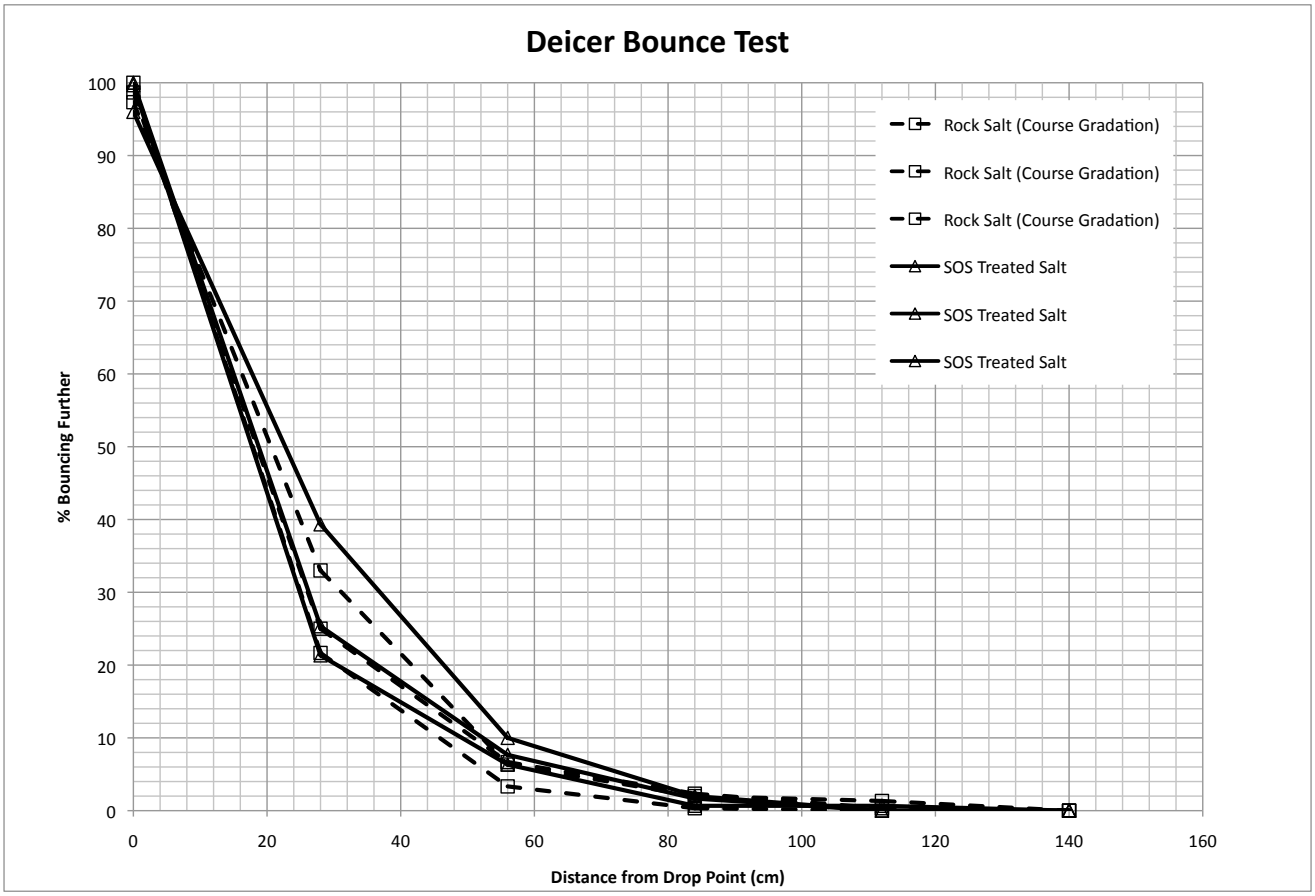
Bounce Test Results
MN/DOT Salt Brine Blending
S. Druschel, MSU Mankato Environmental Engineering
August 10, 2011

| Material | Test Replicate # | Sheet (numbered from drop location) | Distance (cm) | Mean Distance of Range (cm) | Total Mass (Sheet + Deicer) (g) | Net Mass (g) | % of total | Maximum Distance of Step | % Bouncing Beyond Maximum Distance |
|---|---|---|---|---|---|---|---|---|---|
| NaCl (4/10) | 1 | unkacctd | on plate | 0 | | | 0.00 | 0 | 100.00 |
| NaCl (4/10) | 1 | 1 | 0-28 | 14 | 32.5 | 23.5 | 78.33 | 28 | 21.67 |
| NaCl (4/10) | 1 | 2 | 28-56 | 42 | 14.5 | 5.5 | 18.33 | 56 | 3.33 |
| NaCl (4/10) | 1 | 3 | 56-84 | 70 | 9.9 | 0.9 | 3.00 | 84 | 0.33 |
| NaCl (4/10) | 1 | 4 | 84-112 | 98 | 9.1 | 0.1 | 0.33 | 112 | 0.00 |
| NaCl (4/10) | 1 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| NaCl (4/10) | 2 | unkacctd | on plate | 0 | | | 2.67 | 0 | 97.33 |
| NaCl (4/10) | 2 | 1 | 0-28 | 14 | 28.3 | 19.3 | 64.33 | 28 | 33.00 |
| NaCl (4/10) | 2 | 2 | 28-56 | 42 | 17.0 | 8.0 | 26.67 | 56 | 6.33 |
| NaCl (4/10) | 2 | 3 | 56-84 | 70 | 10.3 | 1.3 | 4.33 | 84 | 2.00 |
| NaCl (4/10) | 2 | 4 | 84-112 | 98 | 9.2 | 0.2 | 0.67 | 112 | 1.33 |
| NaCl (4/10) | 2 | 5 | 112-140 | 126 | 9.4 | 0.4 | 1.33 | 140 | 0.00 |
| NaCl (4/10) | 3 | unkacctd | on plate | 0 | | | 1.33 | 0 | 98.67 |
| NaCl (4/10) | 3 | 1 | 0-28 | 14 | 31.1 | 22.1 | 73.67 | 28 | 25.00 |
| NaCl (4/10) | 3 | 2 | 28-56 | 42 | 14.5 | 5.5 | 18.33 | 56 | 6.67 |
| NaCl (4/10) | 3 | 3 | 56-84 | 70 | 10.3 | 1.3 | 4.33 | 84 | 2.33 |
| NaCl (4/10) | 3 | 4 | 84-112 | 98 | 9.6 | 0.6 | 2.00 | 112 | 0.33 |
| NaCl (4/10) | 3 | 5 | 112-140 | 126 | 9.1 | 0.1 | 0.33 | 140 | 0.00 |
| Ice Bite | 1 | unkacctd | on plate | 0 | | | 2.33 | 0 | 97.67 |
| Ice Bite | 1 | 1 | 0-28 | 14 | 28.1 | 19.1 | 63.67 | 28 | 34.00 |
| Ice Bite | 1 | 2 | 28-56 | 42 | 17.8 | 8.8 | 29.33 | 56 | 4.67 |
| Ice Bite | 1 | 3 | 56-84 | 70 | 10.0 | 1.0 | 3.33 | 84 | 1.33 |
| Ice Bite | 1 | 4 | 84-112 | 98 | 9.3 | 0.3 | 1.00 | 112 | 0.33 |
| Ice Bite | 1 | 5 | 112-140 | 126 | 9.1 | 0.1 | 0.33 | 140 | 0.00 |
| Ice Bite | 2 | unkacctd | on plate | 0 | | | 9.67 | 0 | 90.33 |
| Ice Bite | 2 | 1 | 0-28 | 14 | 23.8 | 14.8 | 49.33 | 28 | 41.00 |
| Ice Bite | 2 | 2 | 28-56 | 42 | 16.3 | 7.3 | 24.33 | 56 | 16.67 |
| Ice Bite | 2 | 3 | 56-84 | 70 | 12.6 | 3.6 | 12.00 | 84 | 4.67 |
| Ice Bite | 2 | 4 | 84-112 | 98 | 10.0 | 1.0 | 3.33 | 112 | 1.33 |
| Ice Bite | 2 | 5 | 112-140 | 126 | 9.4 | 0.4 | 1.33 | 140 | 0.00 |
| Ice Bite | 3 | unkacctd | on plate | 0 | | | 2.67 | 0 | 97.33 |
| Ice Bite | 3 | 1 | 0-28 | 14 | 31.6 | 22.6 | 75.33 | 28 | 22.00 |
| Ice Bite | 3 | 2 | 28-56 | 42 | 14.5 | 5.5 | 18.33 | 56 | 3.67 |
| Ice Bite | 3 | 3 | 56-84 | 70 | 9.8 | 0.8 | 2.67 | 84 | 1.00 |
| Ice Bite | 3 | 4 | 84-112 | 98 | 9.2 | 0.2 | 0.67 | 112 | 0.33 |
| Ice Bite | 3 | 5 | 112-140 | 126 | 9.1 | 0.1 | 0.33 | 140 | 0.00 |


Deicer Bounce Test
% Bouncing Further
Distance from Drop Point (cm)
Rock Salt (Course Gradation)
Rock Salt (Course Gradation)
Rock Salt (Course Gradation)
Ice Bite
Ice Bite
Ice Bite
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160

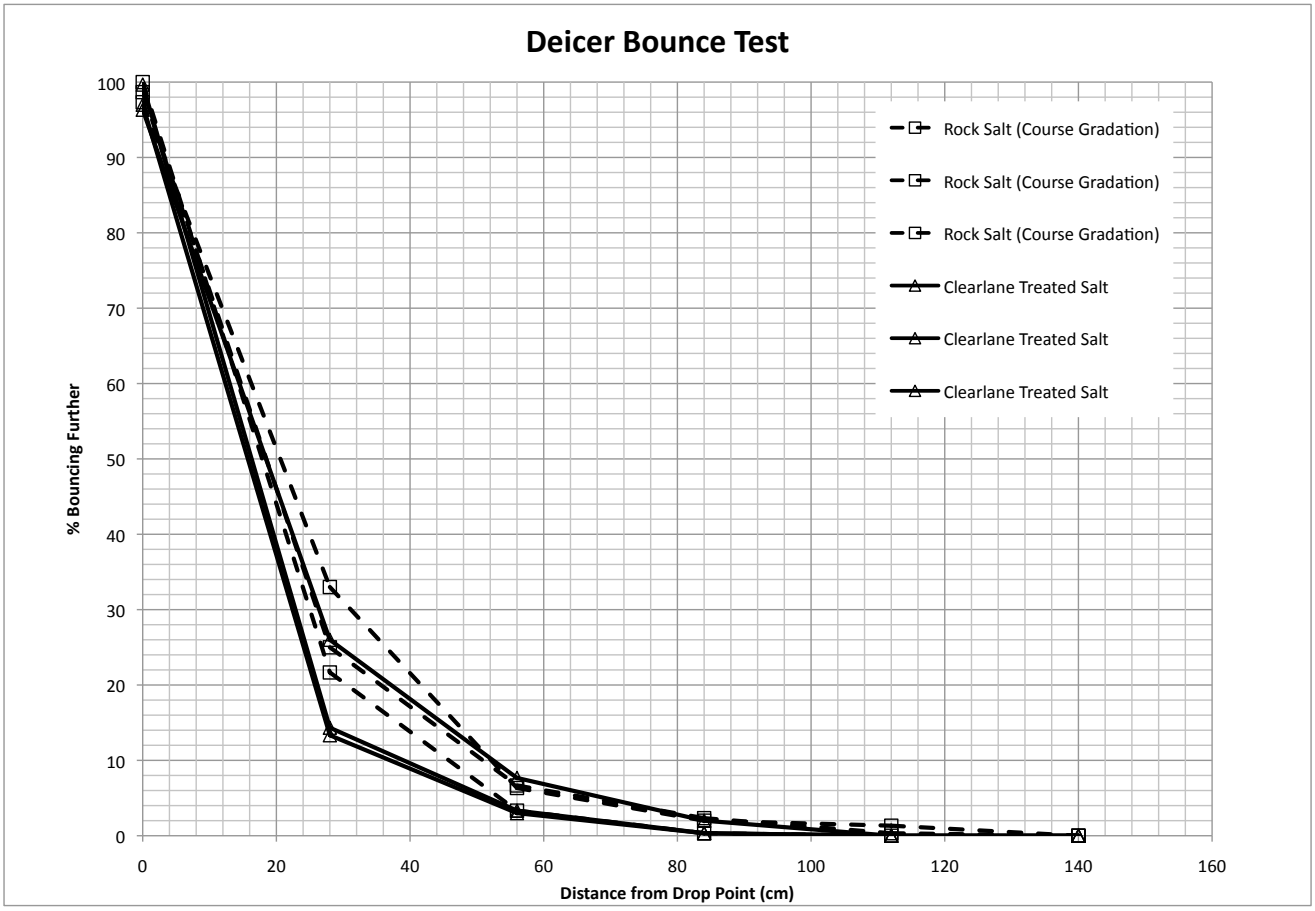
Bounce Test Results
MN/DOT Salt Brine Blending
S. Druschel, MSU Mankato Environmental Engineering
August 10, 2011

| Material | Test Replicate # | Sheet (numbered from drop location) | Distance (cm) | Mean Distance of Range (cm) | Total Mass (Sheet + Deicer) (g) | Net Mass (g) | % of total | Maximum Distance of Step | % Bouncing Beyond Maximum Distance |
|---|---|---|---|---|---|---|---|---|---|
| NaCl (4/10) | 1 | unkacctd | on plate | 0 | | | 0.00 | 0 | 100.00 |
| NaCl (4/10) | 1 | 1 | 0-28 | 14 | 32.5 | 23.5 | 78.33 | 28 | 21.67 |
| NaCl (4/10) | 1 | 2 | 28-56 | 42 | 14.5 | 5.5 | 18.33 | 56 | 3.33 |
| NaCl (4/10) | 1 | 3 | 56-84 | 70 | 9.9 | 0.9 | 3.00 | 84 | 0.33 |
| NaCl (4/10) | 1 | 4 | 84-112 | 98 | 9.1 | 0.1 | 0.33 | 112 | 0.00 |
| NaCl (4/10) | 1 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| NaCl (4/10) | 2 | unkacctd | on plate | 0 | | | 2.67 | 0 | 97.33 |
| NaCl (4/10) | 2 | 1 | 0-28 | 14 | 28.3 | 19.3 | 64.33 | 28 | 33.00 |
| NaCl (4/10) | 2 | 2 | 28-56 | 42 | 17.0 | 8.0 | 26.67 | 56 | 6.33 |
| NaCl (4/10) | 2 | 3 | 56-84 | 70 | 10.3 | 1.3 | 4.33 | 84 | 2.00 |
| NaCl (4/10) | 2 | 4 | 84-112 | 98 | 9.2 | 0.2 | 0.67 | 112 | 1.33 |
| NaCl (4/10) | 2 | 5 | 112-140 | 126 | 9.4 | 0.4 | 1.33 | 140 | 0.00 |
| NaCl (4/10) | 3 | unkacctd | on plate | 0 | | | 1.33 | 0 | 98.67 |
| NaCl (4/10) | 3 | 1 | 0-28 | 14 | 31.1 | 22.1 | 73.67 | 28 | 25.00 |
| NaCl (4/10) | 3 | 2 | 28-56 | 42 | 14.5 | 5.5 | 18.33 | 56 | 6.67 |
| NaCl (4/10) | 3 | 3 | 56-84 | 70 | 10.3 | 1.3 | 4.33 | 84 | 2.33 |
| NaCl (4/10) | 3 | 4 | 84-112 | 98 | 9.6 | 0.6 | 2.00 | 112 | 0.33 |
| NaCl (4/10) | 3 | 5 | 112-140 | 126 | 9.1 | 0.1 | 0.33 | 140 | 0.00 |
| SOS Treated Salt | 1 | unkacctd | on plate | 0 | | | 4.00 | 0 | 96.00 |
| SOS Treated Salt | 1 | 1 | 0-28 | 14 | 26.0 | 17.0 | 56.67 | 28 | 39.33 |
| SOS Treated Salt | 1 | 2 | 28-56 | 42 | 17.8 | 8.8 | 29.33 | 56 | 10.00 |
| SOS Treated Salt | 1 | 3 | 56-84 | 70 | 11.4 | 2.4 | 8.00 | 84 | 2.00 |
| SOS Treated Salt | 1 | 4 | 84-112 | 98 | 9.6 | 0.6 | 2.00 | 112 | 0.00 |
| SOS Treated Salt | 1 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| SOS Treated Salt | 2 | unkacctd | on plate | 0 | | | 0.00 | 0 | 100.00 |
| SOS Treated Salt | 2 | 1 | 0-28 | 14 | 31.4 | 22.4 | 74.67 | 28 | 25.33 |
| SOS Treated Salt | 2 | 2 | 28-56 | 42 | 14.3 | 5.3 | 17.67 | 56 | 7.67 |
| SOS Treated Salt | 2 | 3 | 56-84 | 70 | 10.8 | 1.8 | 6.00 | 84 | 1.67 |
| SOS Treated Salt | 2 | 4 | 84-112 | 98 | 9.5 | 0.5 | 1.67 | 112 | 0.00 |
| SOS Treated Salt | 2 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| SOS Treated Salt | 3 | unkacctd | on plate | 0 | | | 0.33 | 0 | 99.67 |
| SOS Treated Salt | 3 | 1 | 0-28 | 14 | 32.5 | 23.5 | 78.33 | 28 | 21.33 |
| SOS Treated Salt | 3 | 2 | 28-56 | 42 | 13.5 | 4.5 | 15.00 | 56 | 6.33 |
| SOS Treated Salt | 3 | 3 | 56-84 | 70 | 10.7 | 1.7 | 5.67 | 84 | 0.67 |
| SOS Treated Salt | 3 | 4 | 84-112 | 98 | 9.0 | 0.0 | 0.00 | 112 | 0.67 |
| SOS Treated Salt | 3 | 5 | 112-140 | 126 | 9.2 | 0.2 | 0.67 | 140 | 0.00 |


Deicer Bounce Test
% Bouncing Further
Distance from Drop Point (cm)
Rock Salt (Course Gradation)
Rock Salt (Course Gradation)
Rock Salt (Course Gradation)
SOS Treated Salt
SOS Treated Salt
SOS Treated Salt
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160

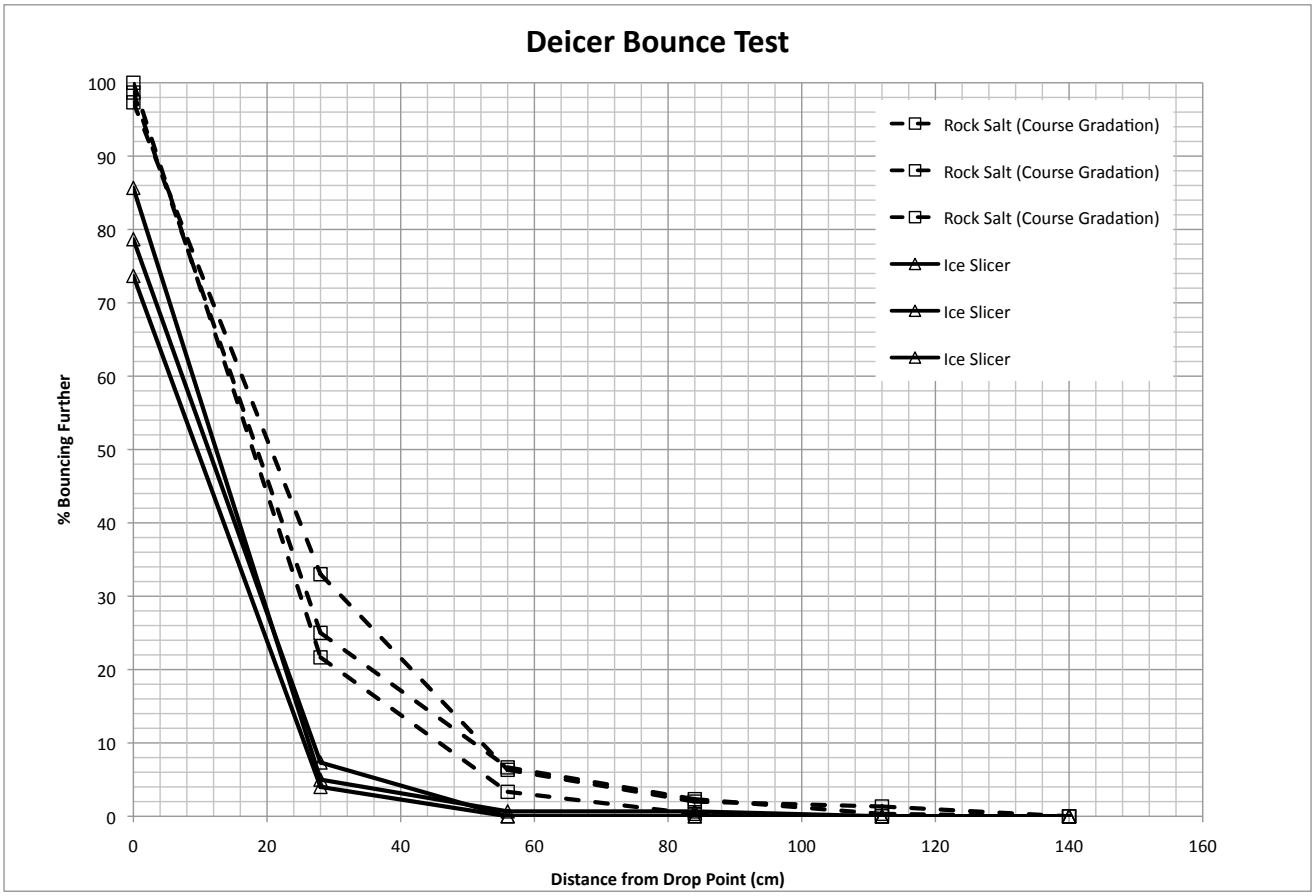
Bounce Test Results
MN/DOT Salt Brine Blending
S. Druschel, MSU Mankato Environmental Engineering
August 10, 2011

| Material | Test Replicate # | Sheet (numbered from drop location) | Distance (cm) | Mean Distance of Range (cm) | Total Mass (Sheet + Deicer) (g) | Net Mass (g) | % of total | Maximum Distance of Step | % Bouncing Beyond Maximum Distance |
|---|---|---|---|---|---|---|---|---|---|
| NaCl (4/10) | 1 | unkacctd | on plate | 0 | | | 0.00 | 0 | 100.00 |
| NaCl (4/10) | 1 | 1 | 0-28 | 14 | 32.5 | 23.5 | 78.33 | 28 | 21.67 |
| NaCl (4/10) | 1 | 2 | 28-56 | 42 | 14.5 | 5.5 | 18.33 | 56 | 3.33 |
| NaCl (4/10) | 1 | 3 | 56-84 | 70 | 9.9 | 0.9 | 3.00 | 84 | 0.33 |
| NaCl (4/10) | 1 | 4 | 84-112 | 98 | 9.1 | 0.1 | 0.33 | 112 | 0.00 |
| NaCl (4/10) | 1 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| NaCl (4/10) | 2 | unkacctd | on plate | 0 | | | 2.67 | 0 | 97.33 |
| NaCl (4/10) | 2 | 1 | 0-28 | 14 | 28.3 | 19.3 | 64.33 | 28 | 33.00 |
| NaCl (4/10) | 2 | 2 | 28-56 | 42 | 17.0 | 8.0 | 26.67 | 56 | 6.33 |
| NaCl (4/10) | 2 | 3 | 56-84 | 70 | 10.3 | 1.3 | 4.33 | 84 | 2.00 |
| NaCl (4/10) | 2 | 4 | 84-112 | 98 | 9.2 | 0.2 | 0.67 | 112 | 1.33 |
| NaCl (4/10) | 2 | 5 | 112-140 | 126 | 9.4 | 0.4 | 1.33 | 140 | 0.00 |
| NaCl (4/10) | 3 | unkacctd | on plate | 0 | | | 1.33 | 0 | 98.67 |
| NaCl (4/10) | 3 | 1 | 0-28 | 14 | 31.1 | 22.1 | 73.67 | 28 | 25.00 |
| NaCl (4/10) | 3 | 2 | 28-56 | 42 | 14.5 | 5.5 | 18.33 | 56 | 6.67 |
| NaCl (4/10) | 3 | 3 | 56-84 | 70 | 10.3 | 1.3 | 4.33 | 84 | 2.33 |
| NaCl (4/10) | 3 | 4 | 84-112 | 98 | 9.6 | 0.6 | 2.00 | 112 | 0.33 |
| NaCl (4/10) | 3 | 5 | 112-140 | 126 | 9.1 | 0.1 | 0.33 | 140 | 0.00 |
| Clearlane Treated Salt | 1 | unkacctd | on plate | 0 | | | 3.67 | 0 | 96.33 |
| Clearlane Treated Salt | 1 | 1 | 0-28 | 14 | 30.1 | 21.1 | 70.33 | 28 | 26.00 |
| Clearlane Treated Salt | 1 | 2 | 28-56 | 42 | 14.5 | 5.5 | 18.33 | 56 | 7.67 |
| Clearlane Treated Salt | 1 | 3 | 56-84 | 70 | 10.7 | 1.7 | 5.67 | 84 | 2.00 |
| Clearlane Treated Salt | 1 | 4 | 84-112 | 98 | 9.6 | 0.6 | 2.00 | 112 | 0.00 |
| Clearlane Treated Salt | 1 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| Clearlane Treated Salt | 2 | unkacctd | on plate | 0 | | | 3.00 | 0 | 97.00 |
| Clearlane Treated Salt | 2 | 1 | 0-28 | 14 | 34.1 | 25.1 | 83.67 | 28 | 13.33 |
| Clearlane Treated Salt | 2 | 2 | 28-56 | 42 | 12.1 | 3.1 | 10.33 | 56 | 3.00 |
| Clearlane Treated Salt | 2 | 3 | 56-84 | 70 | 9.8 | 0.8 | 2.67 | 84 | 0.33 |
| Clearlane Treated Salt | 2 | 4 | 84-112 | 98 | 9.1 | 0.1 | 0.33 | 112 | 0.00 |
| Clearlane Treated Salt | 2 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| Clearlane Treated Salt | 3 | unkacctd | on plate | 0 | | | 0.33 | 0 | 99.67 |
| Clearlane Treated Salt | 3 | 1 | 0-28 | 14 | 34.6 | 25.6 | 85.33 | 28 | 14.33 |
| Clearlane Treated Salt | 3 | 2 | 28-56 | 42 | 12.3 | 3.3 | 11.00 | 56 | 3.33 |
| Clearlane Treated Salt | 3 | 3 | 56-84 | 70 | 9.9 | 0.9 | 3.00 | 84 | 0.33 |
| Clearlane Treated Salt | 3 | 4 | 84-112 | 98 | 9.1 | 0.1 | 0.33 | 112 | 0.00 |
| Clearlane Treated Salt | 3 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |


Deicer Bounce Test
% Bouncing Further
Distance from Drop Point (cm)
Rock Salt (Course Gradation)
Rock Salt (Course Gradation)
Rock Salt (Course Gradation)
Clearlane Treated Salt
Clearlane Treated Salt
Clearlane Treated Salt
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160

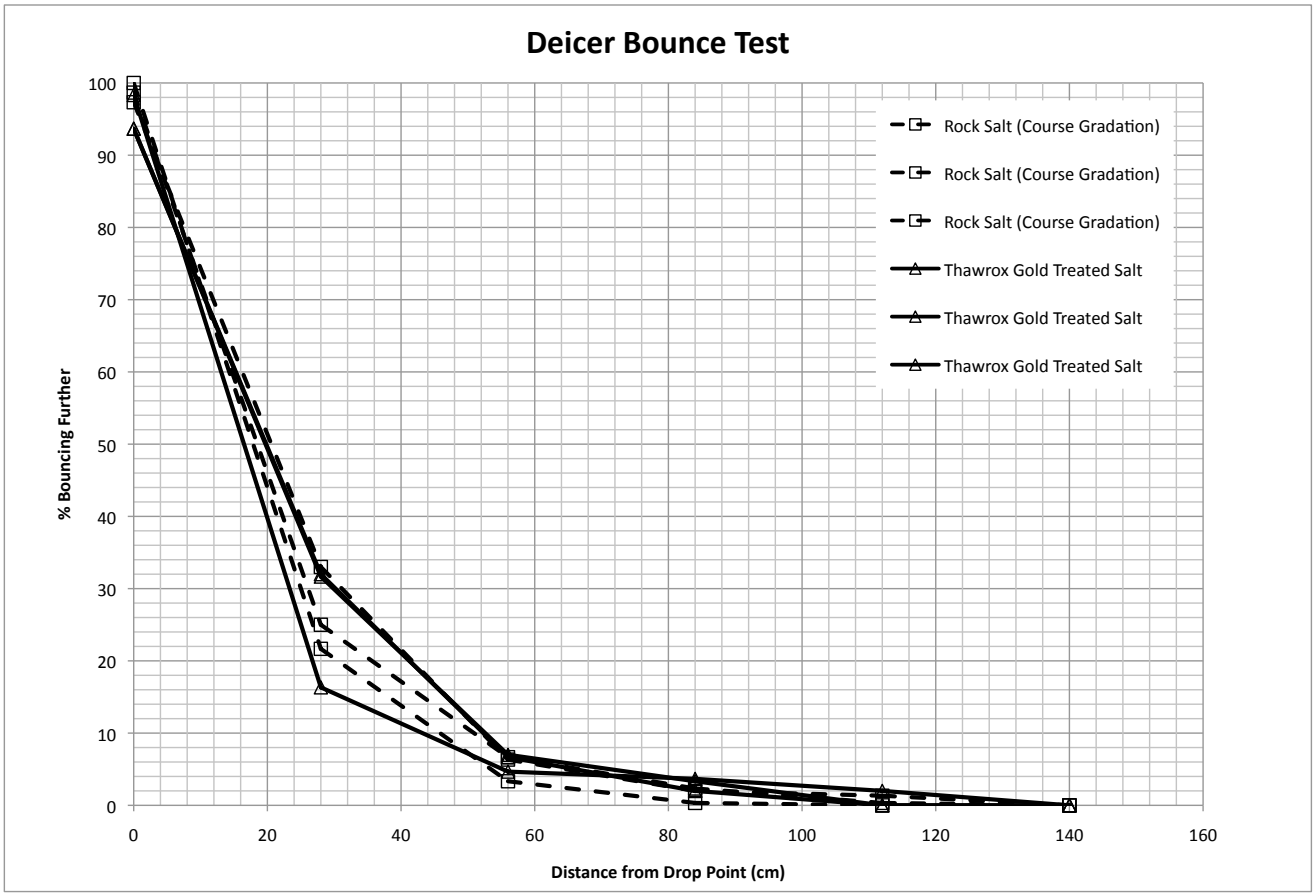
Bounce Test Results
MN/DOT Salt Brine Blending
S. Druschel, MSU Mankato Environmental Engineering
August 10, 2011

| Material | Test Replicate # | Sheet (numbered from drop location) | Distance (cm) | Mean Distance of Range (cm) | Total Mass (Sheet + Deicer) (g) | Net Mass (g) | % of total | Maximum Distance of Step | % Bouncing Beyond Maximum Distance |
|---|---|---|---|---|---|---|---|---|---|
| NaCl (4/10) | 1 | unkacctd | on plate | 0 | | | 0.00 | 0 | 100.00 |
| NaCl (4/10) | 1 | 1 | 0-28 | 14 | 32.5 | 23.5 | 78.33 | 28 | 21.67 |
| NaCl (4/10) | 1 | 2 | 28-56 | 42 | 14.5 | 5.5 | 18.33 | 56 | 3.33 |
| NaCl (4/10) | 1 | 3 | 56-84 | 70 | 9.9 | 0.9 | 3.00 | 84 | 0.33 |
| NaCl (4/10) | 1 | 4 | 84-112 | 98 | 9.1 | 0.1 | 0.33 | 112 | 0.00 |
| NaCl (4/10) | 1 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| NaCl (4/10) | 2 | unkacctd | on plate | 0 | | | 2.67 | 0 | 97.33 |
| NaCl (4/10) | 2 | 1 | 0-28 | 14 | 28.3 | 19.3 | 64.33 | 28 | 33.00 |
| NaCl (4/10) | 2 | 2 | 28-56 | 42 | 17.0 | 8.0 | 26.67 | 56 | 6.33 |
| NaCl (4/10) | 2 | 3 | 56-84 | 70 | 10.3 | 1.3 | 4.33 | 84 | 2.00 |
| NaCl (4/10) | 2 | 4 | 84-112 | 98 | 9.2 | 0.2 | 0.67 | 112 | 1.33 |
| NaCl (4/10) | 2 | 5 | 112-140 | 126 | 9.4 | 0.4 | 1.33 | 140 | 0.00 |
| NaCl (4/10) | 3 | unkacctd | on plate | 0 | | | 1.33 | 0 | 98.67 |
| NaCl (4/10) | 3 | 1 | 0-28 | 14 | 31.1 | 22.1 | 73.67 | 28 | 25.00 |
| NaCl (4/10) | 3 | 2 | 28-56 | 42 | 14.5 | 5.5 | 18.33 | 56 | 6.67 |
| NaCl (4/10) | 3 | 3 | 56-84 | 70 | 10.3 | 1.3 | 4.33 | 84 | 2.33 |
| NaCl (4/10) | 3 | 4 | 84-112 | 98 | 9.6 | 0.6 | 2.00 | 112 | 0.33 |
| NaCl (4/10) | 3 | 5 | 112-140 | 126 | 9.1 | 0.1 | 0.33 | 140 | 0.00 |
| Ice Slicer | 1 | unkacctd | on plate | 0 | | | 14.33 | 0 | 85.67 |
| Ice Slicer | 1 | 1 | 0-28 | 14 | 33.2 | 24.2 | 80.67 | 28 | 5.00 |
| Ice Slicer | 1 | 2 | 28-56 | 42 | 10.3 | 1.3 | 4.33 | 56 | 0.67 |
| Ice Slicer | 1 | 3 | 56-84 | 70 | 9.0 | 0.0 | 0.00 | 84 | 0.67 |
| Ice Slicer | 1 | 4 | 84-112 | 98 | 9.2 | 0.2 | 0.67 | 112 | 0.00 |
| Ice Slicer | 1 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| Ice Slicer | 2 | unkacctd | on plate | 0 | | | 26.33 | 0 | 73.67 |
| Ice Slicer | 2 | 1 | 0-28 | 14 | 29.9 | 20.9 | 69.67 | 28 | 4.00 |
| Ice Slicer | 2 | 2 | 28-56 | 42 | 10.2 | 1.2 | 4.00 | 56 | 0.00 |
| Ice Slicer | 2 | 3 | 56-84 | 70 | 9.0 | 0.0 | 0.00 | 84 | 0.00 |
| Ice Slicer | 2 | 4 | 84-112 | 98 | 9.0 | 0.0 | 0.00 | 112 | 0.00 |
| Ice Slicer | 2 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| Ice Slicer | 3 | unkacctd | on plate | 0 | | | 21.33 | 0 | 78.67 |
| Ice Slicer | 3 | 1 | 0-28 | 14 | 30.4 | 21.4 | 71.33 | 28 | 7.33 |
| Ice Slicer | 3 | 2 | 28-56 | 42 | 11.2 | 2.2 | 7.33 | 56 | 0.00 |
| Ice Slicer | 3 | 3 | 56-84 | 70 | 9.1 | 0.0 | 0.00 | 84 | 0.00 |
| Ice Slicer | 3 | 4 | 84-112 | 98 | 9.0 | 0.0 | 0.00 | 112 | 0.00 |
| Ice Slicer | 3 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |


Deicer Bounce Test
% Bouncing Further
Distance from Drop Point (cm)
Rock Salt (Course Gradation)
Rock Salt (Course Gradation)
Rock Salt (Course Gradation)
Ice Slicer
Ice Slicer
Ice Slicer
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160

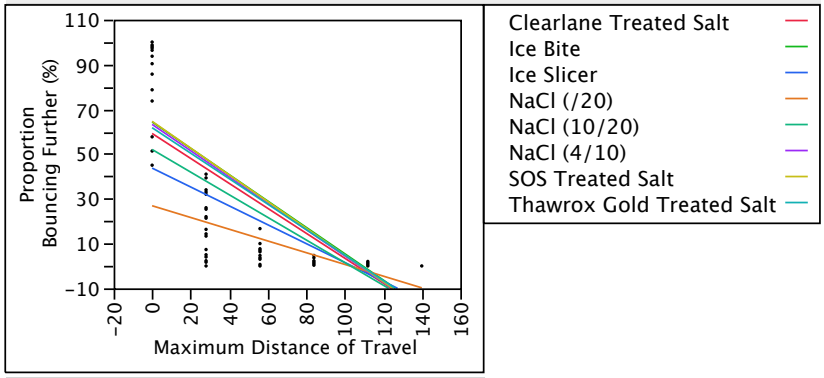
Bounce Test Results
MN/DOT Salt Brine Blending
S. Druschel, MSU Mankato Environmental Engineering
August 10, 2011

| Material | Test Replicate # | Sheet (numbered from drop location) | Distance (cm) | Mean Distance of Range (cm) | Total Mass (Sheet + Deicer) (g) | Net Mass (g) | % of total | Maximum Distance of Step | % Bouncing Beyond Maximum Distance |
|---|---|---|---|---|---|---|---|---|---|
| NaCl (4/10) | 1 | unkacctd | on plate | 0 | | | 0.00 | 0 | 100.00 |
| NaCl (4/10) | 1 | 1 | 0-28 | 14 | 32.5 | 23.5 | 78.33 | 28 | 21.67 |
| NaCl (4/10) | 1 | 2 | 28-56 | 42 | 14.5 | 5.5 | 18.33 | 56 | 3.33 |
| NaCl (4/10) | 1 | 3 | 56-84 | 70 | 9.9 | 0.9 | 3.00 | 84 | 0.33 |
| NaCl (4/10) | 1 | 4 | 84-112 | 98 | 9.1 | 0.1 | 0.33 | 112 | 0.00 |
| NaCl (4/10) | 1 | 5 | 112-140 | 126 | 0.0 | 0.0 | 0.00 | 140 | 0.00 |
| NaCl (4/10) | 2 | unkacctd | on plate | 0 | | | 2.67 | 0 | 97.33 |
| NaCl (4/10) | 2 | 1 | 0-28 | 14 | 28.3 | 19.3 | 64.33 | 28 | 33.00 |
| NaCl (4/10) | 2 | 2 | 28-56 | 42 | 17.0 | 8.0 | 26.67 | 56 | 6.33 |
| NaCl (4/10) | 2 | 3 | 56-84 | 70 | 10.3 | 1.3 | 4.33 | 84 | 2.00 |
| NaCl (4/10) | 2 | 4 | 84-112 | 98 | 9.2 | 0.2 | 0.67 | 112 | 1.33 |
| NaCl (4/10) | 2 | 5 | 112-140 | 126 | 9.4 | 0.4 | 1.33 | 140 | 0.00 |
| NaCl (4/10) | 3 | unkacctd | on plate | 0 | | | 1.33 | 0 | 98.67 |
| NaCl (4/10) | 3 | 1 | 0-28 | 14 | 31.1 | 22.1 | 73.67 | 28 | 25.00 |
| NaCl (4/10) | 3 | 2 | 28-56 | 42 | 14.5 | 5.5 | 18.33 | 56 | 6.67 |
| NaCl (4/10) | 3 | 3 | 56-84 | 70 | 10.3 | 1.3 | 4.33 | 84 | 2.33 |
| NaCl (4/10) | 3 | 4 | 84-112 | 98 | 9.6 | 0.6 | 2.00 | 112 | 0.33 |
| NaCl (4/10) | 3 | 5 | 112-140 | 126 | 9.1 | 0.1 | 0.33 | 140 | 0.00 |
| Thawrox Gold Treated Salt | 1 | unkacctd | on plate | 0 | | | 1.67 | 0 | 98.33 |
| Thawrox Gold Treated Salt | 1 | 1 | 0-28 | 14 | 33.6 | 24.6 | 82.00 | 28 | 16.33 |
| Thawrox Gold Treated Salt | 1 | 2 | 28-56 | 42 | 12.5 | 3.5 | 11.67 | 56 | 4.67 |
| Thawrox Gold Treated Salt | 1 | 3 | 56-84 | 70 | 9.3 | 0.3 | 1.00 | 84 | 3.67 |
| Thawrox Gold Treated Salt | 1 | 4 | 84-112 | 98 | 9.5 | 0.5 | 1.67 | 112 | 2.00 |
| Thawrox Gold Treated Salt | 1 | 5 | 112-140 | 126 | 9.6 | 0.6 | 2.00 | 140 | 0.00 |
| Thawrox Gold Treated Salt | 2 | unkacctd | on plate | 0 | | | 6.33 | 0 | 93.67 |
| Thawrox Gold Treated Salt | 2 | 1 | 0-28 | 14 | 27.6 | 18.6 | 62.00 | 28 | 31.67 |
| Thawrox Gold Treated Salt | 2 | 2 | 28-56 | 42 | 16.4 | 7.4 | 24.67 | 56 | 7.00 |
| Thawrox Gold Treated Salt | 2 | 3 | 56-84 | 70 | 10.1 | 1.1 | 3.67 | 84 | 3.33 |
| Thawrox Gold Treated Salt | 2 | 4 | 84-112 | 98 | 10.0 | 1.0 | 3.33 | 112 | 0.00 |
| Thawrox Gold Treated Salt | 2 | 5 | 112-140 | 126 | 9.0 | 0.0 | 0.00 | 140 | 0.00 |
| Thawrox Gold Treated Salt | 3 | unkacctd | on plate | 0 | | | 6.33 | 0 | 93.67 |
| Thawrox Gold Treated Salt | 3 | 1 | 0-28 | 14 | 27.8 | 18.5 | 61.67 | 28 | 32.00 |
| Thawrox Gold Treated Salt | 3 | 2 | 28-56 | 42 | 16.6 | 7.6 | 25.33 | 56 | 6.67 |
| Thawrox Gold Treated Salt | 3 | 3 | 56-84 | 70 | 10.4 | 1.4 | 4.67 | 84 | 2.00 |
| Thawrox Gold Treated Salt | 3 | 4 | 84-112 | 98 | 9.6 | 0.6 | 2.00 | 112 | 0.00 |
| Thawrox Gold Treated Salt | 3 | 5 | 112-140 | 126 | 9.0 | 0.0 | 0.00 | 140 | 0.00 |

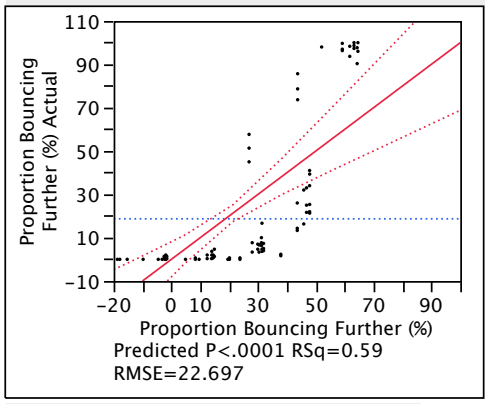

Deicer Bounce Test
% Bouncing Further
Distance from Drop Point (cm)
Rock Salt (Course Gradation)
Rock Salt (Course Gradation)
Rock Salt (Course Gradation)
Thawrox Gold Treated Salt
Thawrox Gold Treated Salt
Thawrox Gold Treated Salt
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160

## Response Proportion Bouncing Further (%)

### Regression Plot




### Actual by Predicted Plot




### Summary of Fit

| | |
|---|---|
| RSquare | 0.58557 |
| RSquare Adj | 0.537004 |
| Root Mean Square Error | 22.69713 |
| Mean of Response | 18.70375 |
| Observations (or Sum Wgts) | 144 |

### Analysis of Variance

| Source | DF | Sum of Squares | Mean Square | F Ratio |
|---|---|---|---|---|
| Model | 15 | 93170.88 | 6211.39 | 12.0572 |
| Error | 128 | 65940.45 | 515.16 | **Prob > F** |
| C. Total | 143 | 159111.33 | | <.0001* |

### Lack Of Fit

| Source | DF | Sum of Squares | Mean Square | F Ratio |
|---|---|---|---|---|
| Lack Of Fit | 32 | 64866.705 | 2027.08 | 181.2348 |
| Pure Error | 96 | 1073.746 | 11.18 | **Prob > F** |
| Total Error | 128 | 65940.450 | | <.0001* |
| | | | | **Max RSq** |
| | | | | 0.9933 |

### Parameter Estimates

| Term | Estimate | Std Error | t Ratio | Prob>\|t\| |
|---|---|---|---|---|
| Intercept | 54.454107 | 3.353143 | 16.24 | <.0001* |
| Maximum Distance of Travel | −0.510719 | 0.039554 | −12.91 | <.0001* |
| (Maximum Distance of Travel−70)*Material[Clearlane Treated Salt] | −0.046192 | 0.10465 | −0.44 | 0.6597 |
| (Maximum Distance of Travel−70)*Material[Ice Bite] | −0.077611 | 0.10465 | −0.74 | 0.4597 |
| (Maximum Distance of Travel−70)*Material[Ice Slicer] | 0.0892772 | 0.10465 | 0.85 | 0.3952 |
| (Maximum Distance of Travel−70)*Material[NaCl (/20)] | 0.2488146 | 0.10465 | 2.38 | 0.0189* |
| (Maximum Distance of Travel−70)*Material[NaCl (10/20)] | 0.005716 | 0.10465 | 0.05 | 0.9565 |
| (Maximum Distance of Travel−70)*Material[NaCl (4/10)] | −0.076253 | 0.10465 | −0.73 | 0.4675 |
| (Maximum Distance of Travel−70)*Material[SOS Treated Salt] | −0.085869 | 0.10465 | −0.82 | 0.4134 |
| Material[Clearlane Treated Salt] | 1.4806944 | 5.004247 | 0.30 | 0.7678 |
| Material[Ice Bite] | 4.4256944 | 5.004247 | 0.88 | 0.3781 |
| Material[Ice Slicer] | −4.499306 | 5.004247 | −0.90 | 0.3703 |
| Material[NaCl (/20)] | −10.14819 | 5.004247 | −2.03 | 0.0446* |
| Material[NaCl (10/20)] | −2.036528 | 5.004247 | −0.41 | 0.6847 |
| Material[NaCl (4/10)] | 3.4251389 | 5.004247 | 0.68 | 0.4949 |
| Material[SOS Treated Salt] | 4.11125 | 5.004247 | 0.82 | 0.4129 |

## Response Proportion Bouncing Further (%)

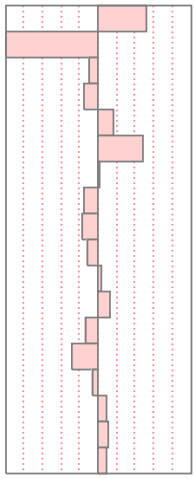
### Effect Tests

| Source | Nparm | DF | Sum of Squares | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Maximum Distance of Travel | 1 | 1 | 85887.516 | 166.7202 | <.0001* |
| Maximum Distance of Travel*Material | 7 | 7 | 3894.041 | 1.0798 | 0.3801 |
| Material | 7 | 7 | 3389.327 | 0.9399 | 0.4783 |

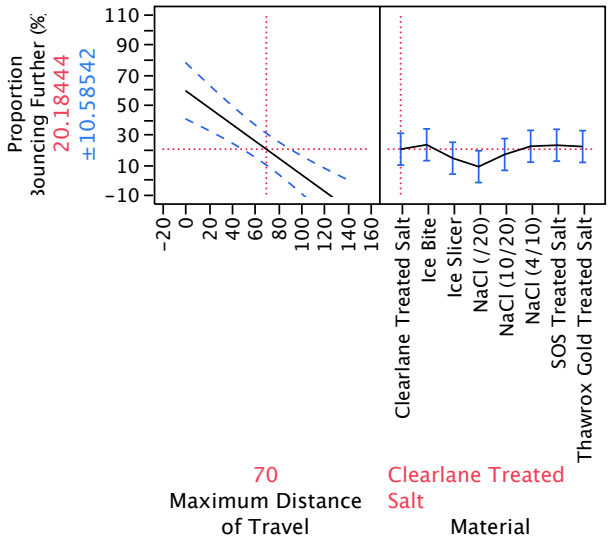
### Scaled Estimates

Nominal factors expanded to all levels
Continuous factors centered by mean, scaled by range/2

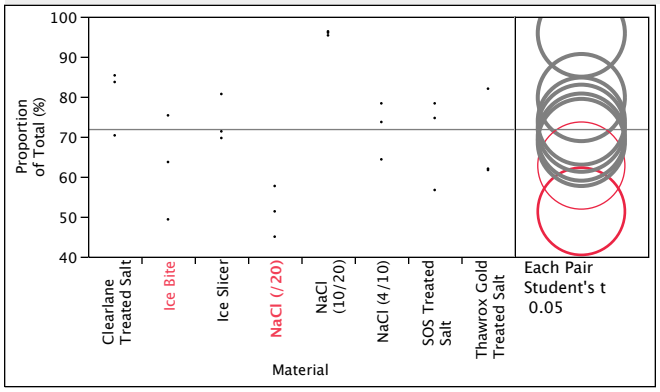
| Term | Scaled Estimate | Std Error | t Ratio | Prob>\|t\| |
|---|---|---|---|---|
| Intercept | 18.70375 | 1.891428 | 9.89 | <.0001* |
| Maximum Distance of Travel | -35.75036 | 2.768767 | -12.91 | <.0001* |
| (Maximum Distance of Travel-70)*Material[Clearlane Treated Salt] | -3.233452 | 7.325468 | -0.44 | 0.6597 |
| (Maximum Distance of Travel-70)*Material[Ice Bite] | -5.432738 | 7.325468 | -0.74 | 0.4597 |
| (Maximum Distance of Travel-70)*Material[Ice Slicer] | 6.2494048 | 7.325468 | 0.85 | 0.3952 |
| (Maximum Distance of Travel-70)*Material[NaCl (/20)] | 17.417024 | 7.325468 | 2.38 | 0.0189* |
| (Maximum Distance of Travel-70)*Material[NaCl (10/20)] | 0.400119 | 7.325468 | 0.05 | 0.9565 |
| (Maximum Distance of Travel-70)*Material[NaCl (4/10)] | -5.337738 | 7.325468 | -0.73 | 0.4675 |
| (Maximum Distance of Travel-70)*Material[SOS Treated Salt] | -6.010833 | 7.325468 | -0.82 | 0.4134 |
| (Maximum Distance of Travel-70)*Material[Thawrox Gold Treated Salt] | -4.051786 | 7.325468 | -0.55 | 0.5812 |
| Material[Clearlane Treated Salt] | 1.4806944 | 5.004247 | 0.30 | 0.7678 |
| Material[Ice Bite] | 4.4256944 | 5.004247 | 0.88 | 0.3781 |
| Material[Ice Slicer] | -4.499306 | 5.004247 | -0.90 | 0.3703 |
| Material[NaCl (/20)] | -10.14819 | 5.004247 | -2.03 | 0.0446* |
| Material[NaCl (10/20)] | -2.036528 | 5.004247 | -0.41 | 0.6847 |
| Material[NaCl (4/10)] | 3.4251389 | 5.004247 | 0.68 | 0.4949 |
| Material[SOS Treated Salt] | 4.11125 | 5.004247 | 0.82 | 0.4129 |
| Material[Thawrox Gold Treated Salt] | 3.24125 | 5.004247 | 0.65 | 0.5183 |



### Prediction Profiler



## Oneway Analysis of Proportion of Total (%) By Material Distance Range=0-28




### Means Comparisons

#### Comparisons for each pair using Student's t

| t | Alpha |
|---|---|
| 2.11991 | 0.05 |

Abs(Dif)-LSD

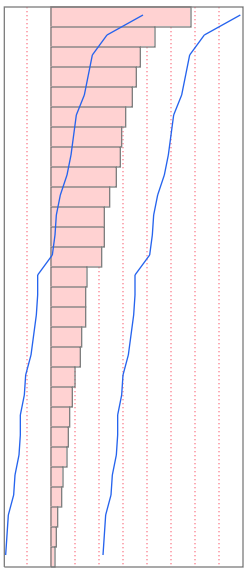
| | NaCl (10/20) | Clearlane Treated Salt | Ice Slicer | NaCl (4/10) | SOS Treated Salt | Thawrox Gold Treated Salt | Ice Bite | NaCl (/20) |
|---|---|---|---|---|---|---|---|---|
| NaCl (10/20) | -15.4039 | 0.706074 | 6.592741 | 8.372741 | 10.59274 | 11.92607 | 17.70607 | 29.14941 |
| Clearlane Treated Salt | 0.706074 | -15.4039 | -9.51726 | -7.73726 | -5.51726 | -4.18393 | 1.596074 | 13.03941 |
| Ice Slicer | 6.592741 | -9.51726 | -15.4039 | -13.6239 | -11.4039 | -10.0706 | -4.29059 | 7.152741 |
| NaCl (4/10) | 8.372741 | -7.73726 | -13.6239 | -15.4039 | -13.1839 | -11.8506 | -6.07059 | 5.372741 |
| SOS Treated Salt | 10.59274 | -5.51726 | -11.4039 | -13.1839 | -15.4039 | -14.0706 | -8.29059 | 3.152741 |
| Thawrox Gold Treated Salt | 11.92607 | -4.18393 | -10.0706 | -11.8506 | -14.0706 | -15.4039 | -9.62393 | 1.819407 |
| Ice Bite | 17.70607 | 1.596074 | -4.29059 | -6.07059 | -8.29059 | -9.62393 | -15.4039 | -3.96059 |
| NaCl (/20) | 29.14941 | 13.03941 | 7.152741 | 5.372741 | 3.152741 | 1.819407 | -3.96059 | -15.4039 |

Positive values show pairs of means that are significantly different.

| Level | | | Mean |
|---|---|---|---|
| NaCl (10/20) | A | | 95.886667 |
| Clearlane Treated Salt | | B | 79.776667 |
| Ice Slicer | | B | C 73.890000 |
| NaCl (4/10) | | B | C 72.110000 |
| SOS Treated Salt | | B | C 69.890000 |
| Thawrox Gold Treated Salt | | B | C 68.556667 |
| Ice Bite | | | C D 62.776667 |
| NaCl (/20) | | | D 51.333333 |

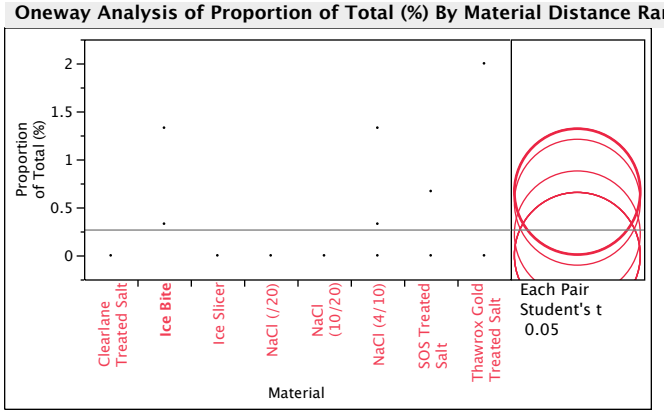
Levels not connected by same letter are significantly different.

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| NaCl (10/20) | NaCl (/20) | 44.55333 | 7.266327 | 29.1494 | 59.95726 | <.0001* |
| NaCl (10/20) | Ice Bite | 33.11000 | 7.266327 | 17.7061 | 48.51393 | 0.0003* |
| Clearlane Treated Salt | NaCl (/20) | 28.44333 | 7.266327 | 13.0394 | 43.84726 | 0.0012* |
| NaCl (10/20) | Thawrox Gold Treated Salt | 27.33000 | 7.266327 | 11.9261 | 42.73393 | 0.0017* |
| NaCl (10/20) | SOS Treated Salt | 25.99667 | 7.266327 | 10.5927 | 41.40059 | 0.0025* |
| NaCl (10/20) | NaCl (4/10) | 23.77667 | 7.266327 | 8.3727 | 39.18059 | 0.0048* |
| Ice Slicer | NaCl (/20) | 22.55667 | 7.266327 | 7.1527 | 37.96059 | 0.0068* |
| NaCl (10/20) | Ice Slicer | 21.99667 | 7.266327 | 6.5927 | 37.40059 | 0.0080* |
| NaCl (4/10) | NaCl (/20) | 20.77667 | 7.266327 | 5.3727 | 36.18059 | 0.0114* |
| SOS Treated Salt | NaCl (/20) | 18.55667 | 7.266327 | 3.1527 | 33.96059 | 0.0212* |
| Thawrox Gold Treated Salt | NaCl (/20) | 17.22333 | 7.266327 | 1.8194 | 32.62726 | 0.0307* |
| Clearlane Treated Salt | Ice Bite | 17.00000 | 7.266327 | 1.5961 | 32.40393 | 0.0326* |
| NaCl (10/20) | Clearlane Treated Salt | 16.11000 | 7.266327 | 0.7061 | 31.51393 | 0.0414* |
| Ice Bite | NaCl (/20) | 11.44333 | 7.266327 | -3.9606 | 26.84726 | 0.1349 |
| Clearlane Treated Salt | Thawrox Gold Treated Salt | 11.22000 | 7.266327 | -4.1839 | 26.62393 | 0.1421 |
| Ice Slicer | Ice Bite | 11.11333 | 7.266327 | -4.2906 | 26.51726 | 0.1457 |
| Clearlane Treated Salt | SOS Treated Salt | 9.88667 | 7.266327 | -5.5173 | 25.29059 | 0.1925 |
| NaCl (4/10) | Ice Bite | 9.33333 | 7.266327 | -6.0706 | 24.73726 | 0.2173 |
| Clearlane Treated Salt | NaCl (4/10) | 7.66667 | 7.266327 | -7.7373 | 23.07059 | 0.3071 |
| SOS Treated Salt | Ice Bite | 7.11333 | 7.266327 | -8.2906 | 22.51726 | 0.3422 |
| Clearlane Treated Salt | Ice Slicer | 5.88667 | 7.266327 | -9.5173 | 21.29059 | 0.4298 |
| Thawrox Gold Treated Salt | Ice Bite | 5.78000 | 7.266327 | -9.6239 | 21.18393 | 0.4380 |
| Ice Slicer | Thawrox Gold Treated Salt | 5.33333 | 7.266327 | -10.0706 | 20.73726 | 0.4736 |
| Ice Slicer | SOS Treated Salt | 4.00000 | 7.266327 | -11.4039 | 19.40393 | 0.5896 |
| NaCl (4/10) | Thawrox Gold Treated Salt | 3.55333 | 7.266327 | -11.8506 | 18.95726 | 0.6315 |
| NaCl (4/10) | SOS Treated Salt | 2.22000 | 7.266327 | -13.1839 | 17.62393 | 0.7639 |
| Ice Slicer | NaCl (4/10) | 1.78000 | 7.266327 | -13.6239 | 17.18393 | 0.8096 |
| SOS Treated Salt | Thawrox Gold Treated Salt | 1.33333 | 7.266327 | -14.0706 | 16.73726 | 0.8567 |



## Oneway Analysis of Proportion of Total (%) By Material Distance Range=112-140

## Oneway Analysis of Proportion of Total (%) By Material Distance Range=112-140




### Means Comparisons

#### Comparisons for each pair using Student's t

| t | Alpha |
|---|---|
| 2.11991 | 0.05 |

Abs(Dif)-LSD

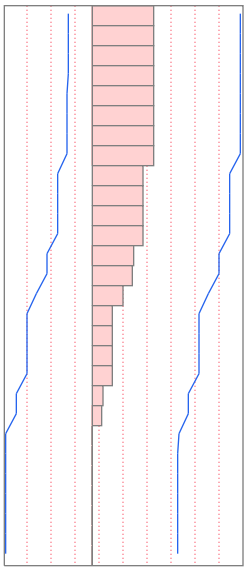
| | Thawrox Gold Treated Salt | Ice Bite | NaCl (4/10) | SOS Treated Salt | Clearlane Treated Salt | NaCl (10/20) | Ice Slicer | NaCl (/20) |
|---|---|---|---|---|---|---|---|---|
| Thawrox Gold Treated Salt | -0.92727 | -0.92394 | -0.81394 | -0.48394 | -0.2606 | -0.2606 | -0.2606 | -0.2606 |
| Ice Bite | -0.92394 | -0.92727 | -0.81727 | -0.48727 | -0.26394 | -0.26394 | -0.26394 | -0.26394 |
| NaCl (4/10) | -0.81394 | -0.81727 | -0.92727 | -0.59727 | -0.37394 | -0.37394 | -0.37394 | -0.37394 |
| SOS Treated Salt | -0.48394 | -0.48727 | -0.59727 | -0.92727 | -0.70394 | -0.70394 | -0.70394 | -0.70394 |
| Clearlane Treated Salt | -0.2606 | -0.26394 | -0.37394 | -0.70394 | -0.92727 | -0.92727 | -0.92727 | -0.92727 |
| NaCl (10/20) | -0.2606 | -0.26394 | -0.37394 | -0.70394 | -0.92727 | -0.92727 | -0.92727 | -0.92727 |
| Ice Slicer | -0.2606 | -0.26394 | -0.37394 | -0.70394 | -0.92727 | -0.92727 | -0.92727 | -0.92727 |
| NaCl (/20) | -0.2606 | -0.26394 | -0.37394 | -0.70394 | -0.92727 | -0.92727 | -0.92727 | -0.92727 |

Positive values show pairs of means that are significantly different.

| Level | | Mean |
|---|---|---|
| Thawrox Gold Treated Salt | A | 0.66666667 |
| Ice Bite | A | 0.66333333 |
| NaCl (4/10) | A | 0.55333333 |
| SOS Treated Salt | A | 0.22333333 |
| Clearlane Treated Salt | A | 0.00000000 |
| NaCl (10/20) | A | 0.00000000 |
| Ice Slicer | A | 0.00000000 |
| NaCl (/20) | A | 0.00000000 |

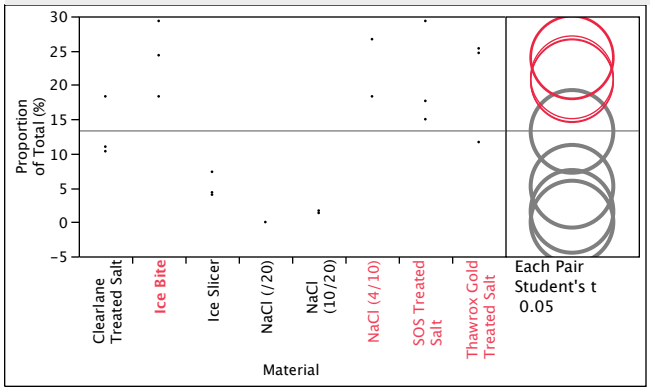
Levels not connected by same letter are significantly different.

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| Thawrox Gold Treated Salt | Clearlane Treated Salt | 0.6666667 | 0.4374103 | -0.260602 | 1.593935 | 0.1470 |
| Thawrox Gold Treated Salt | NaCl (10/20) | 0.6666667 | 0.4374103 | -0.260602 | 1.593935 | 0.1470 |
| Thawrox Gold Treated Salt | Ice Slicer | 0.6666667 | 0.4374103 | -0.260602 | 1.593935 | 0.1470 |
| Thawrox Gold Treated Salt | NaCl (/20) | 0.6666667 | 0.4374103 | -0.260602 | 1.593935 | 0.1470 |
| Ice Bite | Clearlane Treated Salt | 0.6633333 | 0.4374103 | -0.263935 | 1.590602 | 0.1489 |
| Ice Bite | NaCl (10/20) | 0.6633333 | 0.4374103 | -0.263935 | 1.590602 | 0.1489 |
| Ice Bite | Ice Slicer | 0.6633333 | 0.4374103 | -0.263935 | 1.590602 | 0.1489 |
| Ice Bite | NaCl (/20) | 0.6633333 | 0.4374103 | -0.263935 | 1.590602 | 0.1489 |
| NaCl (4/10) | Clearlane Treated Salt | 0.5533333 | 0.4374103 | -0.373935 | 1.480602 | 0.2240 |
| NaCl (4/10) | NaCl (10/20) | 0.5533333 | 0.4374103 | -0.373935 | 1.480602 | 0.2240 |
| NaCl (4/10) | Ice Slicer | 0.5533333 | 0.4374103 | -0.373935 | 1.480602 | 0.2240 |
| NaCl (4/10) | NaCl (/20) | 0.5533333 | 0.4374103 | -0.373935 | 1.480602 | 0.2240 |
| Thawrox Gold Treated Salt | SOS Treated Salt | 0.4433333 | 0.4374103 | -0.483935 | 1.370602 | 0.3259 |
| Ice Bite | SOS Treated Salt | 0.4400000 | 0.4374103 | -0.487268 | 1.367268 | 0.3294 |
| NaCl (4/10) | SOS Treated Salt | 0.3300000 | 0.4374103 | -0.597268 | 1.257268 | 0.4615 |
| SOS Treated Salt | Clearlane Treated Salt | 0.2233333 | 0.4374103 | -0.703935 | 1.150602 | 0.6166 |
| SOS Treated Salt | NaCl (10/20) | 0.2233333 | 0.4374103 | -0.703935 | 1.150602 | 0.6166 |
| SOS Treated Salt | Ice Slicer | 0.2233333 | 0.4374103 | -0.703935 | 1.150602 | 0.6166 |
| SOS Treated Salt | NaCl (/20) | 0.2233333 | 0.4374103 | -0.703935 | 1.150602 | 0.6166 |
| Thawrox Gold Treated Salt | NaCl (4/10) | 0.1133333 | 0.4374103 | -0.813935 | 1.040602 | 0.7989 |
| Ice Bite | NaCl (4/10) | 0.1100000 | 0.4374103 | -0.817268 | 1.037268 | 0.8046 |
| Thawrox Gold Treated Salt | Ice Bite | 0.0033333 | 0.4374103 | -0.923935 | 0.930602 | 0.9940 |
| NaCl (10/20) | Clearlane Treated Salt | 0.0000000 | 0.4374103 | -0.927268 | 0.927268 | 1.0000 |
| Ice Slicer | Clearlane Treated Salt | 0.0000000 | 0.4374103 | -0.927268 | 0.927268 | 1.0000 |
| Ice Slicer | NaCl (10/20) | 0.0000000 | 0.4374103 | -0.927268 | 0.927268 | 1.0000 |
| NaCl (/20) | Clearlane Treated Salt | 0.0000000 | 0.4374103 | -0.927268 | 0.927268 | 1.0000 |
| NaCl (/20) | NaCl (10/20) | 0.0000000 | 0.4374103 | -0.927268 | 0.927268 | 1.0000 |
| NaCl (/20) | Ice Slicer | 0.0000000 | 0.4374103 | -0.927268 | 0.927268 | 1.0000 |



## Oneway Analysis of Proportion of Total (%) By Material Distance Range=28-56

## Oneway Analysis of Proportion of Total (%) By Material Distance Range=28-56




### Means Comparisons

#### Comparisons for each pair using Student's t

| t | Alpha |
|---|---|
| 2.11991 | 0.05 |

Abs(Dif)-LSD

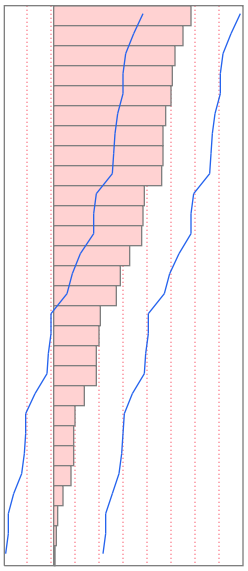
| | Ice Bite | NaCl (4/10) | SOS Treated Salt | Thawrox Gold Treated Salt | Clearlane Treated Salt | Ice Slicer | NaCl (10/20) | NaCl (/20) |
|---|---|---|---|---|---|---|---|---|
| Ice Bite | -8.52434 | -5.63767 | -5.19434 | -5.08434 | 2.252327 | 10.25233 | 13.91566 | 15.47233 |
| NaCl (4/10) | -5.63767 | -8.52434 | -8.08101 | -7.97101 | -0.63434 | 7.36566 | 11.02899 | 12.58566 |
| SOS Treated Salt | -5.19434 | -8.08101 | -8.52434 | -8.41434 | -1.07767 | 6.922327 | 10.58566 | 12.14233 |
| Thawrox Gold Treated Salt | -5.08434 | -7.97101 | -8.41434 | -8.52434 | -1.18767 | 6.812327 | 10.47566 | 12.03233 |
| Clearlane Treated Salt | 2.252327 | -0.63434 | -1.07767 | -1.18767 | -8.52434 | -0.52434 | 3.138993 | 4.69566 |
| Ice Slicer | 10.25233 | 7.36566 | 6.922327 | 6.812327 | -0.52434 | -8.52434 | -4.86101 | -3.30434 |
| NaCl (10/20) | 13.91566 | 11.02899 | 10.58566 | 10.47566 | 3.138993 | -4.86101 | -8.52434 | -6.96767 |
| NaCl (/20) | 15.47233 | 12.58566 | 12.14233 | 12.03233 | 4.69566 | -3.30434 | -6.96767 | -8.52434 |

Positive values show pairs of means that are significantly different.

| Level | | | Mean |
|---|---|---|---|
| Ice Bite | A | | 23.996667 |
| NaCl (4/10) | A | B | 21.110000 |
| SOS Treated Salt | A | B | 20.666667 |
| Thawrox Gold Treated Salt | A | B | 20.556667 |
| Clearlane Treated Salt | | B C | 13.220000 |
| Ice Slicer | | C D | 5.220000 |
| NaCl (10/20) | | D | 1.556667 |
| NaCl (/20) | | D | 0.000000 |

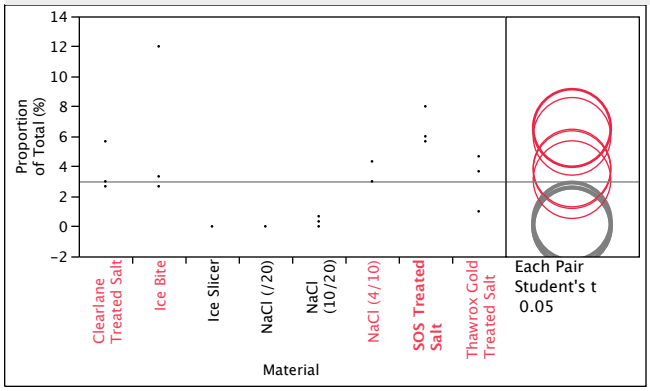
Levels not connected by same letter are significantly different.

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| Ice Bite | NaCl (/20) | 23.99667 | 4.021095 | 15.4723 | 32.52101 | <.0001* |
| Ice Bite | NaCl (10/20) | 22.44000 | 4.021095 | 13.9157 | 30.96434 | <.0001* |
| NaCl (4/10) | NaCl (/20) | 21.11000 | 4.021095 | 12.5857 | 29.63434 | <.0001* |
| SOS Treated Salt | NaCl (/20) | 20.66667 | 4.021095 | 12.1423 | 29.19101 | <.0001* |
| Thawrox Gold Treated Salt | NaCl (/20) | 20.55667 | 4.021095 | 12.0323 | 29.08101 | 0.0001* |
| NaCl (4/10) | NaCl (10/20) | 19.55333 | 4.021095 | 11.0290 | 28.07767 | 0.0002* |
| SOS Treated Salt | NaCl (10/20) | 19.11000 | 4.021095 | 10.5857 | 27.63434 | 0.0002* |
| Thawrox Gold Treated Salt | NaCl (10/20) | 19.00000 | 4.021095 | 10.4757 | 27.52434 | 0.0002* |
| Ice Bite | Ice Slicer | 18.77667 | 4.021095 | 10.2523 | 27.30101 | 0.0003* |
| NaCl (4/10) | Ice Slicer | 15.89000 | 4.021095 | 7.3657 | 24.41434 | 0.0011* |
| SOS Treated Salt | Ice Slicer | 15.44667 | 4.021095 | 6.9223 | 23.97101 | 0.0014* |
| Thawrox Gold Treated Salt | Ice Slicer | 15.33667 | 4.021095 | 6.8123 | 23.86101 | 0.0015* |
| Clearlane Treated Salt | NaCl (/20) | 13.22000 | 4.021095 | 4.6957 | 21.74434 | 0.0046* |
| Clearlane Treated Salt | NaCl (10/20) | 11.66333 | 4.021095 | 3.1390 | 20.18767 | 0.0104* |
| Ice Bite | Clearlane Treated Salt | 10.77667 | 4.021095 | 2.2523 | 19.30101 | 0.0164* |
| Clearlane Treated Salt | Ice Slicer | 8.00000 | 4.021095 | -0.5243 | 16.52434 | 0.0640 |
| NaCl (4/10) | Clearlane Treated Salt | 7.89000 | 4.021095 | -0.6343 | 16.41434 | 0.0674 |
| SOS Treated Salt | Clearlane Treated Salt | 7.44667 | 4.021095 | -1.0777 | 15.97101 | 0.0826 |
| Thawrox Gold Treated Salt | Clearlane Treated Salt | 7.33667 | 4.021095 | -1.1877 | 15.86101 | 0.0868 |
| Ice Slicer | NaCl (/20) | 5.22000 | 4.021095 | -3.3043 | 13.74434 | 0.2126 |
| Ice Slicer | NaCl (10/20) | 3.66333 | 4.021095 | -4.8610 | 12.18767 | 0.3758 |
| Ice Bite | Thawrox Gold Treated Salt | 3.44000 | 4.021095 | -5.0843 | 11.96434 | 0.4049 |
| Ice Bite | SOS Treated Salt | 3.33000 | 4.021095 | -5.1943 | 11.85434 | 0.4198 |
| Ice Bite | NaCl (4/10) | 2.88667 | 4.021095 | -5.6377 | 11.41101 | 0.4832 |
| NaCl (10/20) | NaCl (/20) | 1.55667 | 4.021095 | -6.9677 | 10.08101 | 0.7038 |
| NaCl (4/10) | Thawrox Gold Treated Salt | 0.55333 | 4.021095 | -7.9710 | 9.07767 | 0.8923 |
| NaCl (4/10) | SOS Treated Salt | 0.44333 | 4.021095 | -8.0810 | 8.96767 | 0.9136 |
| SOS Treated Salt | Thawrox Gold Treated Salt | 0.11000 | 4.021095 | -8.4143 | 8.63434 | 0.9785 |



## Oneway Analysis of Proportion of Total (%) By Material Distance Range=56-84

## Oneway Analysis of Proportion of Total (%) By Material Distance Range=56-84




### Means Comparisons

#### Comparisons for each pair using Student's t

| t | Alpha |
|---|---|
| 2.11991 | 0.05 |

Abs(Dif)-LSD

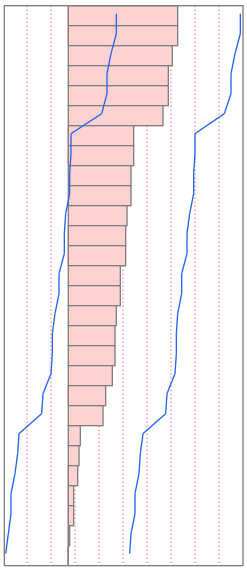
| | SOS Treated Salt | Ice Bite | NaCl (4/10) | Clearlane Treated Salt | Thawrox Gold Treated Salt | NaCl (10/20) | Ice Slicer | NaCl (/20) |
|---|---|---|---|---|---|---|---|---|
| SOS Treated Salt | -3.65678 | -3.10011 | -0.98678 | -0.88011 | -0.21344 | 2.566556 | 2.89989 | 2.89989 |
| Ice Bite | -3.10011 | -3.65678 | -1.54344 | -1.43678 | -0.77011 | 2.00989 | 2.343223 | 2.343223 |
| NaCl (4/10) | -0.98678 | -1.54344 | -3.65678 | -3.55011 | -2.88344 | -0.10344 | 0.22989 | 0.22989 |
| Clearlane Treated Salt | -0.88011 | -1.43678 | -3.55011 | -3.65678 | -2.99011 | -0.21011 | 0.123223 | 0.123223 |
| Thawrox Gold Treated Salt | -0.21344 | -0.77011 | -2.88344 | -2.99011 | -3.65678 | -0.87678 | -0.54344 | -0.54344 |
| NaCl (10/20) | 2.566556 | 2.00989 | -0.10344 | -0.21011 | -0.87678 | -3.65678 | -3.32344 | -3.32344 |
| Ice Slicer | 2.89989 | 2.343223 | 0.22989 | 0.123223 | -0.54344 | -3.32344 | -3.65678 | -3.65678 |
| NaCl (/20) | 2.89989 | 2.343223 | 0.22989 | 0.123223 | -0.54344 | -3.32344 | -3.65678 | -3.65678 |

Positive values show pairs of means that are significantly different.

| Level | | Mean |
|---|---|---|
| SOS Treated Salt | A | 6.5566667 |
| Ice Bite | A | 6.0000000 |
| NaCl (4/10) | A B | 3.8866667 |
| Clearlane Treated Salt | A B | 3.7800000 |
| Thawrox Gold Treated Salt | A B C | 3.1133333 |
| NaCl (10/20) | B C | 0.3333333 |
| Ice Slicer | C | 0.0000000 |
| NaCl (/20) | C | 0.0000000 |

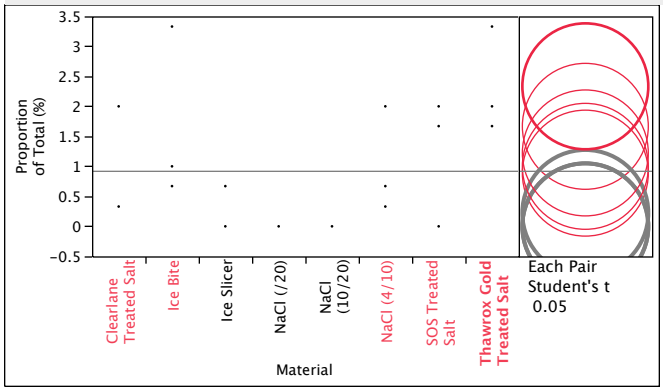
Levels not connected by same letter are significantly different.

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| SOS Treated Salt | Ice Slicer | 6.556667 | 1.724972 | 2.89989 | 10.21344 | 0.0016* |
| SOS Treated Salt | NaCl (/20) | 6.556667 | 1.724972 | 2.89989 | 10.21344 | 0.0016* |
| SOS Treated Salt | NaCl (10/20) | 6.223333 | 1.724972 | 2.56656 | 9.88011 | 0.0024* |
| Ice Bite | Ice Slicer | 6.000000 | 1.724972 | 2.34322 | 9.65678 | 0.0031* |
| Ice Bite | NaCl (/20) | 6.000000 | 1.724972 | 2.34322 | 9.65678 | 0.0031* |
| Ice Bite | NaCl (10/20) | 5.666667 | 1.724972 | 2.00989 | 9.32344 | 0.0047* |
| NaCl (4/10) | Ice Slicer | 3.886667 | 1.724972 | 0.22989 | 7.54344 | 0.0386* |
| NaCl (4/10) | NaCl (/20) | 3.886667 | 1.724972 | 0.22989 | 7.54344 | 0.0386* |
| Clearlane Treated Salt | Ice Slicer | 3.780000 | 1.724972 | 0.12322 | 7.43678 | 0.0436* |
| Clearlane Treated Salt | NaCl (/20) | 3.780000 | 1.724972 | 0.12322 | 7.43678 | 0.0436* |
| NaCl (4/10) | NaCl (10/20) | 3.553333 | 1.724972 | -0.10344 | 7.21011 | 0.0561 |
| Clearlane Treated Salt | NaCl (10/20) | 3.446667 | 1.724972 | -0.21011 | 7.10344 | 0.0630 |
| SOS Treated Salt | Thawrox Gold Treated Salt | 3.443333 | 1.724972 | -0.21344 | 7.10011 | 0.0632 |
| Thawrox Gold Treated Salt | Ice Slicer | 3.113333 | 1.724972 | -0.54344 | 6.77011 | 0.0899 |
| Thawrox Gold Treated Salt | NaCl (/20) | 3.113333 | 1.724972 | -0.54344 | 6.77011 | 0.0899 |
| Ice Bite | Thawrox Gold Treated Salt | 2.886667 | 1.724972 | -0.77011 | 6.54344 | 0.1137 |
| Thawrox Gold Treated Salt | NaCl (10/20) | 2.780000 | 1.724972 | -0.87678 | 6.43678 | 0.1266 |
| SOS Treated Salt | Clearlane Treated Salt | 2.776667 | 1.724972 | -0.88011 | 6.43344 | 0.1270 |
| SOS Treated Salt | NaCl (4/10) | 2.670000 | 1.724972 | -0.98678 | 6.32678 | 0.1412 |
| Ice Bite | Clearlane Treated Salt | 2.220000 | 1.724972 | -1.43678 | 5.87678 | 0.2164 |
| Ice Bite | NaCl (4/10) | 2.113333 | 1.724972 | -1.54344 | 5.77011 | 0.2383 |
| NaCl (4/10) | Thawrox Gold Treated Salt | 0.773333 | 1.724972 | -2.88344 | 4.43011 | 0.6599 |
| Clearlane Treated Salt | Thawrox Gold Treated Salt | 0.666667 | 1.724972 | -2.99011 | 4.32344 | 0.7042 |
| SOS Treated Salt | Ice Bite | 0.556667 | 1.724972 | -3.10011 | 4.21344 | 0.7511 |
| NaCl (10/20) | Ice Slicer | 0.333333 | 1.724972 | -3.32344 | 3.99011 | 0.8492 |
| NaCl (10/20) | NaCl (/20) | 0.333333 | 1.724972 | -3.32344 | 3.99011 | 0.8492 |
| NaCl (4/10) | Clearlane Treated Salt | 0.106667 | 1.724972 | -3.55011 | 3.76344 | 0.9515 |
| NaCl (/20) | Ice Slicer | 0.000000 | 1.724972 | -3.65678 | 3.65678 | 1.0000 |



## Oneway Analysis of Proportion of Total (%) By Material Distance Range=84-112

## Oneway Analysis of Proportion of Total (%) By Material Distance Range=84-112




### Means Comparisons

#### Comparisons for each pair using Student's t

| t | Alpha |
|---|---|
| 2.11991 | 0.05 |

Abs(Dif)-LSD

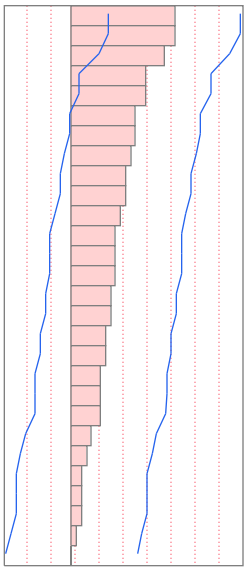
| | Thawrox Gold Treated Salt | Ice Bite | SOS Treated Salt | NaCl (4/10) | Clearlane Treated Salt | Ice Slicer | NaCl (10/20) | NaCl (/20) |
|---|---|---|---|---|---|---|---|---|
| Thawrox Gold Treated Salt | -1.48422 | -0.81755 | -0.37422 | -0.15089 | -0.03755 | 0.62578 | 0.849114 | 0.849114 |
| Ice Bite | -0.81755 | -1.48422 | -1.04089 | -0.81755 | -0.70422 | -0.04089 | 0.182447 | 0.182447 |
| SOS Treated Salt | -0.37422 | -1.04089 | -1.48422 | -1.26089 | -1.14755 | -0.48422 | -0.26089 | -0.26089 |
| NaCl (4/10) | -0.15089 | -0.81755 | -1.26089 | -1.48422 | -1.37089 | -0.70755 | -0.48422 | -0.48422 |
| Clearlane Treated Salt | -0.03755 | -0.70422 | -1.14755 | -1.37089 | -1.48422 | -0.82089 | -0.59755 | -0.59755 |
| Ice Slicer | 0.62578 | -0.04089 | -0.48422 | -0.70755 | -0.82089 | -1.48422 | -1.26089 | -1.26089 |
| NaCl (10/20) | 0.849114 | 0.182447 | -0.26089 | -0.48422 | -0.59755 | -1.26089 | -1.48422 | -1.48422 |
| NaCl (/20) | 0.849114 | 0.182447 | -0.26089 | -0.48422 | -0.59755 | -1.26089 | -1.48422 | -1.48422 |

Positive values show pairs of means that are significantly different.

| Level | | Mean |
|---|---|---|
| Thawrox Gold Treated Salt | A | 2.3333333 |
| Ice Bite | A B | 1.6666667 |
| SOS Treated Salt | A B C | 1.2233333 |
| NaCl (4/10) | A B C | 1.0000000 |
| Clearlane Treated Salt | A B C | 0.8866667 |
| Ice Slicer | B C | 0.2233333 |
| NaCl (10/20) | C | 0.0000000 |
| NaCl (/20) | C | 0.0000000 |

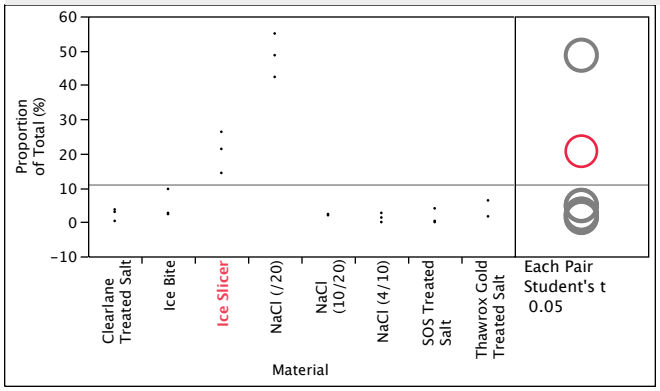
Levels not connected by same letter are significantly different.

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| Thawrox Gold Treated Salt | NaCl (10/20) | 2.333333 | 0.7001349 | 0.84911 | 3.817553 | 0.0042* |
| Thawrox Gold Treated Salt | NaCl (/20) | 2.333333 | 0.7001349 | 0.84911 | 3.817553 | 0.0042* |
| Thawrox Gold Treated Salt | Ice Slicer | 2.110000 | 0.7001349 | 0.62578 | 3.594220 | 0.0082* |
| Ice Bite | NaCl (10/20) | 1.666667 | 0.7001349 | 0.18245 | 3.150886 | 0.0301* |
| Ice Bite | NaCl (/20) | 1.666667 | 0.7001349 | 0.18245 | 3.150886 | 0.0301* |
| Thawrox Gold Treated Salt | Clearlane Treated Salt | 1.446667 | 0.7001349 | -0.03755 | 2.930886 | 0.0554 |
| Ice Bite | Ice Slicer | 1.443333 | 0.7001349 | -0.04089 | 2.927553 | 0.0559 |
| Thawrox Gold Treated Salt | NaCl (4/10) | 1.333333 | 0.7001349 | -0.15089 | 2.817553 | 0.0750 |
| SOS Treated Salt | NaCl (10/20) | 1.223333 | 0.7001349 | -0.26089 | 2.707553 | 0.0998 |
| SOS Treated Salt | NaCl (/20) | 1.223333 | 0.7001349 | -0.26089 | 2.707553 | 0.0998 |
| Thawrox Gold Treated Salt | SOS Treated Salt | 1.110000 | 0.7001349 | -0.37422 | 2.594220 | 0.1324 |
| SOS Treated Salt | Ice Slicer | 1.000000 | 0.7001349 | -0.48422 | 2.484220 | 0.1724 |
| NaCl (4/10) | NaCl (10/20) | 1.000000 | 0.7001349 | -0.48422 | 2.484220 | 0.1724 |
| NaCl (4/10) | NaCl (/20) | 1.000000 | 0.7001349 | -0.48422 | 2.484220 | 0.1724 |
| Clearlane Treated Salt | NaCl (10/20) | 0.886667 | 0.7001349 | -0.59755 | 2.370886 | 0.2235 |
| Clearlane Treated Salt | NaCl (/20) | 0.886667 | 0.7001349 | -0.59755 | 2.370886 | 0.2235 |
| Ice Bite | Clearlane Treated Salt | 0.780000 | 0.7001349 | -0.70422 | 2.264220 | 0.2817 |
| NaCl (4/10) | Ice Slicer | 0.776667 | 0.7001349 | -0.70755 | 2.260886 | 0.2837 |
| Thawrox Gold Treated Salt | Ice Bite | 0.666667 | 0.7001349 | -0.81755 | 2.150886 | 0.3552 |
| Ice Bite | NaCl (4/10) | 0.666667 | 0.7001349 | -0.81755 | 2.150886 | 0.3552 |
| Clearlane Treated Salt | Ice Slicer | 0.663333 | 0.7001349 | -0.82089 | 2.147553 | 0.3575 |
| Ice Bite | SOS Treated Salt | 0.443333 | 0.7001349 | -1.04089 | 1.927553 | 0.5355 |
| SOS Treated Salt | Clearlane Treated Salt | 0.336667 | 0.7001349 | -1.14755 | 1.820886 | 0.6371 |
| SOS Treated Salt | NaCl (4/10) | 0.223333 | 0.7001349 | -1.26089 | 1.707553 | 0.7539 |
| Ice Slicer | NaCl (10/20) | 0.223333 | 0.7001349 | -1.26089 | 1.707553 | 0.7539 |
| Ice Slicer | NaCl (/20) | 0.223333 | 0.7001349 | -1.26089 | 1.707553 | 0.7539 |
| NaCl (4/10) | Clearlane Treated Salt | 0.113333 | 0.7001349 | -1.37089 | 1.597553 | 0.8734 |
| NaCl (/20) | NaCl (10/20) | 0.000000 | 0.7001349 | -1.48422 | 1.484220 | 1.0000 |



## Oneway Analysis of Proportion of Total (%) By Material Distance Range=on plate

## Oneway Analysis of Proportion of Total (%) By Material Distance Range=on plate




## Means Comparisons

### Comparisons for each pair using Student's t

| t | Alpha |
|---|---|
| 2.11991 | 0.05 |

Abs(Dif)-LSD

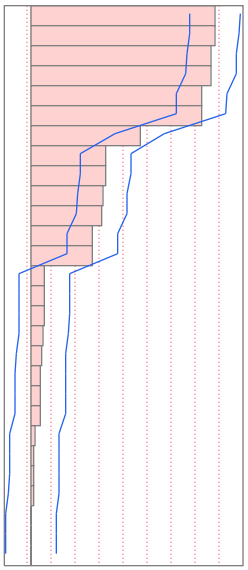
| | NaCl (/20) | Ice Slicer | Ice Bite | Thawrox Gold Treated Salt | Clearlane Treated Salt | NaCl (10/20) | SOS Treated Salt | NaCl (4/10) |
|---|---|---|---|---|---|---|---|---|
| NaCl (/20) | -6.43988 | 21.56346 | 37.33679 | 37.45012 | 39.89346 | 40.00679 | 40.78346 | 40.89346 |
| Ice Slicer | 21.56346 | -6.43988 | 9.333457 | 9.446791 | 11.89012 | 12.00346 | 12.78012 | 12.89012 |
| Ice Bite | 37.33679 | 9.333457 | -6.43988 | -6.32654 | -3.88321 | -3.76988 | -2.99321 | -2.88321 |
| Thawrox Gold Treated Salt | 37.45012 | 9.446791 | -6.32654 | -6.43988 | -3.99654 | -3.88321 | -3.10654 | -2.99654 |
| Clearlane Treated Salt | 39.89346 | 11.89012 | -3.88321 | -3.99654 | -6.43988 | -6.32654 | -5.54988 | -5.43988 |
| NaCl (10/20) | 40.00679 | 12.00346 | -3.76988 | -3.88321 | -6.32654 | -6.43988 | -5.66321 | -5.55321 |
| SOS Treated Salt | 40.78346 | 12.78012 | -2.99321 | -3.10654 | -5.54988 | -5.66321 | -6.43988 | -6.32988 |
| NaCl (4/10) | 40.89346 | 12.89012 | -2.88321 | -2.99654 | -5.43988 | -5.55321 | -6.32988 | -6.43988 |

Positive values show pairs of means that are significantly different.

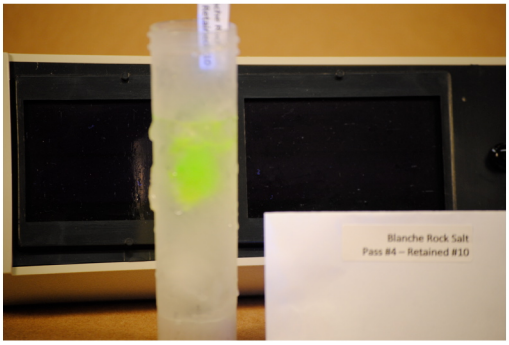
| Level | | Mean |
|---|---|---|
| NaCl (/20) | A | 48.666667 |
| Ice Slicer | B | 20.663333 |
| Ice Bite | C | 4.890000 |
| Thawrox Gold Treated Salt | C | 4.776667 |
| Clearlane Treated Salt | C | 2.333333 |
| NaCl (10/20) | C | 2.220000 |
| SOS Treated Salt | C | 1.443333 |
| NaCl (4/10) | C | 1.333333 |

Levels not connected by same letter are significantly different.

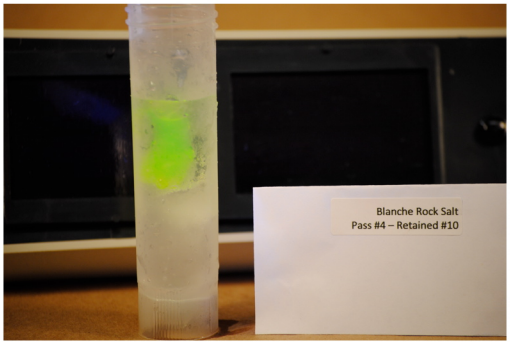
| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| NaCl (/20) | NaCl (4/10) | 47.33333 | 3.037813 | 40.8935 | 53.77321 | <.0001* |
| NaCl (/20) | SOS Treated Salt | 47.22333 | 3.037813 | 40.7835 | 53.66321 | <.0001* |
| NaCl (/20) | NaCl (10/20) | 46.44667 | 3.037813 | 40.0068 | 52.88654 | <.0001* |
| NaCl (/20) | Clearlane Treated Salt | 46.33333 | 3.037813 | 39.8935 | 52.77321 | <.0001* |
| NaCl (/20) | Thawrox Gold Treated Salt | 43.89000 | 3.037813 | 37.4501 | 50.32988 | <.0001* |
| NaCl (/20) | Ice Bite | 43.77667 | 3.037813 | 37.3368 | 50.21654 | <.0001* |
| NaCl (/20) | Ice Slicer | 28.00333 | 3.037813 | 21.5635 | 34.44321 | <.0001* |
| Ice Slicer | NaCl (4/10) | 19.33000 | 3.037813 | 12.8901 | 25.76988 | <.0001* |
| Ice Slicer | SOS Treated Salt | 19.22000 | 3.037813 | 12.7801 | 25.65988 | <.0001* |
| Ice Slicer | NaCl (10/20) | 18.44333 | 3.037813 | 12.0035 | 24.88321 | <.0001* |
| Ice Slicer | Clearlane Treated Salt | 18.33000 | 3.037813 | 11.8901 | 24.76988 | <.0001* |
| Ice Slicer | Thawrox Gold Treated Salt | 15.88667 | 3.037813 | 9.4468 | 22.32654 | <.0001* |
| Ice Slicer | Ice Bite | 15.77333 | 3.037813 | 9.3335 | 22.21321 | <.0001* |
| Ice Bite | NaCl (4/10) | 3.55667 | 3.037813 | -2.8832 | 9.99654 | 0.2588 |
| Ice Bite | SOS Treated Salt | 3.44667 | 3.037813 | -2.9932 | 9.88654 | 0.2733 |
| Thawrox Gold Treated Salt | NaCl (4/10) | 3.44333 | 3.037813 | -2.9965 | 9.88321 | 0.2737 |
| Thawrox Gold Treated Salt | SOS Treated Salt | 3.33333 | 3.037813 | -3.1065 | 9.77321 | 0.2888 |
| Ice Bite | NaCl (10/20) | 2.67000 | 3.037813 | -3.7699 | 9.10988 | 0.3925 |
| Ice Bite | Clearlane Treated Salt | 2.55667 | 3.037813 | -3.8832 | 8.99654 | 0.4124 |
| Thawrox Gold Treated Salt | NaCl (10/20) | 2.55667 | 3.037813 | -3.8832 | 8.99654 | 0.4124 |
| Thawrox Gold Treated Salt | Clearlane Treated Salt | 2.44333 | 3.037813 | -3.9965 | 8.88321 | 0.4330 |
| Clearlane Treated Salt | NaCl (4/10) | 1.00000 | 3.037813 | -5.4399 | 7.43988 | 0.7463 |
| Clearlane Treated Salt | SOS Treated Salt | 0.89000 | 3.037813 | -5.5499 | 7.32988 | 0.7733 |
| NaCl (10/20) | NaCl (4/10) | 0.88667 | 3.037813 | -5.5532 | 7.32654 | 0.7741 |
| NaCl (10/20) | SOS Treated Salt | 0.77667 | 3.037813 | -5.6632 | 7.21654 | 0.8015 |
| Ice Bite | Thawrox Gold Treated Salt | 0.11333 | 3.037813 | -6.3265 | 6.55321 | 0.9707 |
| Clearlane Treated Salt | NaCl (10/20) | 0.11333 | 3.037813 | -6.3265 | 6.55321 | 0.9707 |
| SOS Treated Salt | NaCl (4/10) | 0.11000 | 3.037813 | -6.3299 | 6.54988 | 0.9716 |



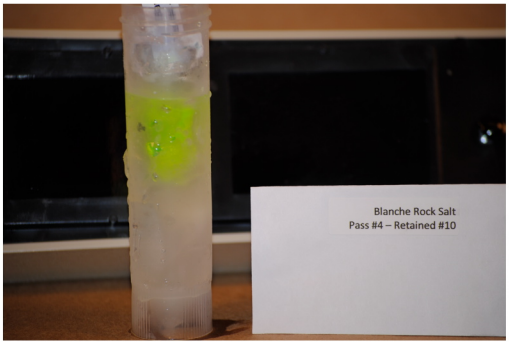
# Appendix F – Penetration Test Photographic Results



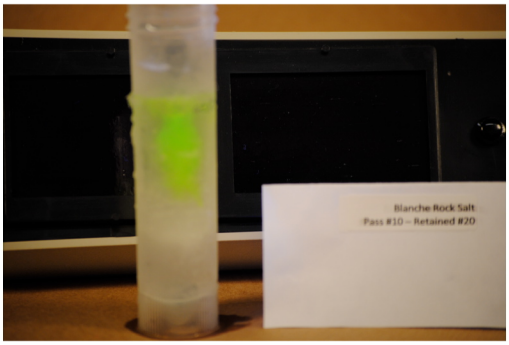

Blanche Rock Salt Pass 4/Ret 10 A



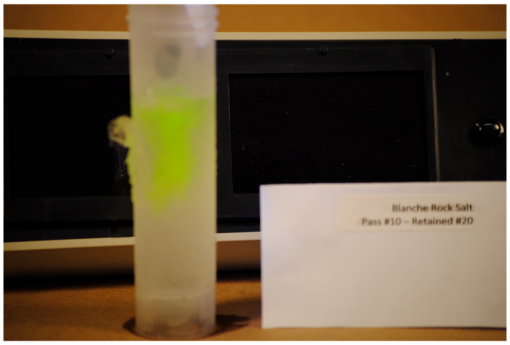

Blanche Rock Salt Pass 4/Ret 10 B



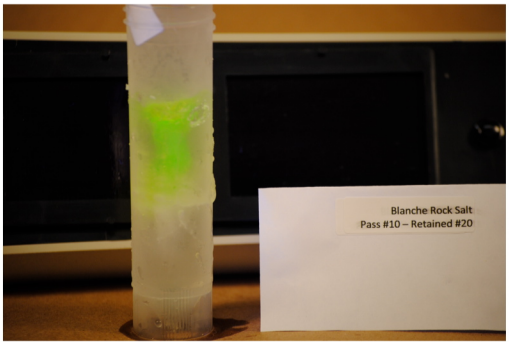

Blanche Rock Salt Pass 4/Ret 10 C



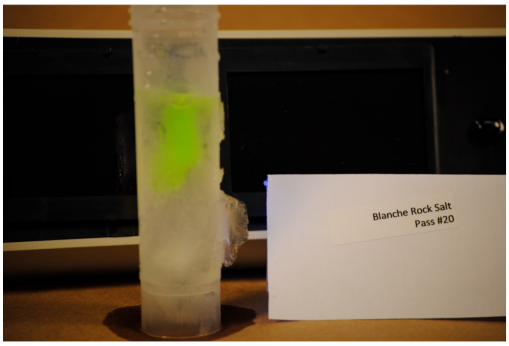

Blanche Rock Salt Pass 10/Ret 20 A



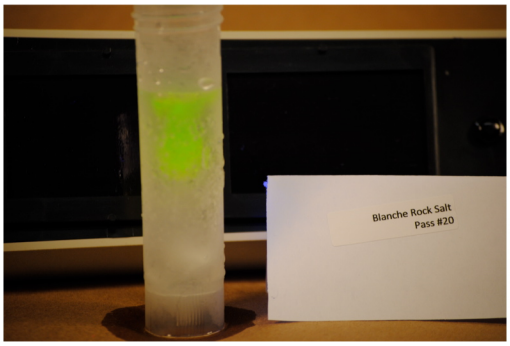

Blanche Rock Salt Pass 10/Ret 20 B



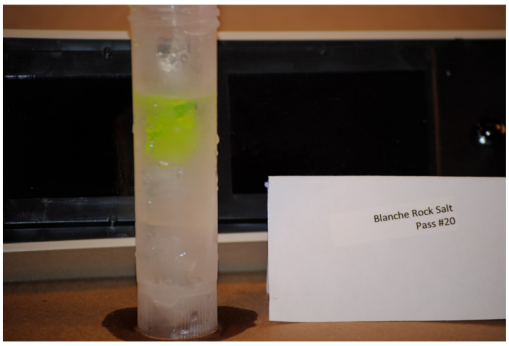

Blanche Rock Salt Pass 10/Ret 20 C



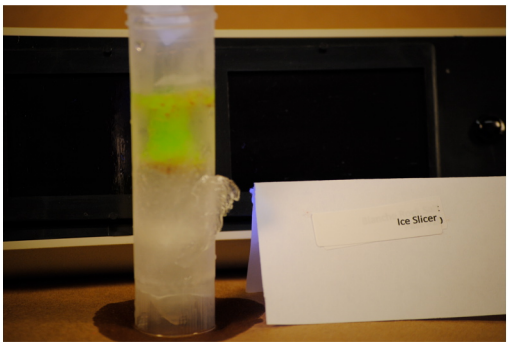

Blanche Rock Salt Passing #20 A



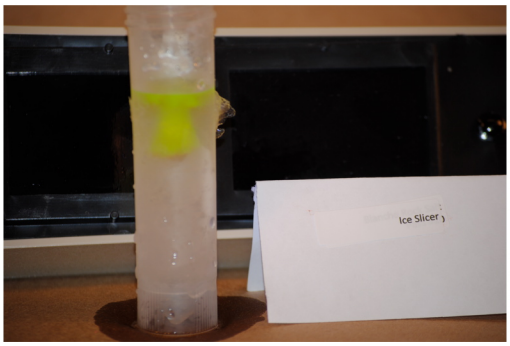

Blanche Rock Salt Passing #20 B




Blanche Rock Salt Passing #20 C

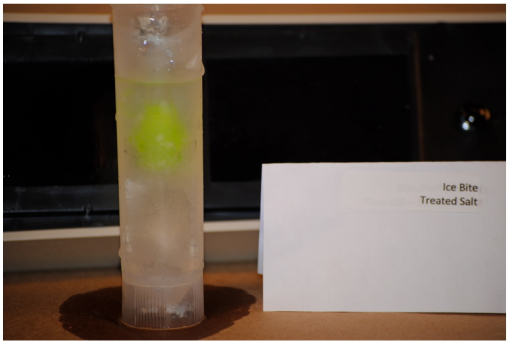



Ice Slicer A

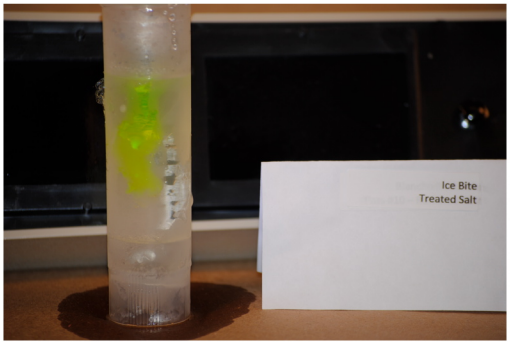



Ice Slicer B

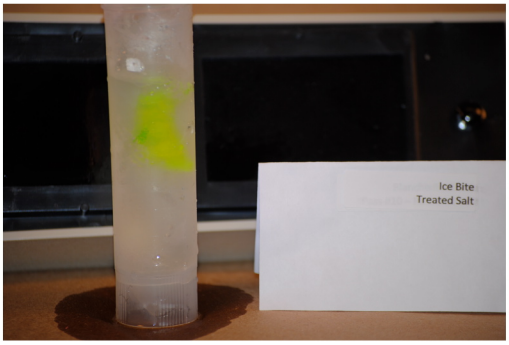

Ice Slicer C



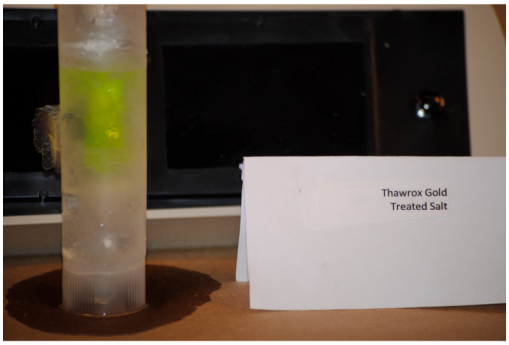

Ice Bite A



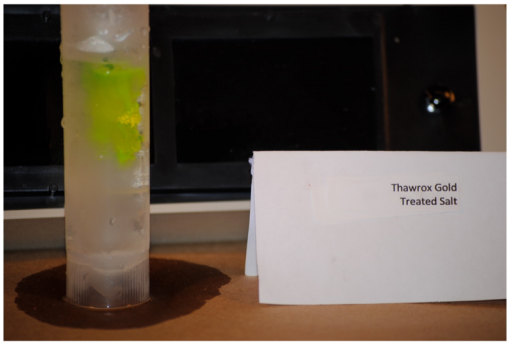

Ice Bite B



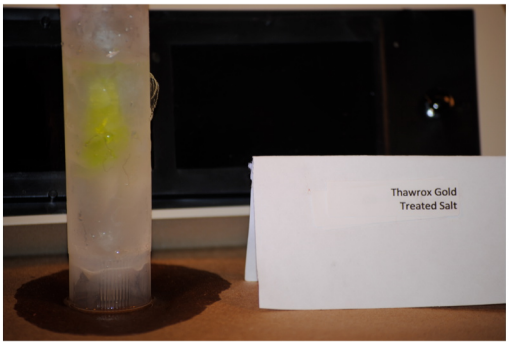

Ice Bite C



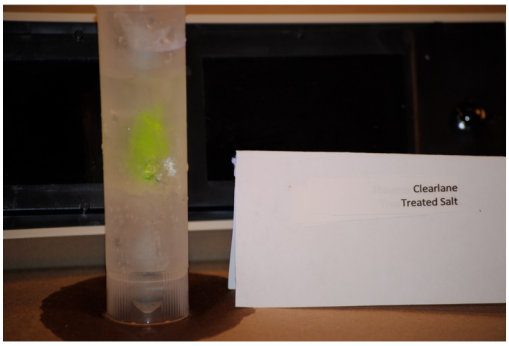

Thawrox Gold Treated Salt A



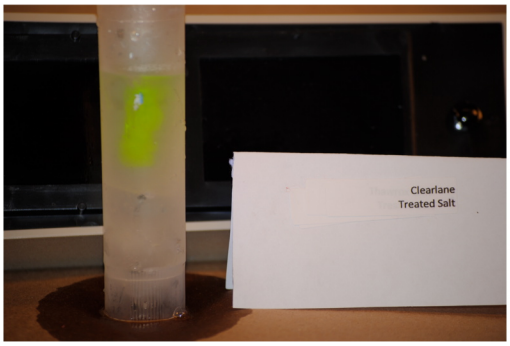

Thawrox Gold Treated Salt B



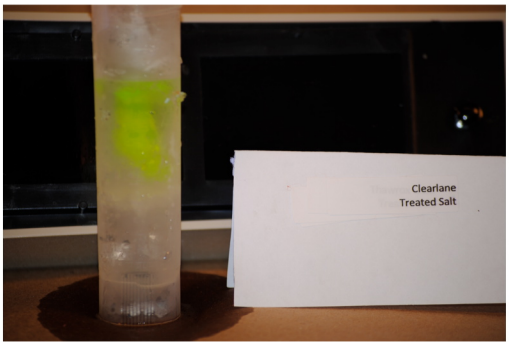

Thawrox Gold Treated Salt C




Clearlane Treated Salt A

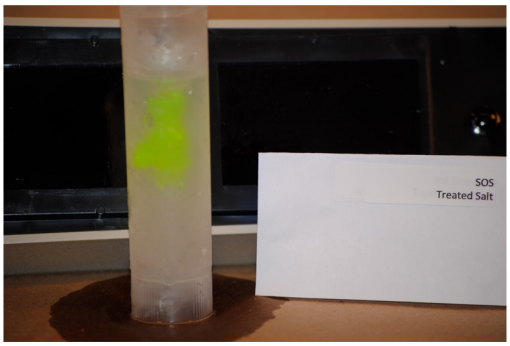



Clearlane Treated Salt B

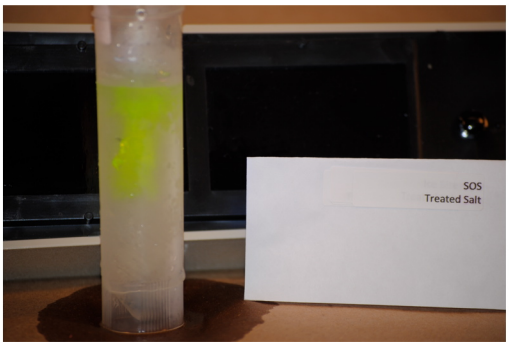



Clearlane Treated Salt C

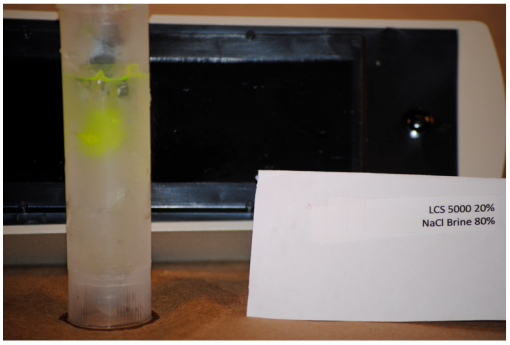

SOS Treated Salt A



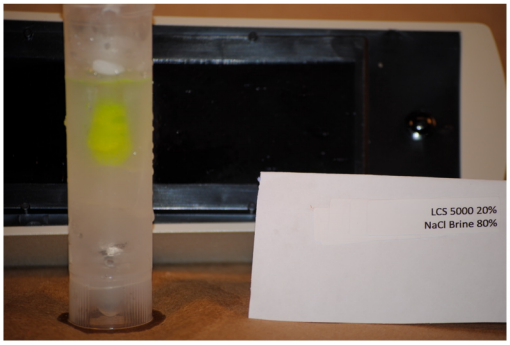

SOS Treated Salt B



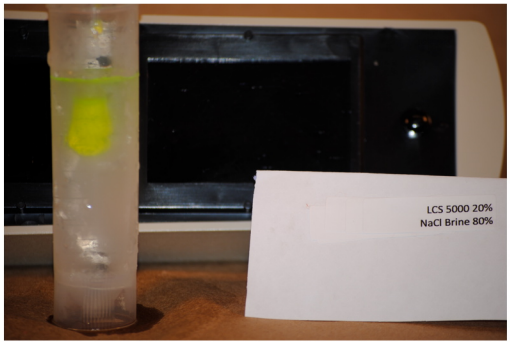

SOS Treated Salt C



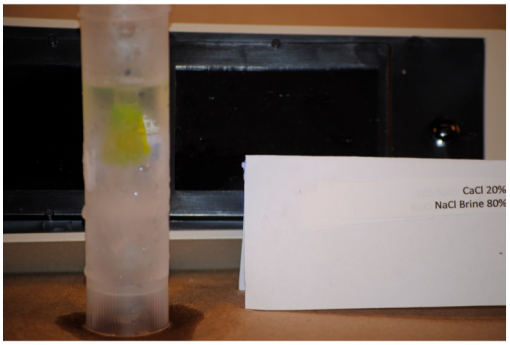

LCS 5000 20% w/80% Brine A




LCS 5000 20% w/80% Brine B

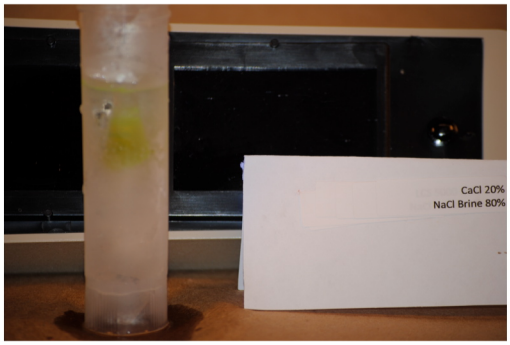



LCS 5000 20% w/80% Brine C

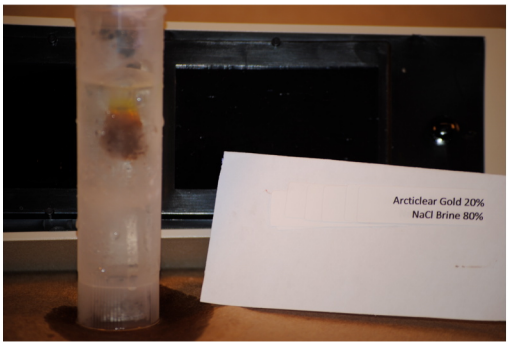



CaCl 20% w/80% Brine A

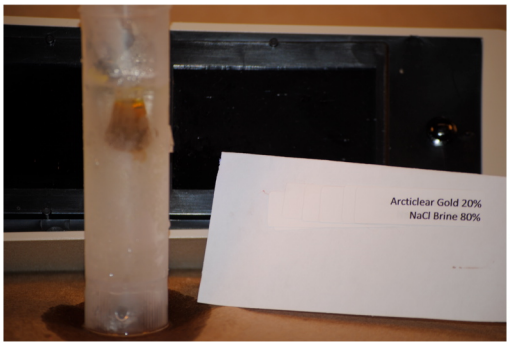

CaCl 20% w/80% Brine B



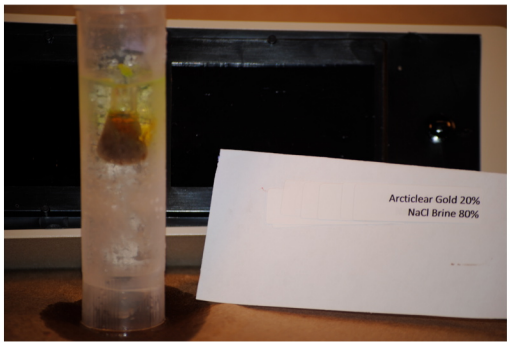

CaCl 20% w/80% Brine C



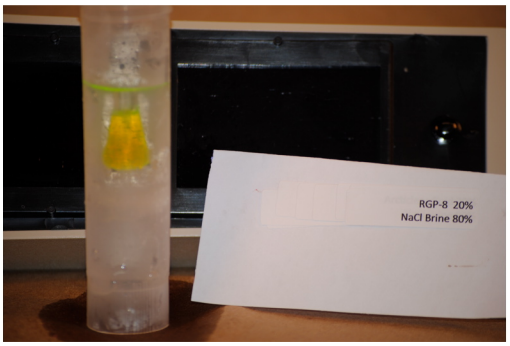

Articlear Gold 20% w/80% Brine A



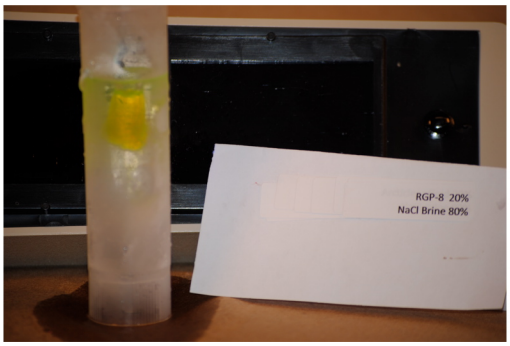

Articlear Gold 20% w/80% Brine B



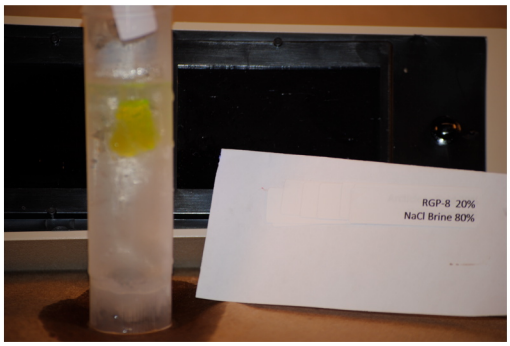

Articlear Gold 20% w/80% Brine C



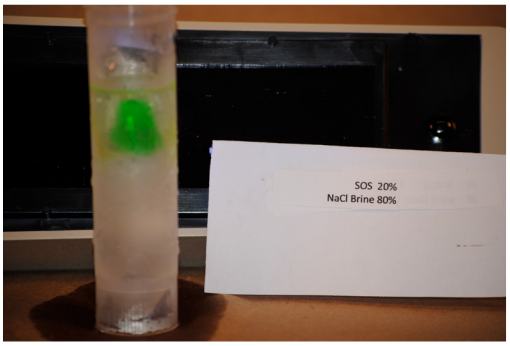

RGP-8 20% w/80% Brine A



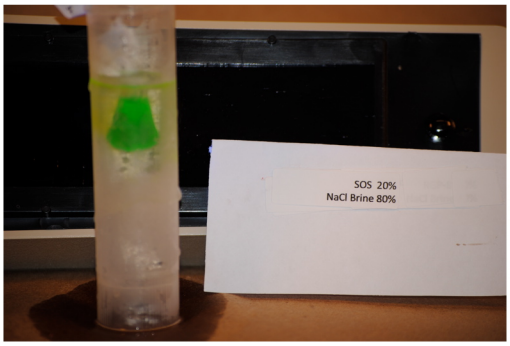

RGP-8 20% w/80% Brine B



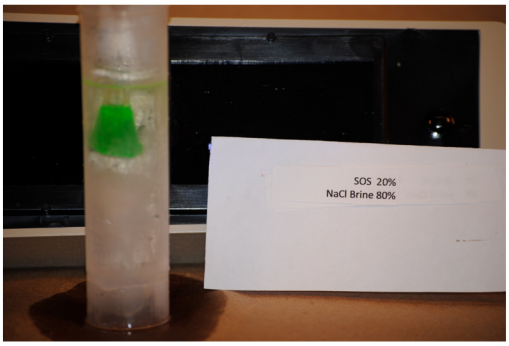

RGP-8 20% w/80% Brine C



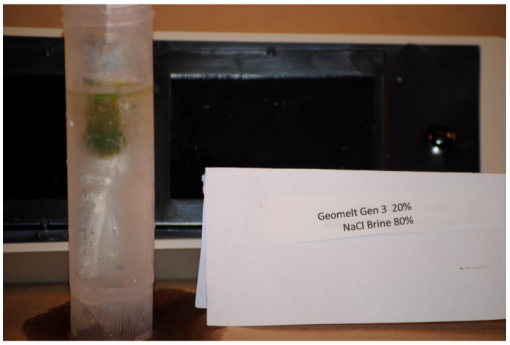

SOS 20% w/80% Brine A



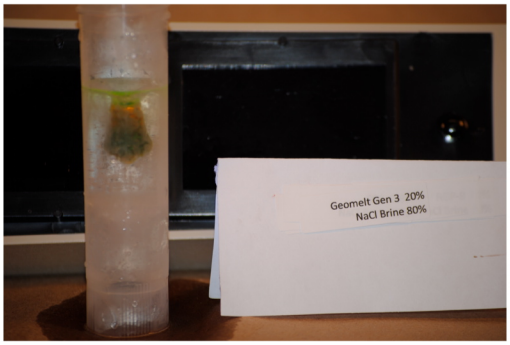

SOS 20% w/80% Brine B



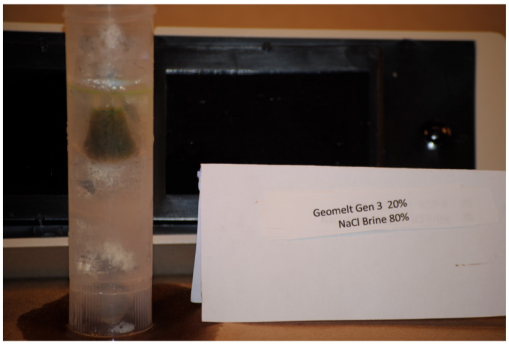

SOS 20% w/80% Brine C




Geomelt Gen 3 20% w/80% Brine A

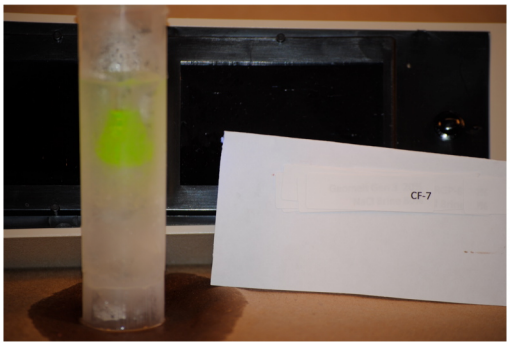



Geomelt Gen 3 20% w/80% Brine B

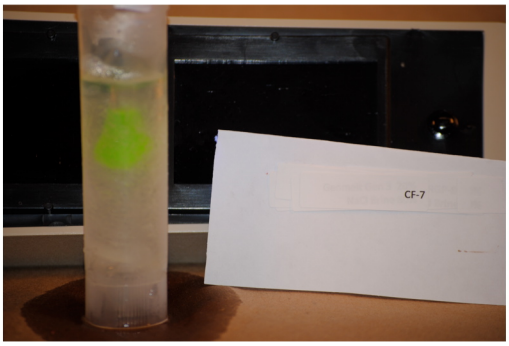



Geomelt Gen 3 20% w/80% Brine C

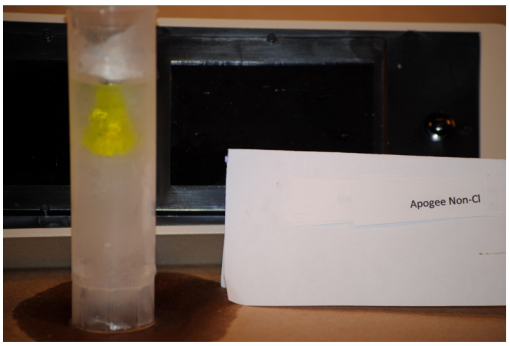

CF-7 A



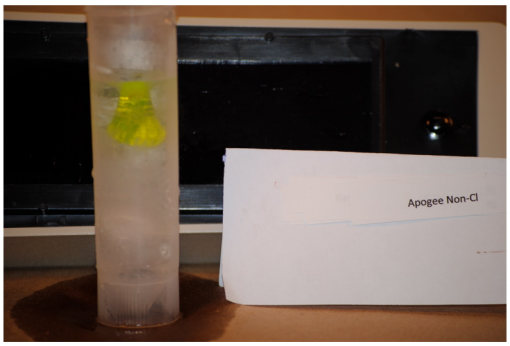

CF-7 B




CF-7 C

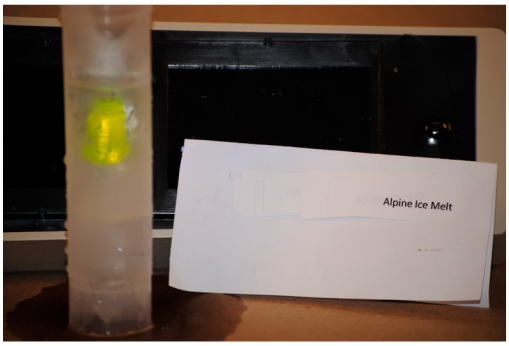



Apogee Non-Cl A

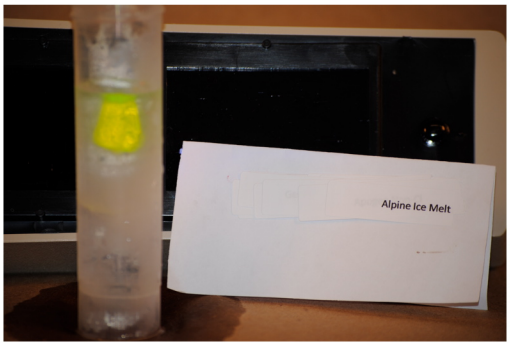



Apogee Non-Cl B

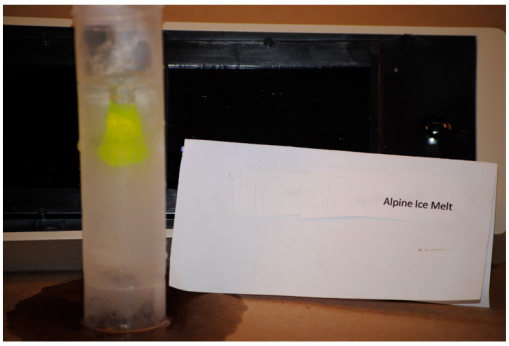

Apogee Non-Cl C




Salt Brine (mislabled as Alpine Ice Melt) A




Salt Brine (mislabled as Alpine Ice Melt) B




Salt Brine (mislabled as Alpine Ice Melt) C

# Appendix G – Cost Model Spreadsheet for Deicing and Prewet Applications

Deicing Cost Model
Mn/DOT Research Contract 96319

Name/Date: _____

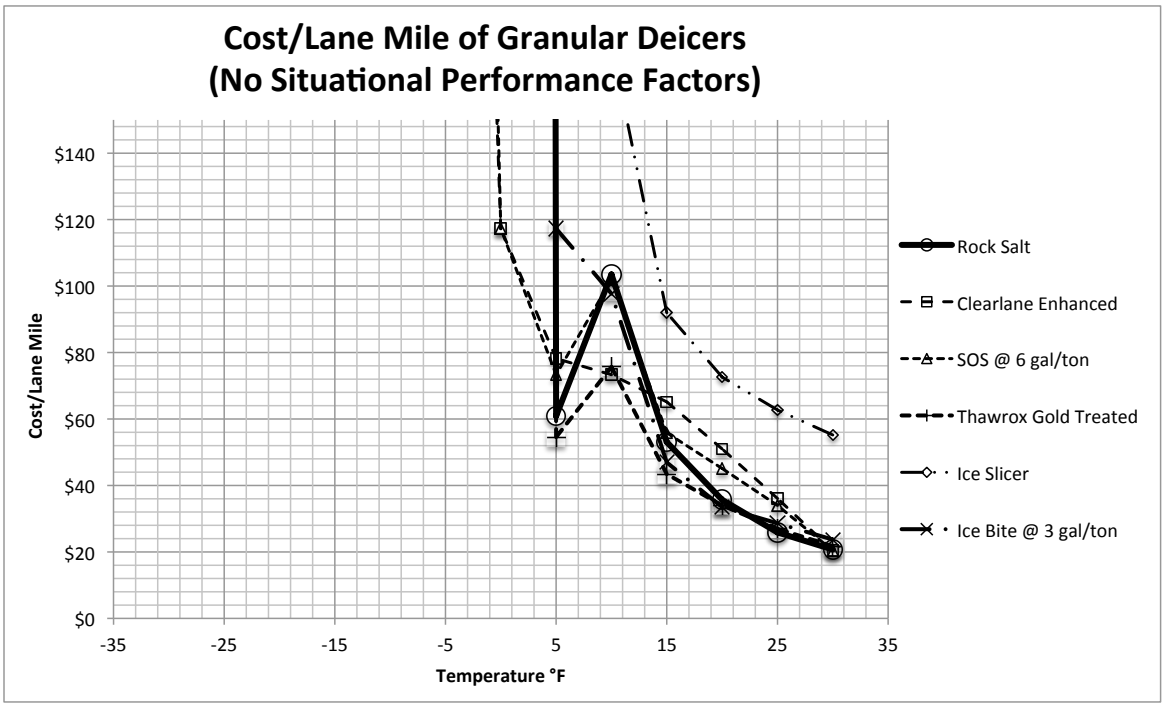
Roadway: _____

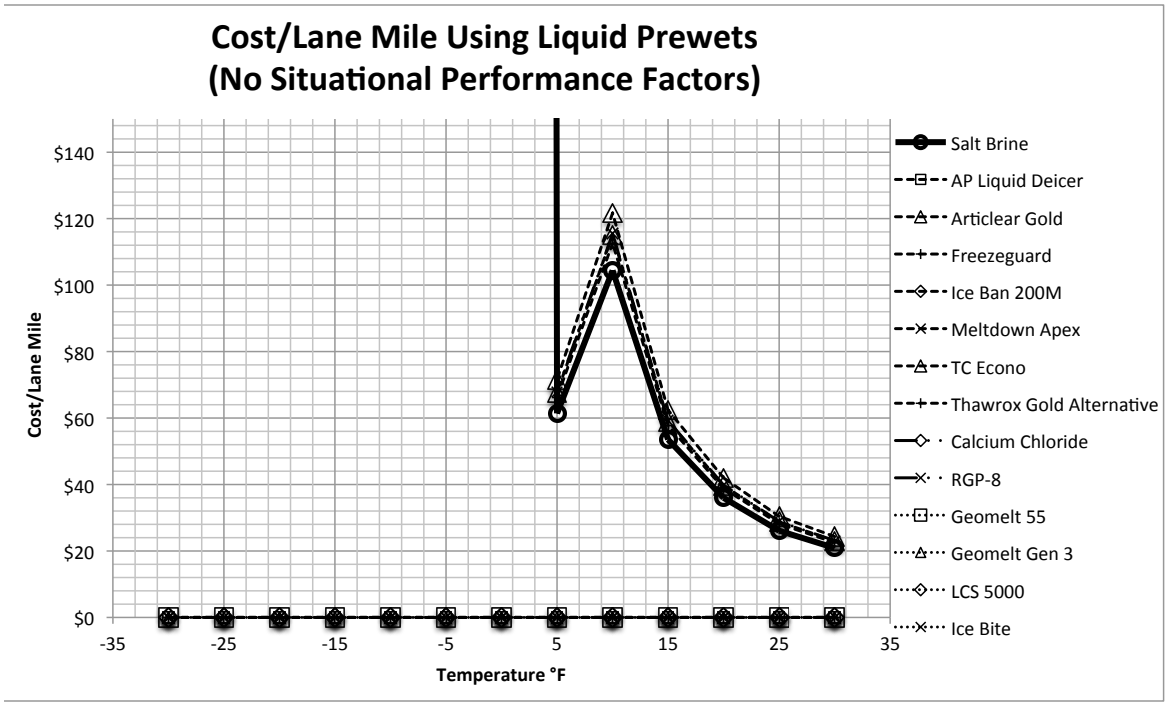
**Application Factors - Select levels by placing a "Y" in the appropriate blocks.**

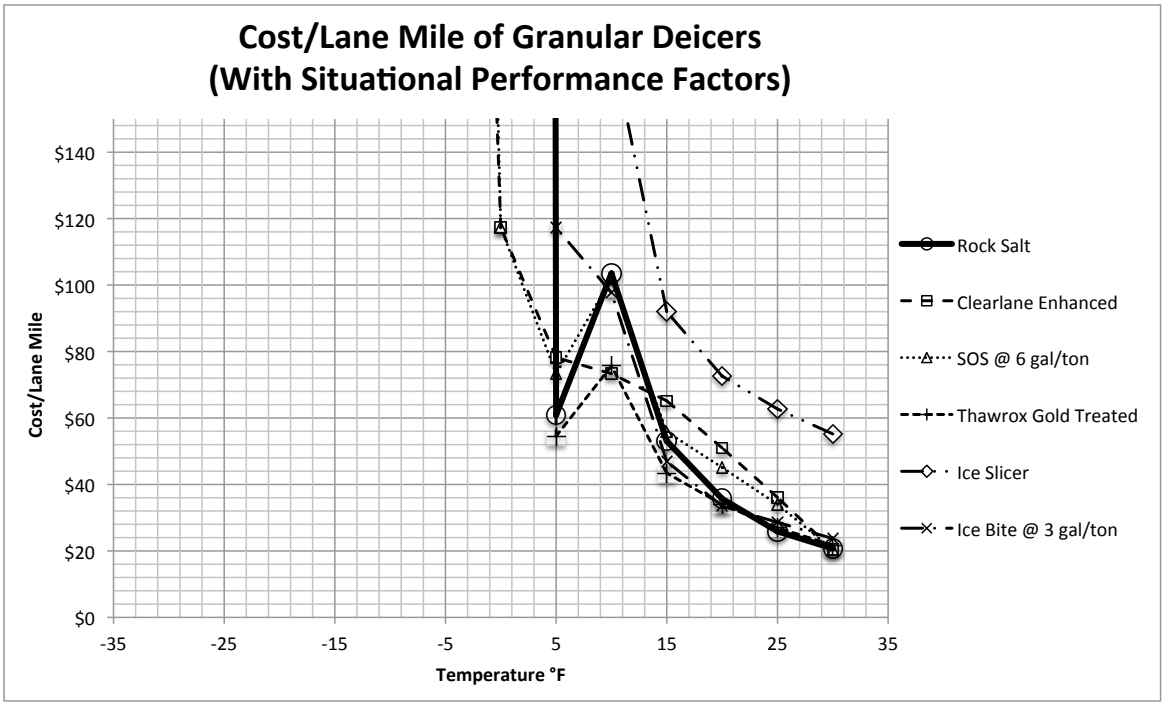
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Application Rate | 600 | lb/LM | (600 lb/LM Typical) | | Factors | | |
| Ice Thickness (inches) | [ ] < 1/16th | [Y] 1/16-3/16th | [ ] >1/4th | | 1.5 | 1.0 | 0.5 |
| Temperature Movement | [ ] Rising | [Y] Steady | [ ] Falling | | 1.1 | 1.0 | 0.9 |
| Repeat Time | [ ] 30-90 min | [Y] 2-4 hr | [ ] > 4 hrs | | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | |
| Pavement Material | [ ] Asphalt | [Y] Concrete | [ ] Open Graded/Porous | | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | [ ] 0 to 3 yrs | [Y] 4 to 8 yrs | [ ] 8 to 20+ yrs | | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | |
| Sun Condition | [ ] Bright Sky | [Y] Overcast | [ ] Dark | | 1.5 | 1.0 | 0.5 |
| Wind Condition | [ ] Calm | [Y] Light | [ ] Breezy | | 1.25 | 1.00 | 0.75 |
| Roadway Shade | [ ] None | [Y] Occassional | [ ] Sunless | | 1.25 | 1.00 | 0.75 |
| **Roadway Volume (ADT)** | | | | | | | |
| Super Commuter (>30,000 ADT) | [ ] | | | | 2.5 | | |
| Urban Commuter (10,000-30,000 ADT) | [ ] | | | | 2.0 | | |
| Rural Commuter (2,000-10,000 ADT) | [ ] | | | | 1.5 | | |
| Primary (800-2000 ADT) | [Y] | | | | 1.0 | | |
| Secondary (<800 ADT) | [ ] | | | | 0.75 | | |
| Rural Low Volume | [ ] | | | | 0.50 | | |
| **Truck Proportion** | [ ] >5% ADT | [Y] 2-5% ADT | [ ] <2% ADT | | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | |
| Corrosion Sensitve Struct. | [ ] Low | [Y] Medium | [ ] High | | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | [ ] Low | [Y] Medium | [ ] High | | 1.25 | 1.00 | 0.75 |

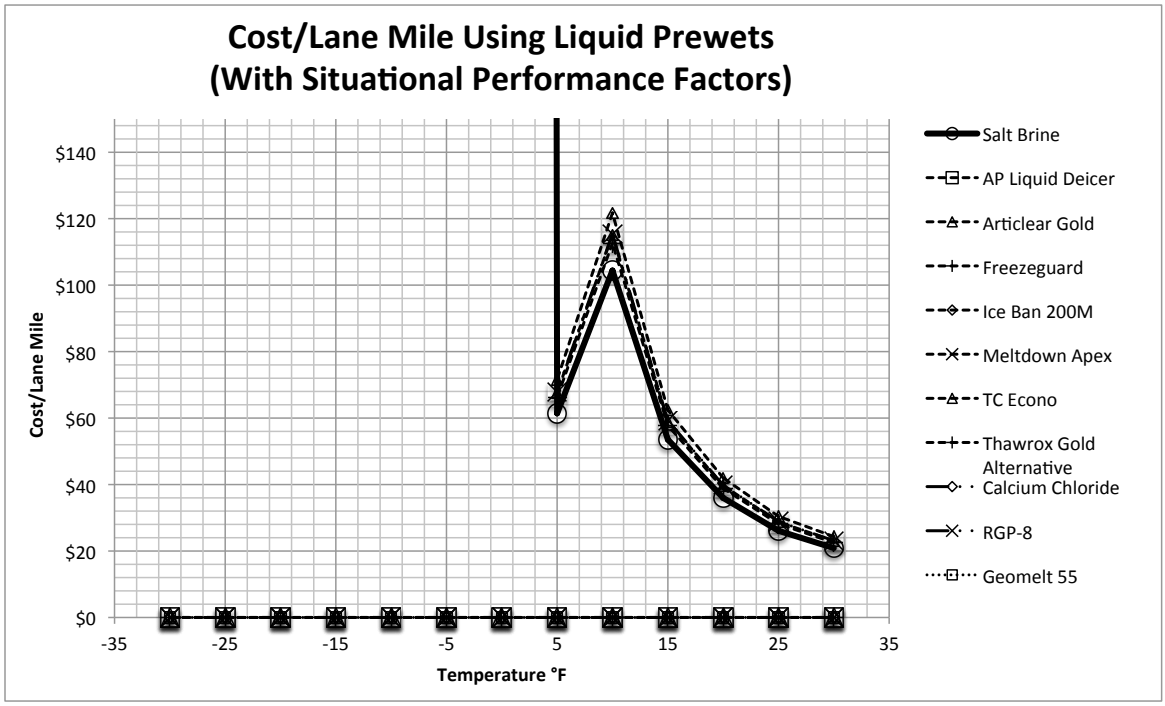
| **Solid Deicers to Consider ("Y" to graph)** | | **Cost (Delivered)** | |
|---|---|---|---|
| [Y] Rock Salt | NaCl | $75.00 | /ton |
| [Y] Clearlane Enhanced | $MgCl_2$ | $85.00 | /ton |
| [Y] SOS @ 6 gal/ton | $MgCl_2$ | $85.00 | /ton |
| [Y] Thawrox Gold Treated | $MgCl_2$ | $85.00 | /ton |
| [Y] Ice Slicer | $CaCl_2$ | $150.00 | /ton |
| [Y] Ice Bite @ 3 gal/ton | Carb | $85.00 | /ton |

| **Liquid Prewets to Consider ("Y" to graph)** | | **Cost (Delivered)** | | Prewet Rate | |
|---|---|---|---|---|---|
| [Y] Salt Brine | NaCl | $0.11 | /gallon | 6 | gal/ton |
| [N] AP Liquid Deicer | $MgCl_2$ | $1.25 | /gallon | 6 | gal/ton |
| [Y] Articlear Gold | $MgCl_2$ | $2.20 | /gallon | 6 | gal/ton |
| [Y] Freezeguard | $MgCl_2$ | $1.10 | /gallon | 6 | gal/ton |
| [N] Ice Ban 200M | $MgCl_2$ | $1.25 | /gallon | 6 | gal/ton |
| [N] Meltdown Apex | $MgCl_2$ | $1.10 | /gallon | 6 | gal/ton |
| [Y] TC Econo | $MgCl_2$ | $1.40 | /gallon | 6 | gal/ton |
| [N] Thawrox Gold Alt | $MgCl_2$ | $1.70 | /gallon | 6 | gal/ton |
| [N] Calcium Chloride | $CaCl_2$ | $4.00 | /gallon | 6 | gal/ton |
| [Y] RGP-8 | $CaCl_2$ | $1.45 | /gallon | 6 | gal/ton |
| [N] Geomelt 55 | Carb | $1.85 | /gallon | 6 | gal/ton |
| [N] Geomelt Gen 3 | Carb | $4.00 | /gallon | 6 | gal/ton |
| [N] LCS 5000 | Carb | $2.75 | /gallon | 6 | gal/ton |
| [N] Ice Bite | Carb | $1.50 | /gallon | 6 | gal/ton |


Cost/Lane Mile of Granular Deicers
(No Situational Performance Factors)
Cost/Lane Mile
$140
$120
$100
$80
$60
$40
$20
$0
-35
-25
-15
-5
5
15
25
35
Temperature °F
Rock Salt
Clearlane Enhanced
SOS @ 6 gal/ton
Thawrox Gold Treated
Ice Slicer
Ice Bite @ 3 gal/ton


Cost/Lane Mile Using Liquid Prewets
(No Situational Performance Factors)
Cost/Lane Mile
$140
$120
$100
$80
$60
$40
$20
$0
-35
-25
-15
-5
5
15
25
35
Temperature °F
Salt Brine
AP Liquid Deicer
Articlear Gold
Freezeguard
Ice Ban 200M
Meltdown Apex
TC Econo
Thawrox Gold Alternative
Calcium Chloride
RGP-8
Geomelt 55
Geomelt Gen 3
LCS 5000
Ice Bite


Cost/Lane Mile of Granular Deicers
(With Situational Performance Factors)
Cost/Lane Mile
$140
$120
$100
$80
$60
$40
$20
$0
-35
-25
-15
-5
5
15
25
35
Temperature °F
Rock Salt
Clearlane Enhanced
SOS @ 6 gal/ton
Thawrox Gold Treated
Ice Slicer
Ice Bite @ 3 gal/ton


Cost/Lane Mile Using Liquid Prewets
(With Situational Performance Factors)
Cost/Lane Mile
$140
$120
$100
$80
$60
$40
$20
$0
-35
-25
-15
-5
5
15
25
35
Temperature °F
Salt Brine
AP Liquid Deicer
Articlear Gold
Freezeguard
Ice Ban 200M
Meltdown Apex
TC Econo
Thawrox Gold Alternative
Calcium Chloride
RGP-8
Geomelt 55

# Appendix H – Cost Model Spreadsheet for Anti-Icing

Deicing Cost Model
Mn/DOT Research Contract 96319

Name/Date: _____

Roadway: _____

**Application Factors - Select levels by placing a "Y" in the appropriate blocks.**

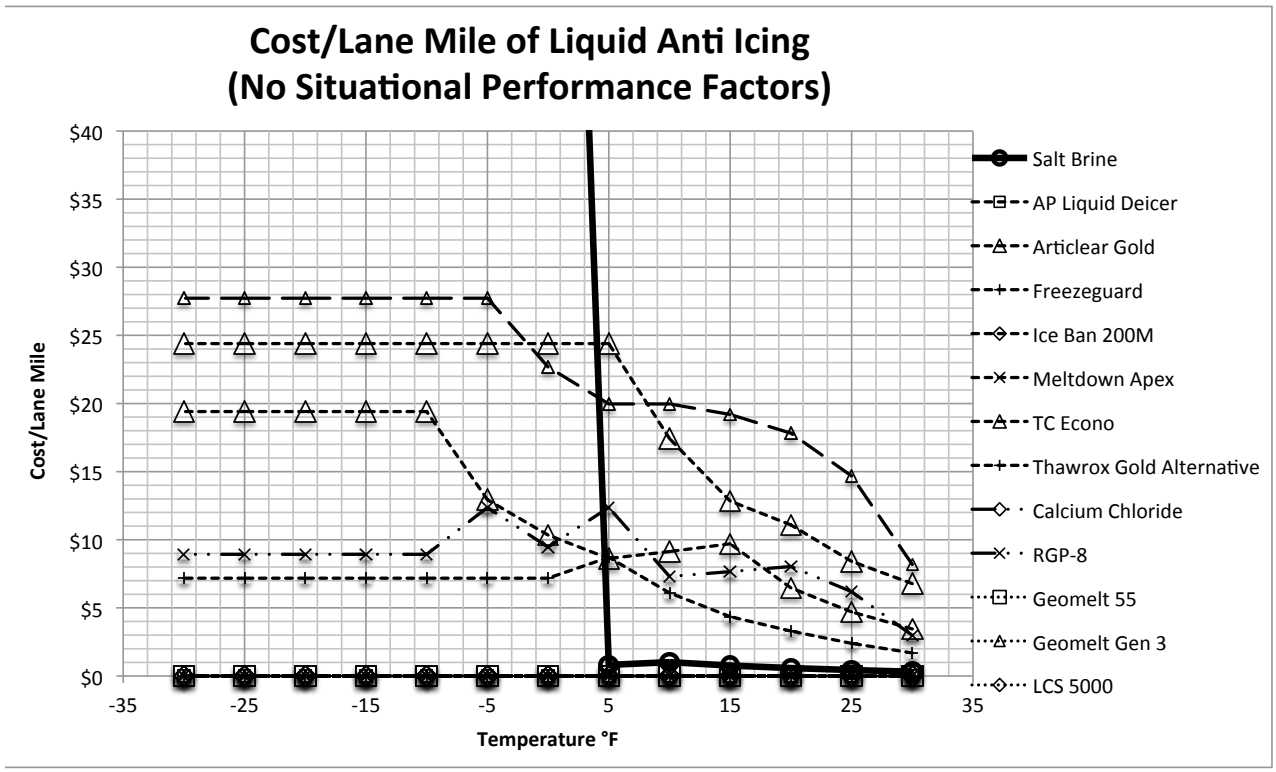
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Application Rate | 25 | gal/LM | (25 gal/LM Typical) | | Factors | | |
| Ice Thickness (inches) | | < 1/16th | Y | 1/16-3/16th | | >1/4th | 1.5 | 1.0 | 0.5 |
| Temperature Movement | | Rising | Y | Steady | | Falling | 1.1 | 1.0 | 0.9 |
| Repeat Time | | 30-90 min | Y | 2-4 hr | | > 4 hrs | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | | | |
| Pavement Material | | Asphalt | Y | Concrete | | Open Graded/Porous | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | | 0 to 3 yrs | Y | 4 to 8 yrs | | 8 to 20+ yrs | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | | | |
| Sun Condition | | Bright Sky | Y | Overcast | | Dark | 1.5 | 1.0 | 0.5 |
| Wind Condition | | Calm | Y | Light | | Breezy | 1.25 | 1.00 | 0.75 |
| Roadway Shade | | None | Y | Occassional | | Sunless | 1.25 | 1.00 | 0.75 |

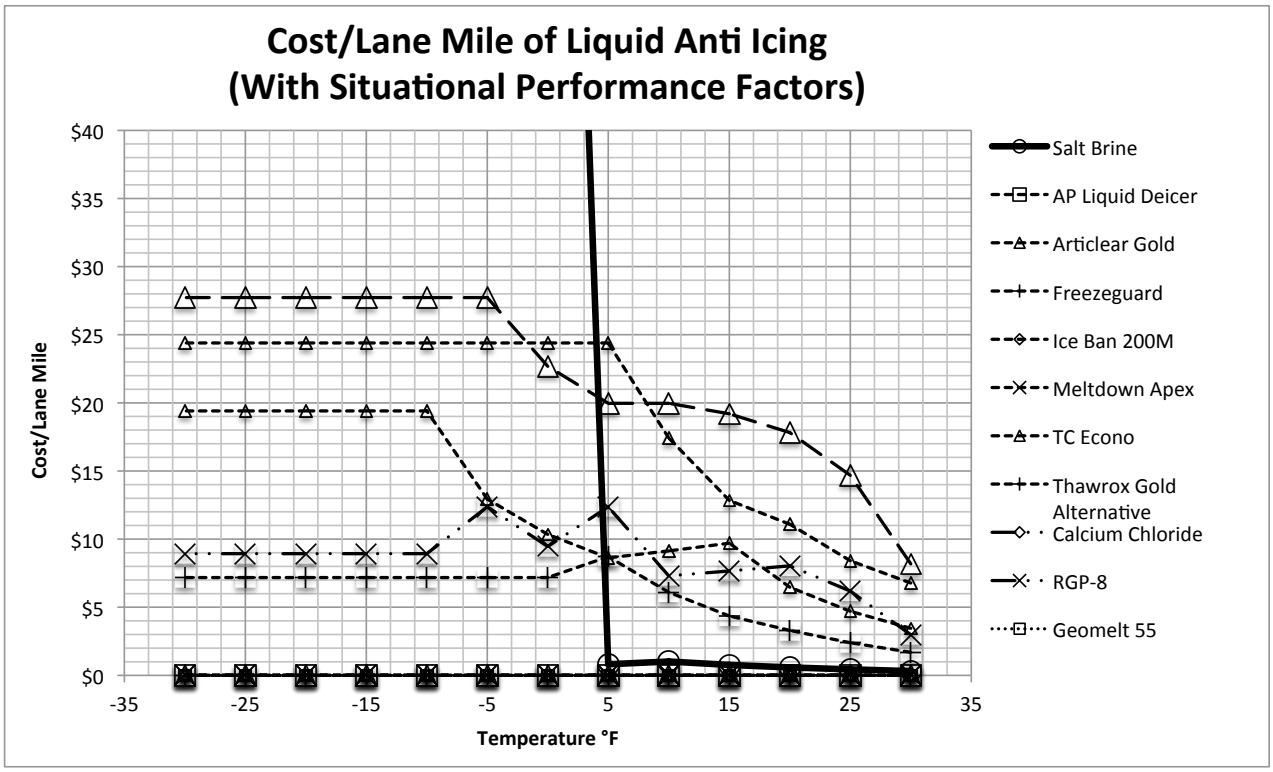
**Roadway Volume (ADT)**

| | | |
|---|---|---|
| Super Commuter (>30,000 ADT) | | 2.5 |
| Urban Commuter (10,000-30,000 ADT) | | 2.0 |
| Rural Commuter (2,000-10,000 ADT) | | 1.5 |
| Primary (800-2000 ADT) | Y | 1.0 |
| Secondary (<800 ADT) | | 0.75 |
| Rural Low Volume | | 0.50 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Truck Proportion** | | >5% ADT | Y | 2-5% ADT | | <2% ADT | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | | | |
| Corrosion Sensitve Struct. | | Low | Y | Medium | | High | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | | Low | Y | Medium | | High | 1.25 | 1.00 | 0.75 |

| **Liquid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | | |
|---|---|---|---|---|---|
| Y | Salt Brine | NaCl | $0.11 | /gallon | |
| N | AP Liquid Deicer | $MgCl_2$ | $1.25 | /gallon | |
| Y | Articlear Gold | $MgCl_2$ | $2.20 | /gallon | |
| Y | Freezeguard | $MgCl_2$ | $1.10 | /gallon | |
| N | Ice Ban 200M | $MgCl_2$ | $1.25 | /gallon | |
| N | Meltdown Apex | $MgCl_2$ | $1.10 | /gallon | |
| N | SOS | $MgCl_2$ | $1.30 | /gallon | |
| Y | TC Econo | $MgCl_2$ | $1.40 | /gallon | |
| N | Thawrox Gold Alt | $MgCl_2$ | $1.70 | /gallon | |
| N | Calcium Chloride | $CaCl_2$ | $4.00 | /gallon | |
| Y | RGP-8 | $CaCl_2$ | $1.45 | /gallon | |
| N | Geomelt 55 | Carb | $1.85 | /gallon | |
| N | Geomelt Gen 3 | Carb | $4.00 | /gallon | |
| N | LCS 5000 | Carb | $2.75 | /gallon | |
| N | Ice Bite | Carb | $1.50 | /gallon | |
| N | Alpine Ice Melt | Acetate | $5.60 | /gallon | (No Corrosion Factor) |
| Y | CF-7 | Acetate | $4.50 | /gallon | (No Corrosion Factor) |
| N | Apogee NonChloride | Acetate | $0.80 | /gallon | (No Corrosion Factor) |


Cost/Lane Mile of Liquid Anti Icing
(No Situational Performance Factors)
Cost/Lane Mile
$40
$35
$30
$25
$20
$15
$10
$5
$0
-35
-25
-15
-5
5
15
25
35
Temperature °F
Salt Brine
AP Liquid Deicer
Articlear Gold
Freezeguard
Ice Ban 200M
Meltdown Apex
TC Econo
Thawrox Gold Alternative
Calcium Chloride
RGP-8
Geomelt 55
Geomelt Gen 3
LCS 5000


Cost/Lane Mile of Liquid Anti Icing
(With Situational Performance Factors)
Cost/Lane Mile
$40
$35
$30
$25
$20
$15
$10
$5
$0
-35
-25
-15
-5
5
15
25
35
Temperature °F
Salt Brine
AP Liquid Deicer
Articlear Gold
Freezeguard
Ice Ban 200M
Meltdown Apex
TC Econo
Thawrox Gold Alternative
Calcium Chloride
RGP-8
Geomelt 55

# Appendix I – Cost Model Factor Evaluation

Deicing Cost Model
Mn/DOT Research Contract 96319

Name/Date: MSU Mankato Civil Engineering

Roadway: Factor Evaluation

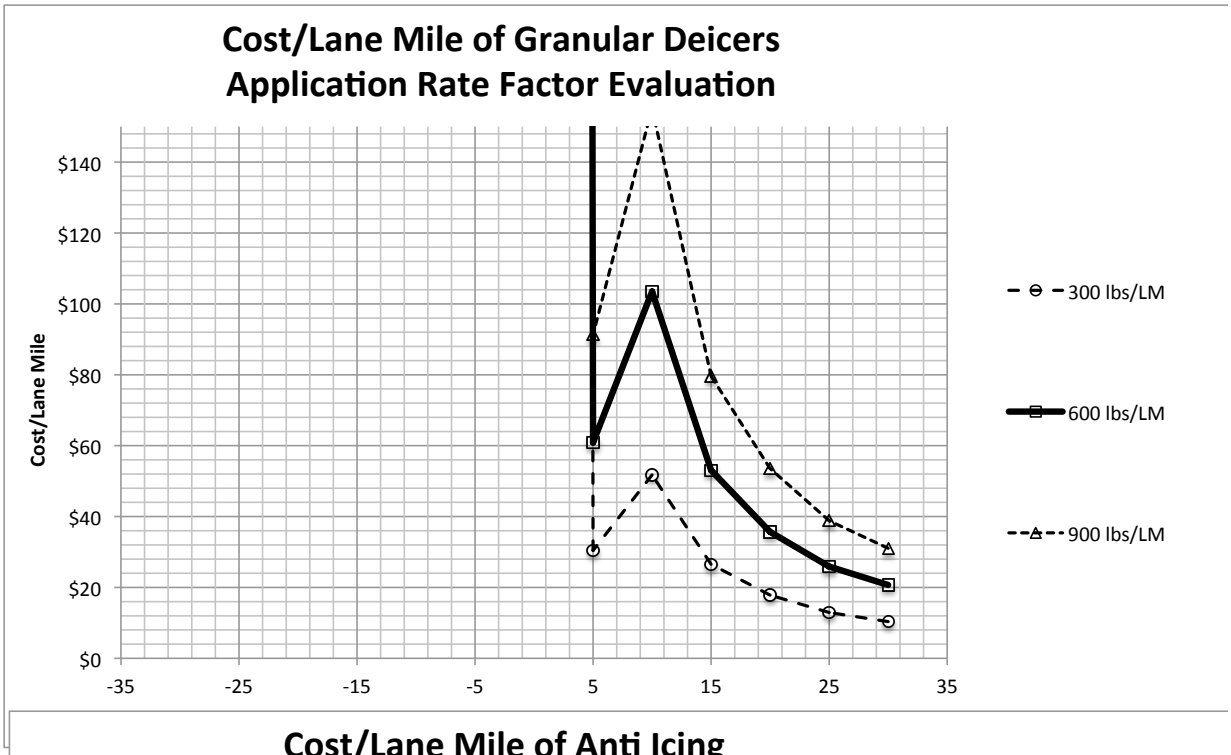
| **Application Factors - Select levels by placing a "Y" in the appropriate blocks.** | | | | | | | Factors | | |
|---|---|---|---|---|---|---|---|---|---|
| Application Rate | Y | 300 lbs/LM | Y | 600 lbs/LM | Y | 900 lbs/LM | 300 | 600 | 900 |
| Ice Thickness (inches) | | < 1/16th | Y | 1/16-3/16th | | >1/4th | 1.5 | 1.0 | 0.5 |
| Temperature Movement | | Rising | Y | Steady | | Falling | 1.1 | 1.0 | 0.9 |
| Repeat Time | | 30-90 min | Y | 2-4 hr | | > 4 hrs | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | | | |
| Pavement Material | | Asphalt | Y | Concrete | | Open Graded/Porous | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | | 0 to 3 yrs | Y | 4 to 8 yrs | | 8 to 20+ yrs | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | | | |
| Sun Condition | | Bright Sky | Y | Overcast | | Dark | 1.5 | 1.0 | 0.5 |
| Wind Condition | | Calm | Y | Light | | Breezy | 1.25 | 1.00 | 0.75 |
| Roadway Shade | | No Shade | Y | Occassional | | Full Shade | 1.25 | 1.00 | 0.75 |

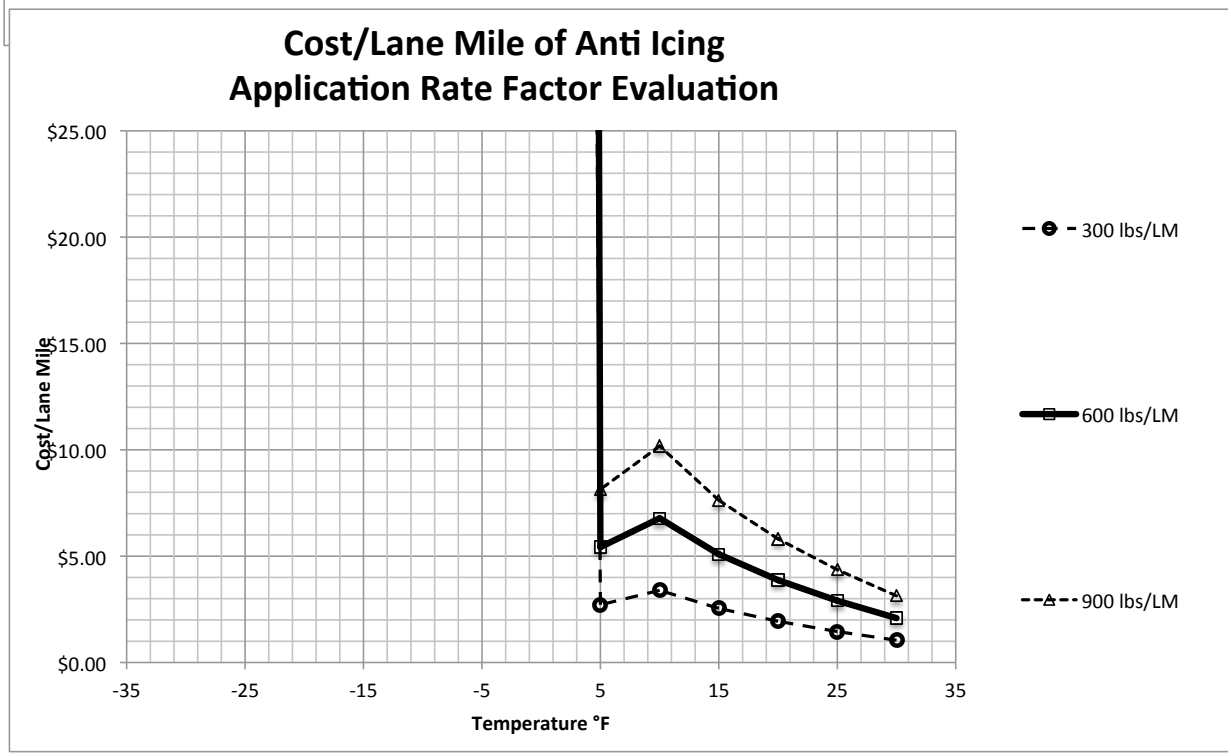
| **Roadway Volume (ADT)** | | | |
|---|---|---|---|
| Super Commuter (>30,000 ADT) | | | 2.5 |
| Urban Commuter (10,000-30,000 ADT) | | | 2.0 |
| Rural Commuter (2,000-10,000 ADT) | | | 1.5 |
| Primary (800-2000 ADT) | Y | ASSUMED LEVEL OF SERVICE | 1.0 |
| Secondary (<800 ADT) | | | 0.75 |
| Rural Low Volume | | | 0.50 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Truck Proportion** | | >5% ADT | Y | 2-5% ADT | | <2% ADT | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | | | |
| Corrosion Sensitve Struct. | | Low | Y | Medium | | High | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | | Low | Y | Medium | | High | 1.25 | 1.00 | 0.75 |

| **Solid Deicers to Consider ("Y" to graph)** | | **Cost (Delivered)** |
|---|---|---|
| Y Rock Salt | NaCl | $75.00 /ton |

| **Liquid Deicers to Consider ("Y" to graph)** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Y | Salt Brine | NaCl | | $0.11 /gallon | | | | | |
| | Application Rate for Anti Icing | Y | 10 gal/LM | Y | 20 gal/LM | Y | 30 gal/LM | 10 | 20 | 30 |


Cost/Lane Mile of Granular Deicers
Application Rate Factor Evaluation
Cost/Lane Mile
$140
$120
$100
$80
$60
$40
$20
$0
-35
-25
-15
-5
5
15
25
35
300 lbs/LM
600 lbs/LM
900 lbs/LM


Cost/Lane Mile of Anti Icing
Application Rate Factor Evaluation
Cost/Lane Mile
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
-35
-25
-15
-5
5
15
25
35
Temperature °F
300 lbs/LM
600 lbs/LM
900 lbs/LM

Deicing Cost Model
Mn/DOT Research Contract 96319

Name/Date: MSU Mankato Civil Engineering

Roadway: Factor Evaluation

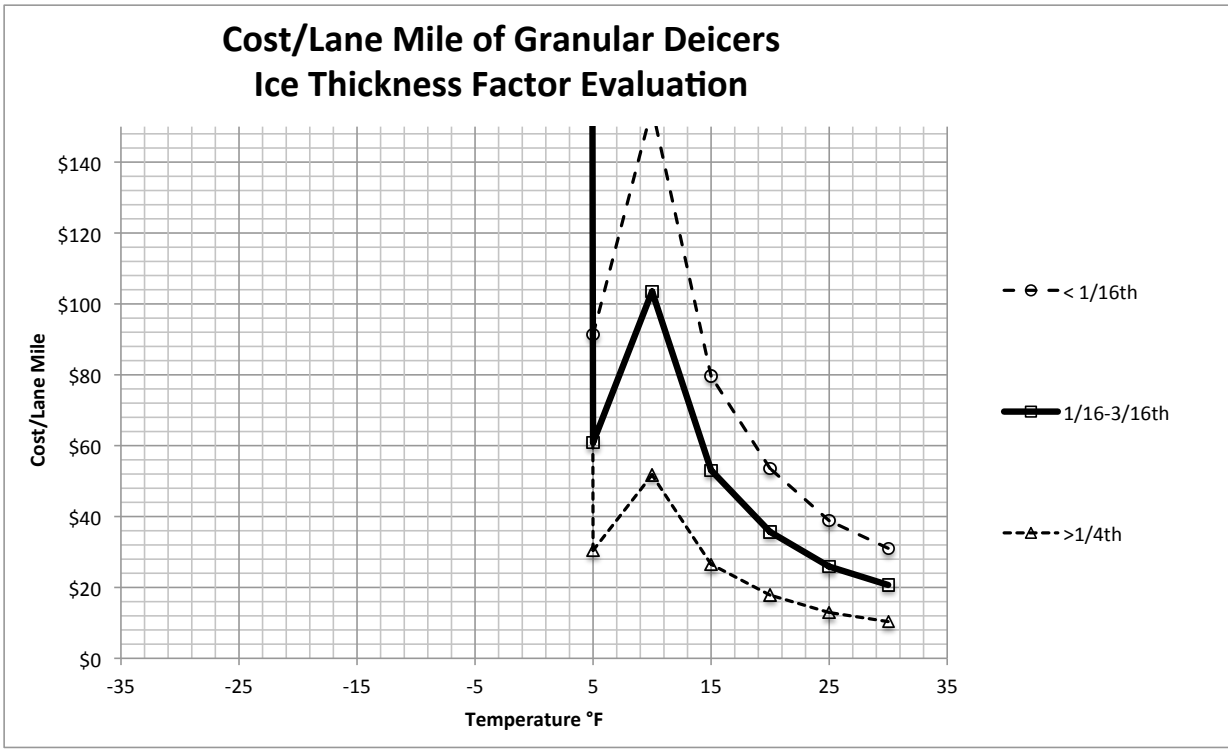
| **Application Factors - Select levels by placing a "Y" in the appropriate blocks.** | | | | | | | Factors | | |
|---|---|---|---|---|---|---|---|---|---|
| Application Rate | | 300 lbs/LM | Y | 600 lbs/LM | | 900 lbs/LM | 300 | 600 | 900 |
| Ice Thickness (inches) | Y | < 1/16th | Y | 1/16-3/16th | Y | >1/4th | 1.5 | 1.0 | 0.5 |
| Temperature Movement | | Rising | Y | Steady | | Falling | 1.1 | 1.0 | 0.9 |
| Repeat Time | | 30-90 min | Y | 2-4 hr | | > 4 hrs | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | | | |
| Pavement Material | | Asphalt | Y | Concrete | | Open Graded/Porous | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | | 0 to 3 yrs | Y | 4 to 8 yrs | | 8 to 20+ yrs | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | | | |
| Sun Condition | | Bright Sky | Y | Overcast | | Dark | 1.5 | 1.0 | 0.5 |
| Wind Condition | | Calm | Y | Light | | Breezy | 1.25 | 1.00 | 0.75 |
| Roadway Shade | | No Shade | Y | Occassional | | Full Shade | 1.25 | 1.00 | 0.75 |

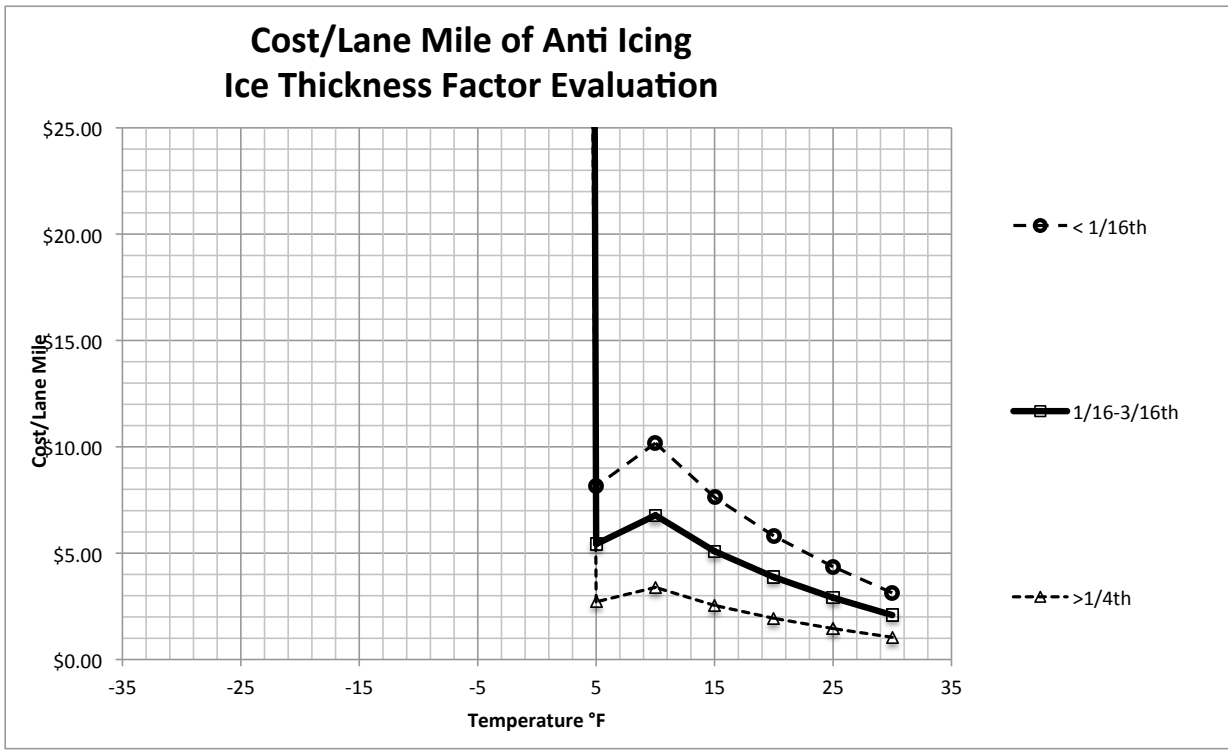
| **Roadway Volume (ADT)** | | | |
|---|---|---|---|
| Super Commuter (>30,000 ADT) | | | 2.5 |
| Urban Commuter (10,000-30,000 ADT) | | | 2.0 |
| Rural Commuter (2,000-10,000 ADT) | | | 1.5 |
| Primary (800-2000 ADT) | Y | ASSUMED LEVEL OF SERVICE | 1.0 |
| Secondary (<800 ADT) | | | 0.75 |
| Rural Low Volume | | | 0.50 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Truck Proportion** | | >5% ADT | Y | 2-5% ADT | | <2% ADT | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | | | |
| Corrosion Sensitve Struct. | | Low | Y | Medium | | High | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | | Low | Y | Medium | | High | 1.25 | 1.00 | 0.75 |

| **Solid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | |
|---|---|---|---|---|
| Y | Rock Salt | NaCl | $75.00 | /ton |

| **Liquid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | | | | | |
|---|---|---|---|---|---|---|---|---|
| Y | Salt Brine | NaCl | $0.11 | /gallon | | | | |
| | Application Rate for Anti Icing | | 10 gal/LM | Y | 20 gal/LM | | 30 gal/LM | 10 | 20 | 30 |


Cost/Lane Mile of Granular Deicers
Ice Thickness Factor Evaluation
$140
$120
$100
$80
$60
$40
$20
$0
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
< 1/16th
1/16-3/16th
>1/4th


Cost/Lane Mile of Anti Icing
Ice Thickness Factor Evaluation
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
< 1/16th
1/16-3/16th
>1/4th

Deicing Cost Model
Mn/DOT Research Contract 96319

Name/Date: MSU Mankato Civil Engineering

Roadway: Factor Evaluation

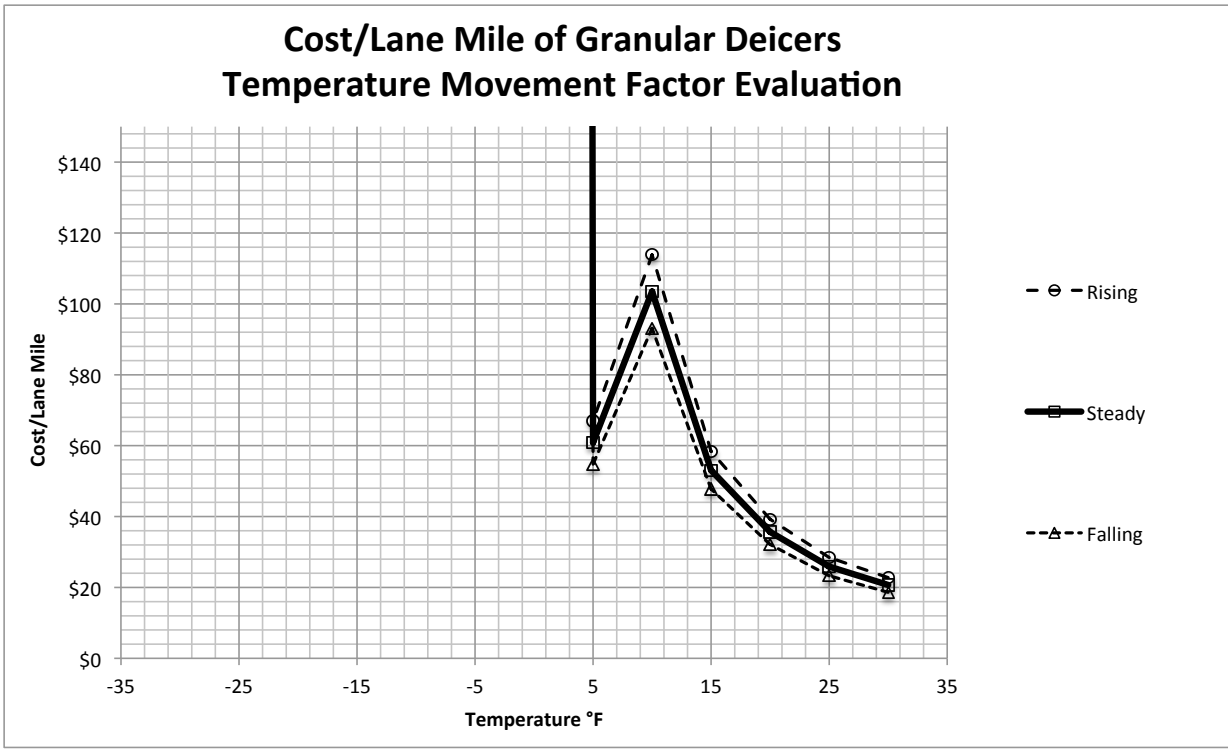
| **Application Factors - Select levels by placing a "Y" in the appropriate blocks.** | | | | | | | Factors | | |
|---|---|---|---|---|---|---|---|---|---|
| Application Rate | | 300 lbs/LM | Y | 600 lbs/LM | | 900 lbs/LM | 300 | 600 | 900 |
| Ice Thickness (inches) | | < 1/16th | Y | 1/16-3/16th | | >1/4th | 1.5 | 1.0 | 0.5 |
| Temperature Movement | Y | Rising | Y | Steady | Y | Falling | 1.1 | 1.0 | 0.9 |
| Repeat Time | | 30-90 min | Y | 2-4 hr | | > 4 hrs | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | | | |
| Pavement Material | | Asphalt | Y | Concrete | | Open Graded/Porous | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | | 0 to 3 yrs | Y | 4 to 8 yrs | | 8 to 20+ yrs | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | | | |
| Sun Condition | | Bright Sky | Y | Overcast | | Dark | 1.5 | 1.0 | 0.5 |
| Wind Condition | | Calm | Y | Light | | Breezy | 1.25 | 1.00 | 0.75 |
| Roadway Shade | | No Shade | Y | Occassional | | Full Shade | 1.25 | 1.00 | 0.75 |

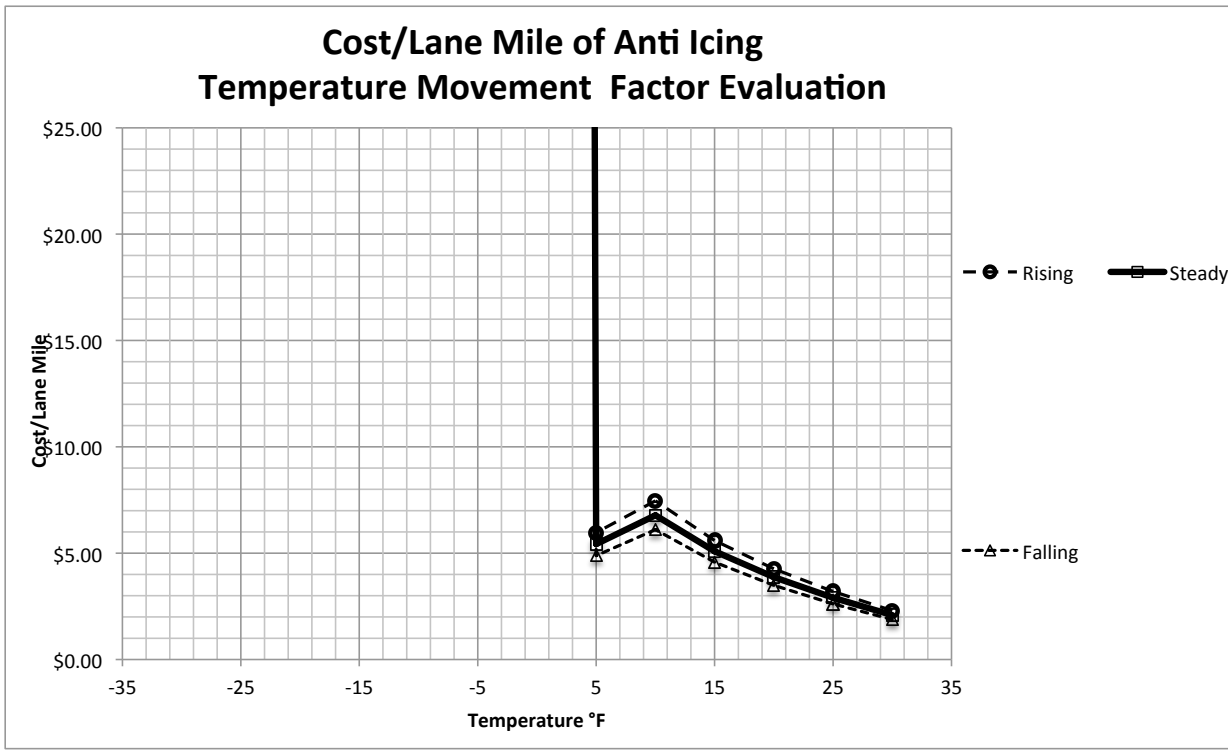
| **Roadway Volume (ADT)** | | | |
|---|---|---|---|
| Super Commuter (>30,000 ADT) | | | 2.5 |
| Urban Commuter (10,000-30,000 ADT) | | | 2.0 |
| Rural Commuter (2,000-10,000 ADT) | | | 1.5 |
| Primary (800-2000 ADT) | Y | ASSUMED LEVEL OF SERVICE | 1.0 |
| Secondary (<800 ADT) | | | 0.75 |
| Rural Low Volume | | | 0.50 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Truck Proportion** | | >5% ADT | Y | 2-5% ADT | | <2% ADT | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | | | |
| Corrosion Sensitve Struct. | | Low | Y | Medium | | High | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | | Low | Y | Medium | | High | 1.25 | 1.00 | 0.75 |

| **Solid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | |
|---|---|---|---|---|
| Y | Rock Salt | NaCl | $75.00 | /ton |

| **Liquid Deicers to Consider ("Y" to graph)** | | | | **Cost (Delivered)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Y | Salt Brine | | NaCl | | $0.11 | /gallon | | | |
| | Application Rate for Anti Icing | | 10 gal/LM | Y | 20 gal/LM | | 30 gal/LM | 10 | 20 | 30 |


Cost/Lane Mile of Granular Deicers
Temperature Movement Factor Evaluation
$140
$120
$100
$80
$60
$40
$20
$0
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
Rising
Steady
Falling


Cost/Lane Mile of Anti Icing
Temperature Movement Factor Evaluation
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
Rising
Steady
Falling

Deicing Cost Model
Mn/DOT Research Contract 96319

Name/Date: MSU Mankato Civil Engineering

Roadway: Factor Evaluation

| **Application Factors - Select levels by placing a "Y" in the appropriate blocks.** | | | | | | | Factors | | |
|---|---|---|---|---|---|---|---|---|---|
| Application Rate | | 300 lbs/LM | Y | 600 lbs/LM | | 900 lbs/LM | 300 | 600 | 900 |
| Ice Thickness (inches) | | < 1/16th | Y | 1/16-3/16th | | >1/4th | 1.5 | 1.0 | 0.5 |
| Temperature Movement | | Rising | Y | Steady | | Falling | 1.1 | 1.0 | 0.9 |
| Repeat Time | Y | 30-90 min | Y | 2-4 hr | Y | > 4 hrs | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | | | |
| Pavement Material | | Asphalt | Y | Concrete | | Open Graded/Porous | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | | 0 to 3 yrs | Y | 4 to 8 yrs | | 8 to 20+ yrs | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | | | |
| Sun Condition | | Bright Sky | Y | Overcast | | Dark | 1.5 | 1.0 | 0.5 |
| Wind Condition | | Calm | Y | Light | | Breezy | 1.25 | 1.00 | 0.75 |
| Roadway Shade | | No Shade | Y | Occassional | | Full Shade | 1.25 | 1.00 | 0.75 |

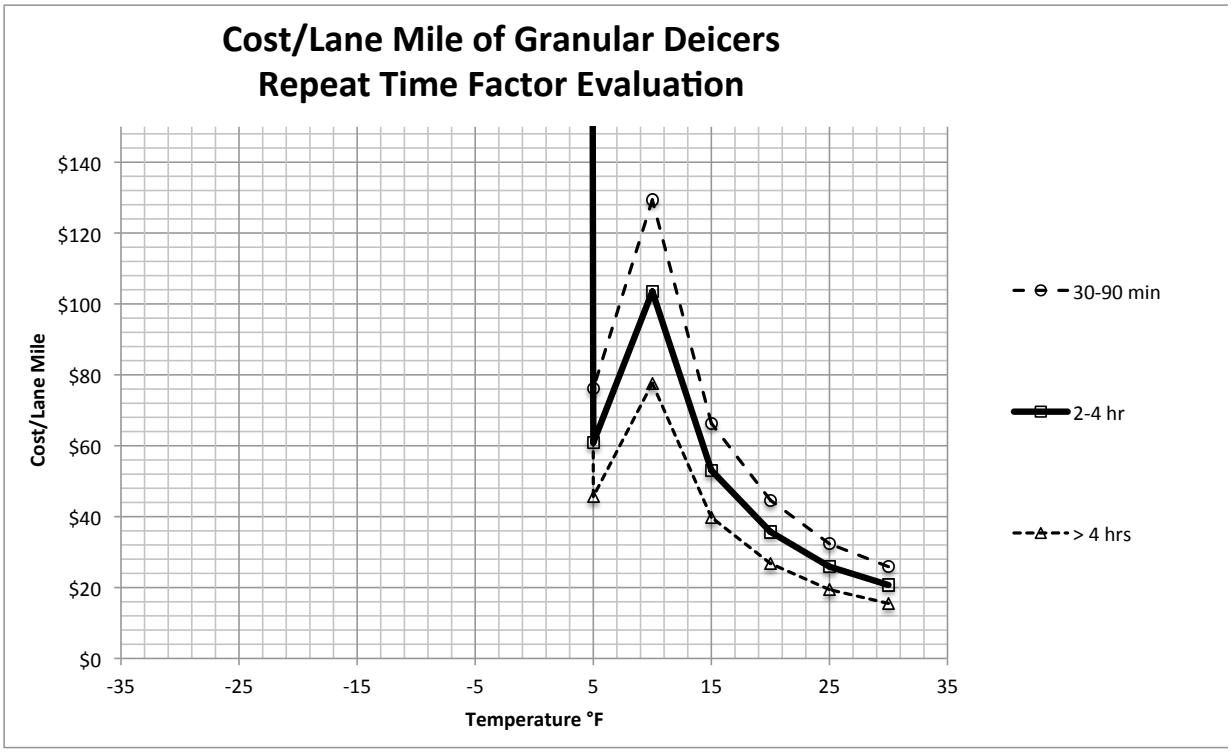
| **Roadway Volume (ADT)** | | | |
|---|---|---|---|
| Super Commuter (>30,000 ADT) | | | 2.5 |
| Urban Commuter (10,000-30,000 ADT) | | | 2.0 |
| Rural Commuter (2,000-10,000 ADT) | | | 1.5 |
| Primary (800-2000 ADT) | Y | ASSUMED LEVEL OF SERVICE | 1.0 |
| Secondary (<800 ADT) | | | 0.75 |
| Rural Low Volume | | | 0.50 |

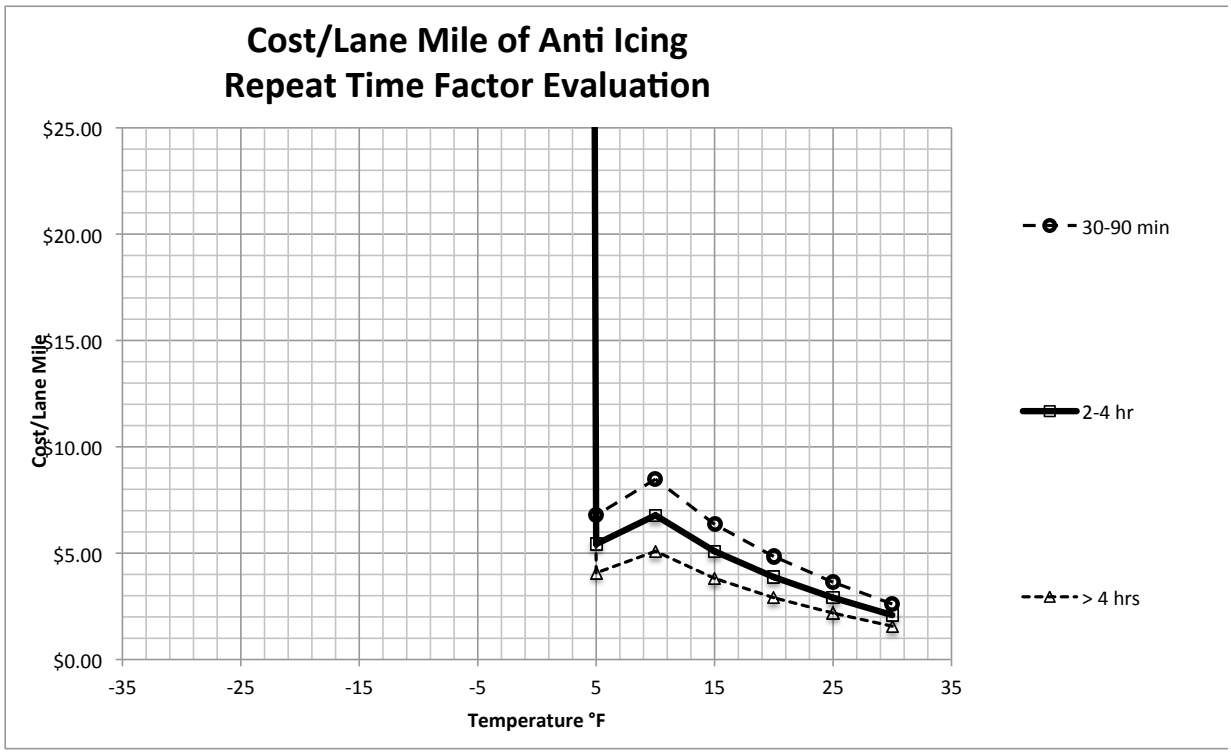
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Truck Proportion** | | >5% ADT | Y | 2-5% ADT | | <2% ADT | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | | | |
| Corrosion Sensitve Struct. | | Low | Y | Medium | | High | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | | Low | Y | Medium | | High | 1.25 | 1.00 | 0.75 |

| **Solid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | |
|---|---|---|---|---|
| Y | Rock Salt | NaCl | $75.00 | /ton |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

| **Liquid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | |
|---|---|---|---|---|
| Y | Salt Brine | NaCl | $0.11 | /gallon |
| | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Application Rate for Anti Icing | | 10 gal/LM | Y | 20 gal/LM | | 30 gal/LM | 10 | 20 | 30 |


Cost/Lane Mile of Granular Deicers
Repeat Time Factor Evaluation
$140
$120
$100
$80
$60
$40
$20
$0
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
30-90 min
2-4 hr
> 4 hrs


Cost/Lane Mile of Anti Icing
Repeat Time Factor Evaluation
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
30-90 min
2-4 hr
> 4 hrs

Deicing Cost Model
Mn/DOT Research Contract 96319

Name/Date: MSU Mankato Civil Engineering

Roadway: Factor Evaluation

| **Application Factors - Select levels by placing a "Y" in the appropriate blocks.** | | | | | | Factors | | |
|---|---|---|---|---|---|---|---|---|
| Application Rate | | 300 lbs/LM | Y | 600 lbs/LM | | 900 lbs/LM | 300 | 600 | 900 |
| Ice Thickness (inches) | | < 1/16th | Y | 1/16-3/16th | | >1/4th | 1.5 | 1.0 | 0.5 |
| Temperature Movement | | Rising | Y | Steady | | Falling | 1.1 | 1.0 | 0.9 |
| Repeat Time | | 30-90 min | Y | 2-4 hr | | > 4 hrs | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | | | |
| Pavement Material | Y | Asphalt | Y | Concrete | Y | Open Graded/Porous | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | | 0 to 3 yrs | Y | 4 to 8 yrs | | 8 to 20+ yrs | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | | | |
| Sun Condition | | Bright Sky | Y | Overcast | | Dark | 1.5 | 1.0 | 0.5 |
| Wind Condition | | Calm | Y | Light | | Breezy | 1.25 | 1.00 | 0.75 |
| Roadway Shade | | No Shade | Y | Occassional | | Full Shade | 1.25 | 1.00 | 0.75 |

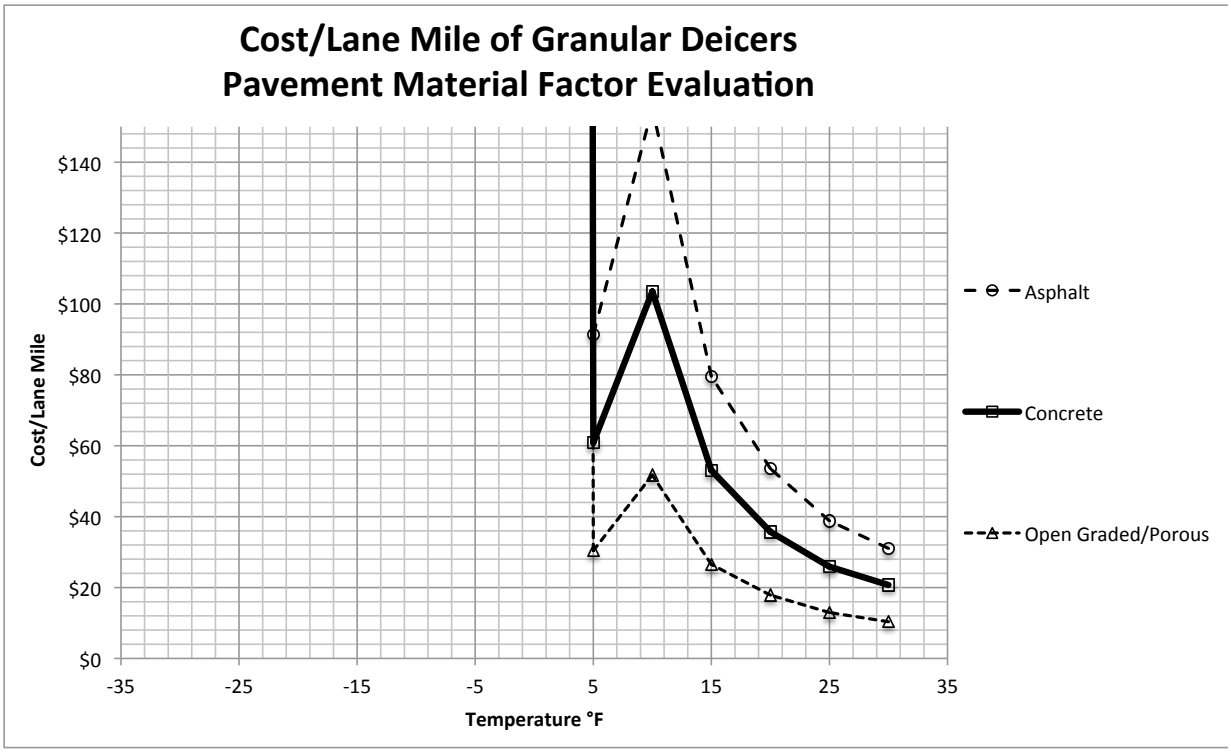
| **Roadway Volume (ADT)** | | | |
|---|---|---|---|
| Super Commuter (>30,000 ADT) | | | 2.5 |
| Urban Commuter (10,000-30,000 ADT) | | | 2.0 |
| Rural Commuter (2,000-10,000 ADT) | | | 1.5 |
| Primary (800-2000 ADT) | Y | ASSUMED LEVEL OF SERVICE | 1.0 |
| Secondary (<800 ADT) | | | 0.75 |
| Rural Low Volume | | | 0.50 |

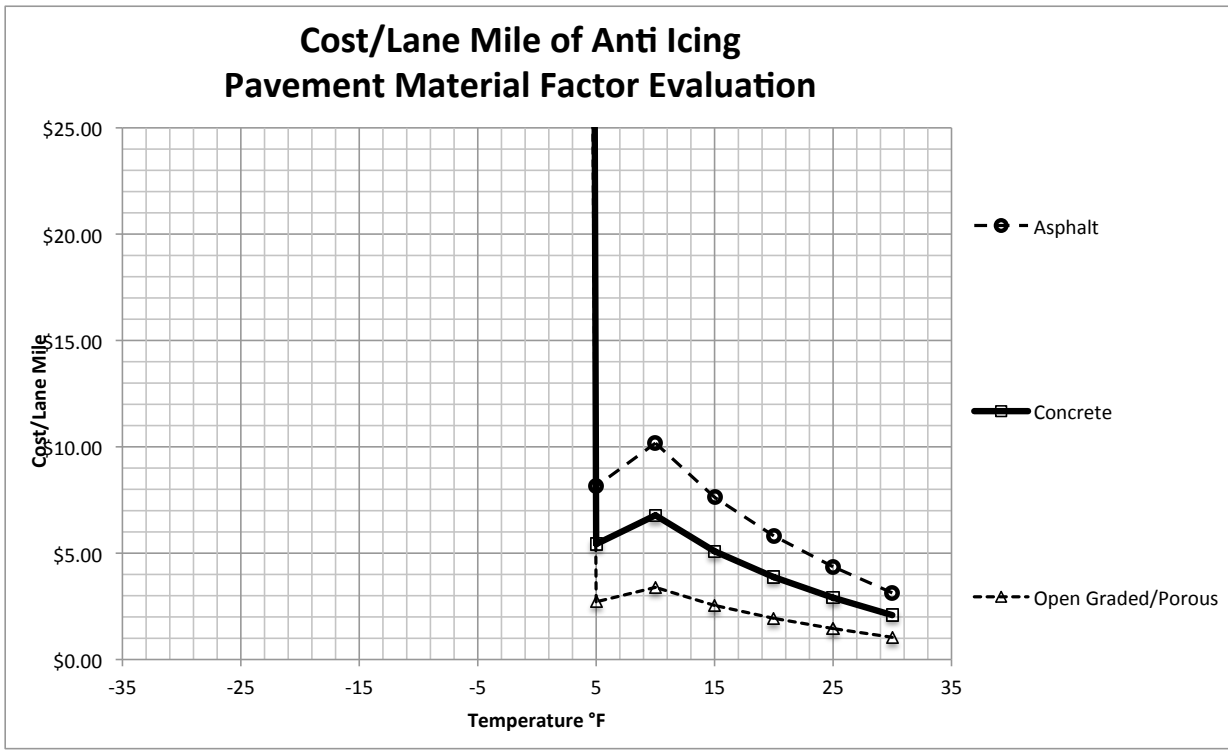
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Truck Proportion** | | >5% ADT | Y | 2-5% ADT | | <2% ADT | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | | | |
| Corrosion Sensitve Struct. | | Low | Y | Medium | | High | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | | Low | Y | Medium | | High | 1.25 | 1.00 | 0.75 |

| **Solid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | |
|---|---|---|---|---|
| Y | Rock Salt | NaCl | $75.00 | /ton |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

| **Liquid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | |
|---|---|---|---|---|
| Y | Salt Brine | NaCl | $0.11 | /gallon |
| | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Application Rate for Anti Icing | | 10 gal/LM | Y | 20 gal/LM | | 30 gal/LM | 10 | 20 | 30 |


Cost/Lane Mile of Granular Deicers
Pavement Material Factor Evaluation
$140
$120
$100
$80
$60
$40
$20
$0
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
Asphalt
Concrete
Open Graded/Porous


Cost/Lane Mile of Anti Icing
Pavement Material Factor Evaluation
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
Asphalt
Concrete
Open Graded/Porous

Deicing Cost Model
Mn/DOT Research Contract 96319

Name/Date: MSU Mankato Civil Engineering

Roadway: Factor Evaluation

| **Application Factors - Select levels by placing a "Y" in the appropriate blocks.** | | | | | | Factors | | |
|---|---|---|---|---|---|---|---|---|
| Application Rate | | 300 lbs/LM | Y | 600 lbs/LM | | 900 lbs/LM | 300 | 600 | 900 |
| Ice Thickness (inches) | | < 1/16th | Y | 1/16-3/16th | | >1/4th | 1.5 | 1.0 | 0.5 |
| Temperature Movement | | Rising | Y | Steady | | Falling | 1.1 | 1.0 | 0.9 |
| Repeat Time | | 30-90 min | Y | 2-4 hr | | > 4 hrs | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | | | |
| Pavement Material | | Asphalt | Y | Concrete | | Open Graded/Porous | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | Y | 0 to 3 yrs | Y | 4 to 8 yrs | Y | 8 to 20+ yrs | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | | | |
| Sun Condition | | Bright Sky | Y | Overcast | | Dark | 1.5 | 1.0 | 0.5 |
| Wind Condition | | Calm | Y | Light | | Breezy | 1.25 | 1.00 | 0.75 |
| Roadway Shade | | No Shade | Y | Occassional | | Full Shade | 1.25 | 1.00 | 0.75 |

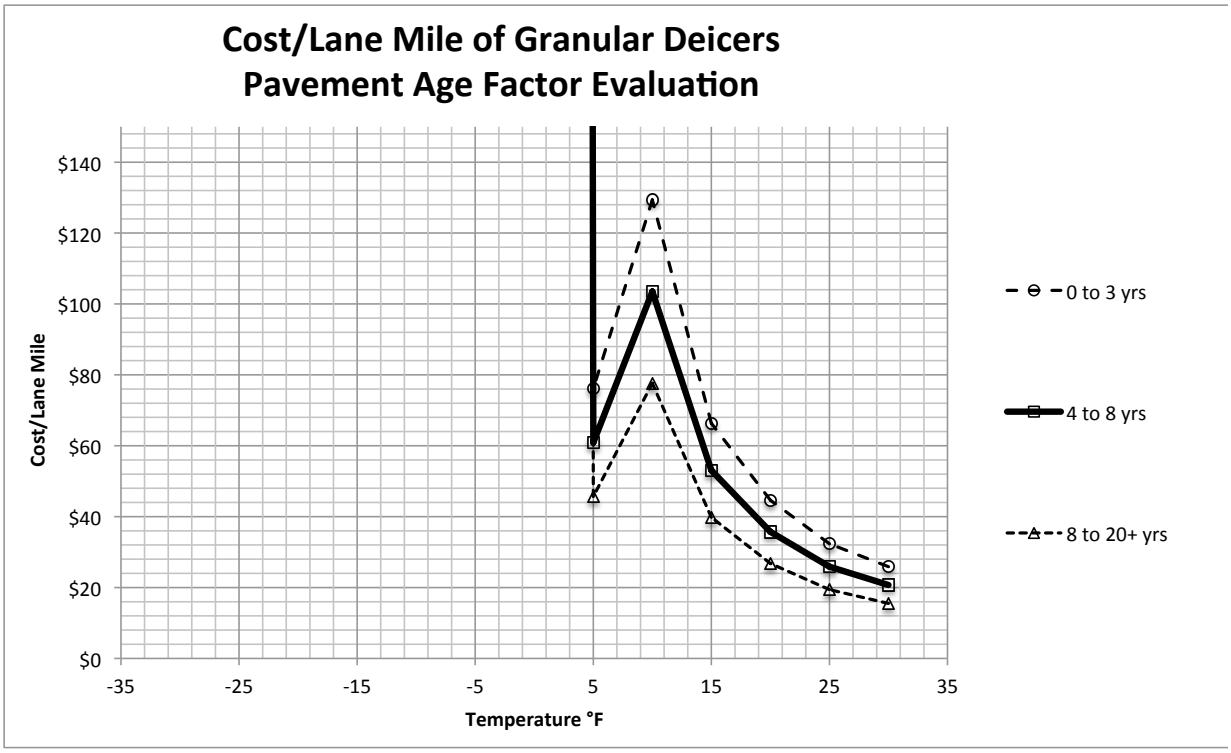
| **Roadway Volume (ADT)** | | | |
|---|---|---|---|
| Super Commuter (>30,000 ADT) | | | 2.5 |
| Urban Commuter (10,000-30,000 ADT) | | | 2.0 |
| Rural Commuter (2,000-10,000 ADT) | | | 1.5 |
| Primary (800-2000 ADT) | Y | ASSUMED LEVEL OF SERVICE | 1.0 |
| Secondary (<800 ADT) | | | 0.75 |
| Rural Low Volume | | | 0.50 |

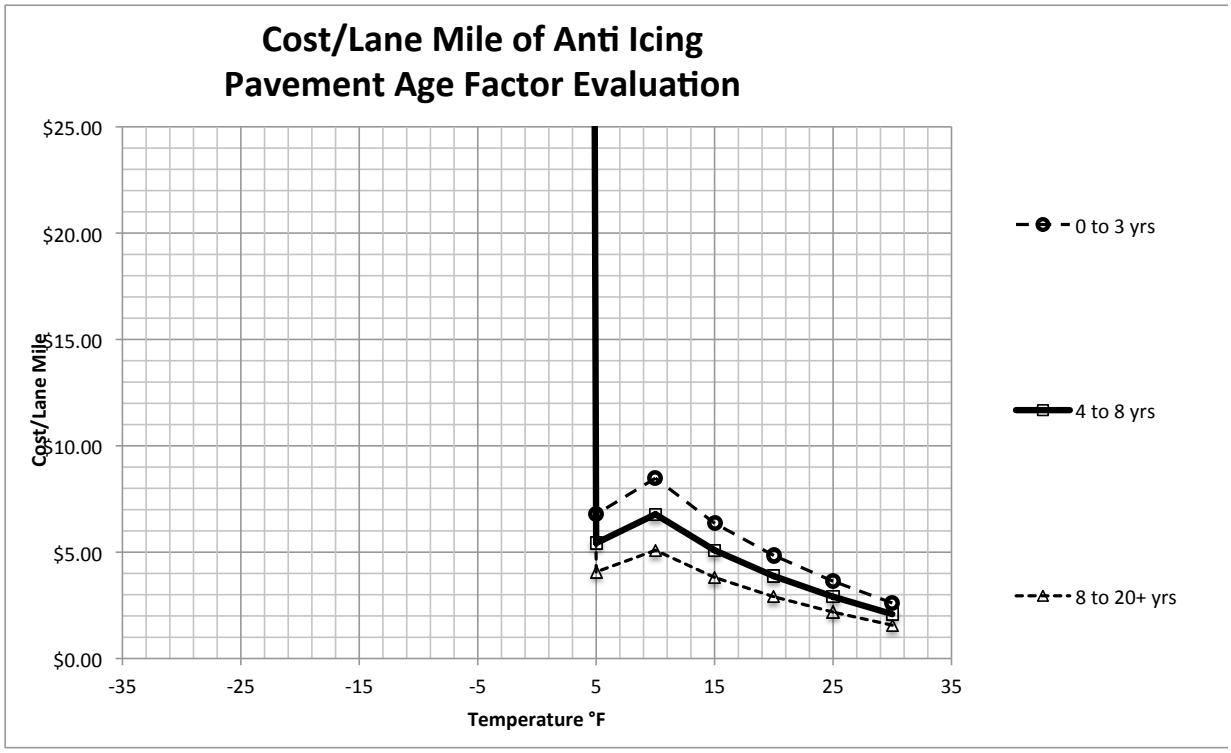
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Truck Proportion** | | >5% ADT | Y | 2-5% ADT | | <2% ADT | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | | | |
| Corrosion Sensitve Struct. | | Low | Y | Medium | | High | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | | Low | Y | Medium | | High | 1.25 | 1.00 | 0.75 |

| **Solid Deicers to Consider ("Y" to graph)** | | **Cost (Delivered)** |
|---|---|---|
| Y Rock Salt | NaCl | $75.00 /ton |

| **Liquid Deicers to Consider ("Y" to graph)** | | **Cost (Delivered)** |
|---|---|---|
| Y Salt Brine | NaCl | $0.11 /gallon |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Application Rate for Anti Icing | | 10 gal/LM | Y | 20 gal/LM | | 30 gal/LM | 10 | 20 | 30 |


Cost/Lane Mile of Granular Deicers
Pavement Age Factor Evaluation
$140
$120
$100
$80
$60
$40
$20
$0
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
0 to 3 yrs
4 to 8 yrs
8 to 20+ yrs


Cost/Lane Mile of Anti Icing
Pavement Age Factor Evaluation
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
0 to 3 yrs
4 to 8 yrs
8 to 20+ yrs

Deicing Cost Model
Mn/DOT Research Contract 96319

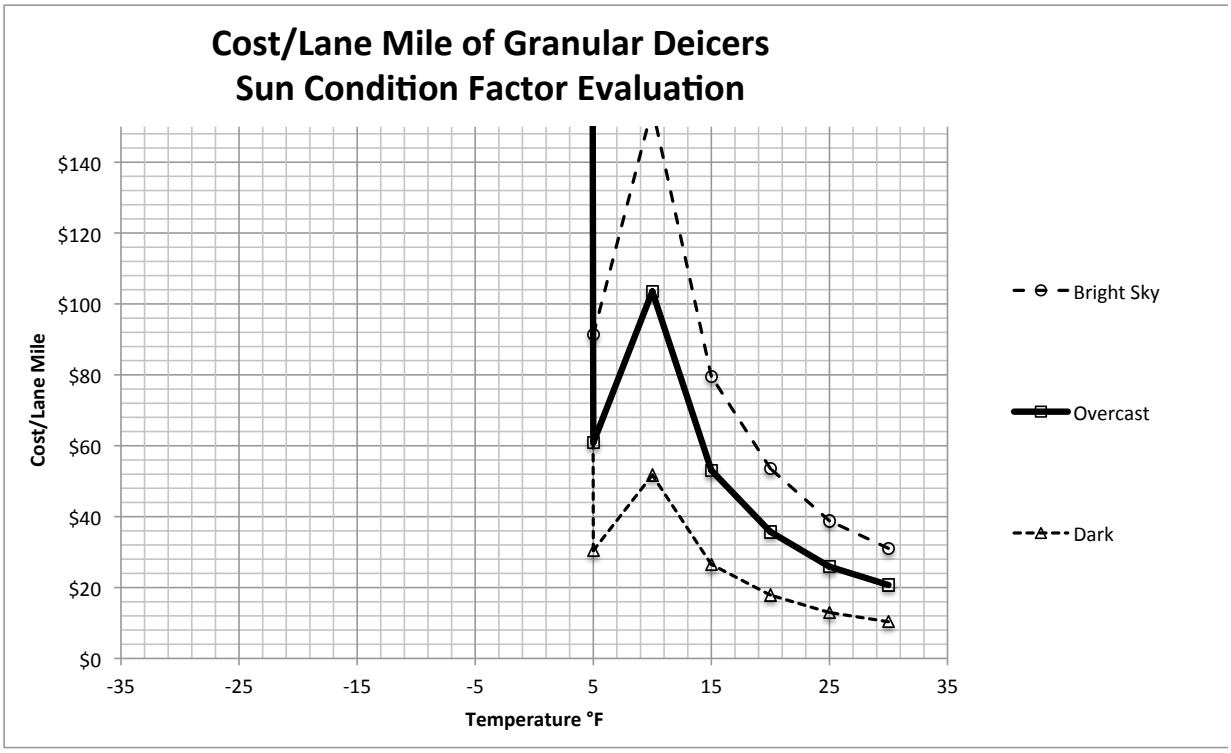
Name/Date: MSU Mankato Civil Engineering

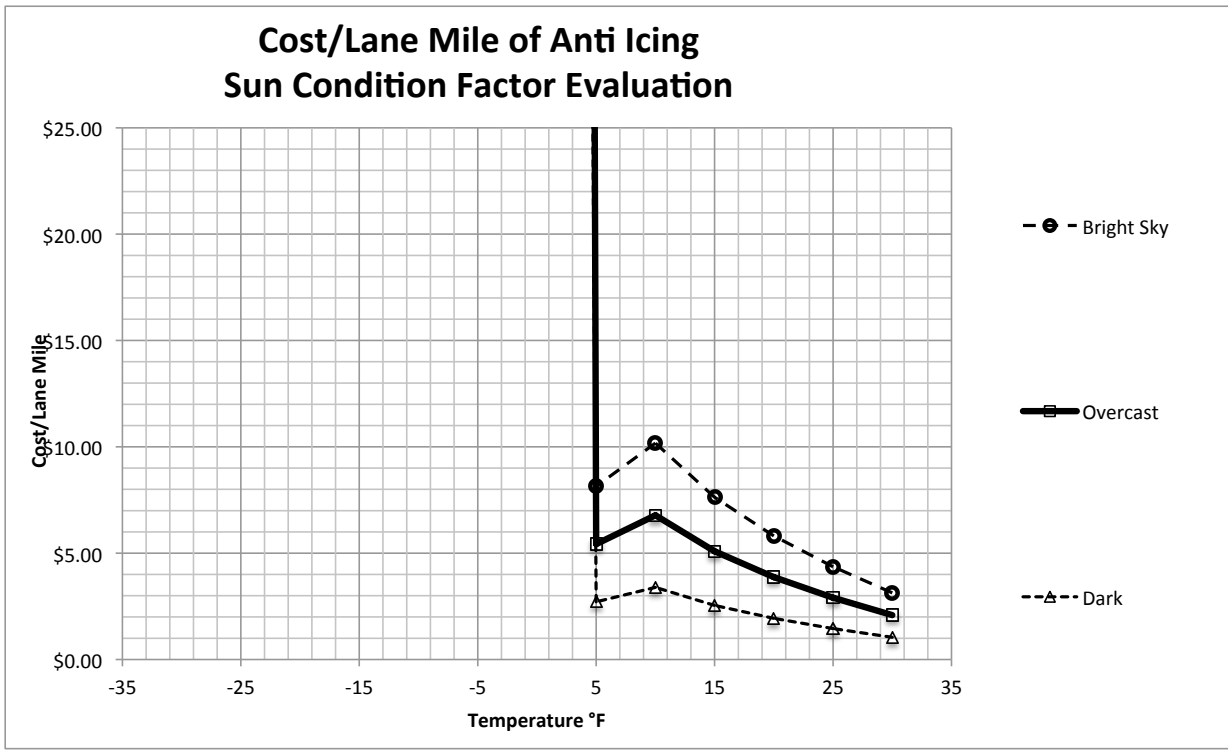
Roadway: Factor Evaluation

| **Application Factors - Select levels by placing a "Y" in the appropriate blocks.** | | | | | | | Factors | | |
|---|---|---|---|---|---|---|---|---|---|
| Application Rate | | 300 lbs/LM | Y | 600 lbs/LM | | 900 lbs/LM | 300 | 600 | 900 |
| Ice Thickness (inches) | | < 1/16th | Y | 1/16-3/16th | | >1/4th | 1.5 | 1.0 | 0.5 |
| Temperature Movement | | Rising | Y | Steady | | Falling | 1.1 | 1.0 | 0.9 |
| Repeat Time | | 30-90 min | Y | 2-4 hr | | > 4 hrs | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | | | |
| Pavement Material | | Asphalt | Y | Concrete | | Open Graded/Porous | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | | 0 to 3 yrs | Y | 4 to 8 yrs | | 8 to 20+ yrs | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | | | |
| Sun Condition | Y | Bright Sky | Y | Overcast | Y | Dark | 1.5 | 1.0 | 0.5 |
| Wind Condition | | Calm | Y | Light | | Breezy | 1.25 | 1.00 | 0.75 |
| Roadway Shade | | No Shade | Y | Occassional | | Full Shade | 1.25 | 1.00 | 0.75 |
| **Roadway Volume (ADT)** | | | | | | | | | |
| Super Commuter (>30,000 ADT) | | | | | | | 2.5 | | |
| Urban Commuter (10,000-30,000 ADT) | | | | | | | 2.0 | | |
| Rural Commuter (2,000-10,000 ADT) | | | | | | | 1.5 | | |
| Primary (800-2000 ADT) | Y | ASSUMED LEVEL OF SERVICE | | | | | 1.0 | | |
| Secondary (<800 ADT) | | | | | | | 0.75 | | |
| Rural Low Volume | | | | | | | 0.50 | | |
| **Truck Proportion** | | >5% ADT | Y | 2-5% ADT | | <2% ADT | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | | | |
| Corrosion Sensitve Struct. | | Low | Y | Medium | | High | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | | Low | Y | Medium | | High | 1.25 | 1.00 | 0.75 |

| **Solid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | |
|---|---|---|---|---|
| Y | Rock Salt | NaCl | $75.00 | /ton |

| **Liquid Deicers to Consider ("Y" to graph)** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Y | Salt Brine | NaCl | | | $0.11 | /gallon | | | |
| | Application Rate for Anti Icing | | 10 gal/LM | Y | 20 gal/LM | | 30 gal/LM | 10 | 20 | 30 |


Cost/Lane Mile of Granular Deicers
Sun Condition Factor Evaluation
$140
$120
$100
$80
$60
$40
$20
$0
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
Bright Sky
Overcast
Dark


Cost/Lane Mile of Anti Icing
Sun Condition Factor Evaluation
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
Bright Sky
Overcast
Dark

Deicing Cost Model
Mn/DOT Research Contract 96319

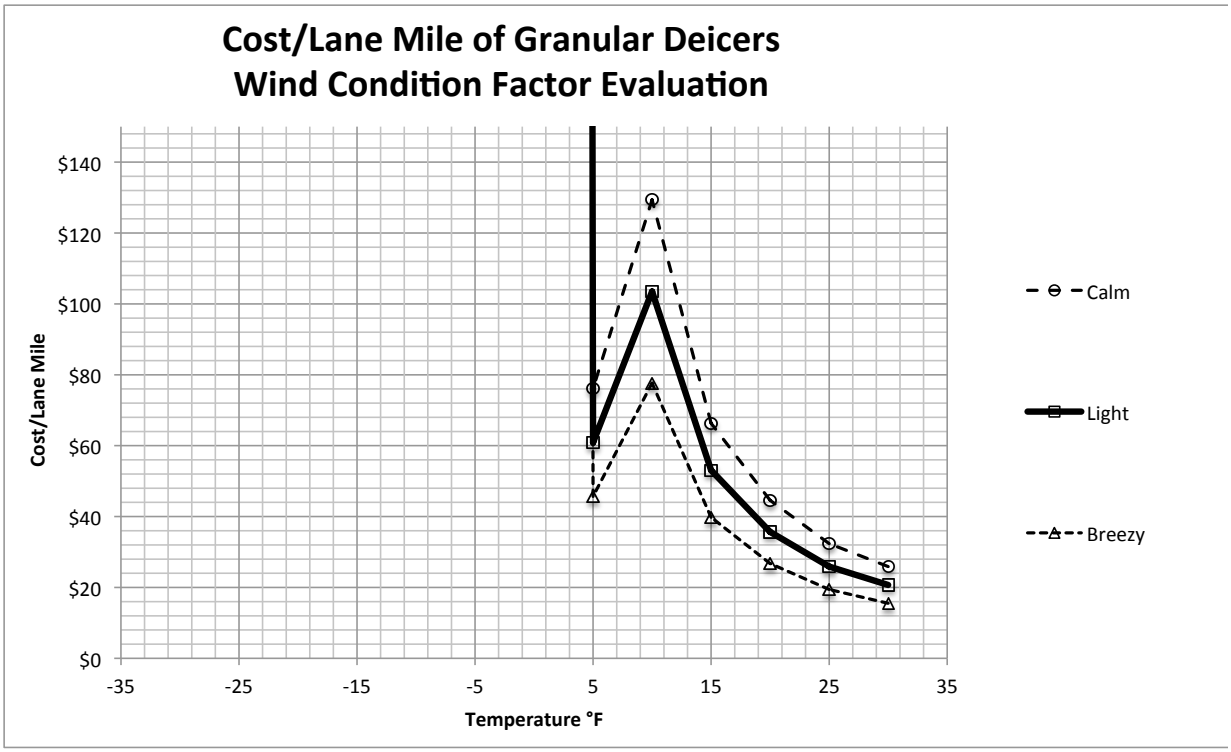
Name/Date: MSU Mankato Civil Engineering

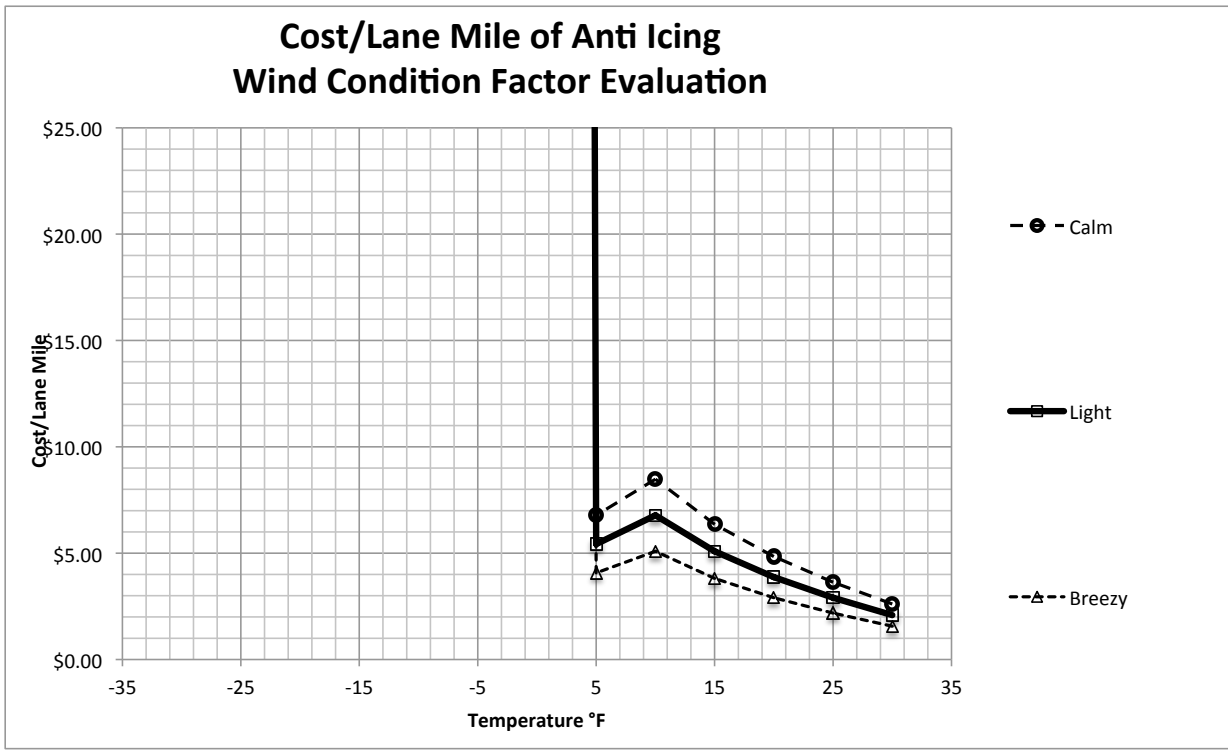
Roadway: Factor Evaluation

| **Application Factors - Select levels by placing a "Y" in the appropriate blocks.** | | | | | | Factors | | |
|---|---|---|---|---|---|---|---|---|
| Application Rate | | 300 lbs/LM | Y | 600 lbs/LM | | 900 lbs/LM | 300 | 600 | 900 |
| Ice Thickness (inches) | | < 1/16th | Y | 1/16-3/16th | | >1/4th | 1.5 | 1.0 | 0.5 |
| Temperature Movement | | Rising | Y | Steady | | Falling | 1.1 | 1.0 | 0.9 |
| Repeat Time | | 30-90 min | Y | 2-4 hr | | > 4 hrs | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | | | |
| Pavement Material | | Asphalt | Y | Concrete | | Open Graded/Porous | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | | 0 to 3 yrs | Y | 4 to 8 yrs | | 8 to 20+ yrs | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | | | |
| Sun Condition | | Bright Sky | Y | Overcast | | Dark | 1.5 | 1.0 | 0.5 |
| Wind Condition | Y | Calm | Y | Light | Y | Breezy | 1.25 | 1.00 | 0.75 |
| Roadway Shade | | No Shade | Y | Occassional | | Full Shade | 1.25 | 1.00 | 0.75 |
| **Roadway Volume (ADT)** | | | | | | | | | |
| Super Commuter (>30,000 ADT) | | | | | | | 2.5 | | |
| Urban Commuter (10,000-30,000 ADT) | | | | | | | 2.0 | | |
| Rural Commuter (2,000-10,000 ADT) | | | | | | | 1.5 | | |
| Primary (800-2000 ADT) | Y | ASSUMED LEVEL OF SERVICE | | | | | 1.0 | | |
| Secondary (<800 ADT) | | | | | | | 0.75 | | |
| Rural Low Volume | | | | | | | 0.50 | | |
| **Truck Proportion** | | >5% ADT | Y | 2-5% ADT | | <2% ADT | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | | | |
| Corrosion Sensitve Struct. | | Low | Y | Medium | | High | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | | Low | Y | Medium | | High | 1.25 | 1.00 | 0.75 |

| **Solid Deicers to Consider ("Y" to graph)** | | **Cost (Delivered)** |
|---|---|---|
| Y Rock Salt | NaCl | $75.00 /ton |

| **Liquid Deicers to Consider ("Y" to graph)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Y | Salt Brine | NaCl | | $0.11 /gallon | | | | |
| | Application Rate for Anti Icing | | 10 gal/LM | Y | 20 gal/LM | | 30 gal/LM | 10 | 20 | 30 |


Cost/Lane Mile of Granular Deicers
Wind Condition Factor Evaluation
$140
$120
$100
$80
$60
$40
$20
$0
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
Calm
Light
Breezy


Cost/Lane Mile of Anti Icing
Wind Condition Factor Evaluation
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
Calm
Light
Breezy

Deicing Cost Model
Mn/DOT Research Contract 96319

Name/Date: MSU Mankato Civil Engineering

Roadway: Factor Evaluation

| **Application Factors - Select levels by placing a "Y" in the appropriate blocks.** | | | | | | | Factors | | |
|---|---|---|---|---|---|---|---|---|---|
| Application Rate | | 300 lbs/LM | Y | 600 lbs/LM | | 900 lbs/LM | 300 | 600 | 900 |
| Ice Thickness (inches) | | < 1/16th | Y | 1/16-3/16th | | >1/4th | 1.5 | 1.0 | 0.5 |
| Temperature Movement | | Rising | Y | Steady | | Falling | 1.1 | 1.0 | 0.9 |
| Repeat Time | | 30-90 min | Y | 2-4 hr | | > 4 hrs | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | | | |
| Pavement Material | | Asphalt | Y | Concrete | | Open Graded/Porous | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | | 0 to 3 yrs | Y | 4 to 8 yrs | | 8 to 20+ yrs | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | | | |
| Sun Condition | | Bright Sky | Y | Overcast | | Dark | 1.5 | 1.0 | 0.5 |
| Wind Condition | | Calm | Y | Light | | Breezy | 1.25 | 1.00 | 0.75 |
| Roadway Shade | Y | No Shade | Y | Occassional | Y | Full Shade | 1.25 | 1.00 | 0.75 |

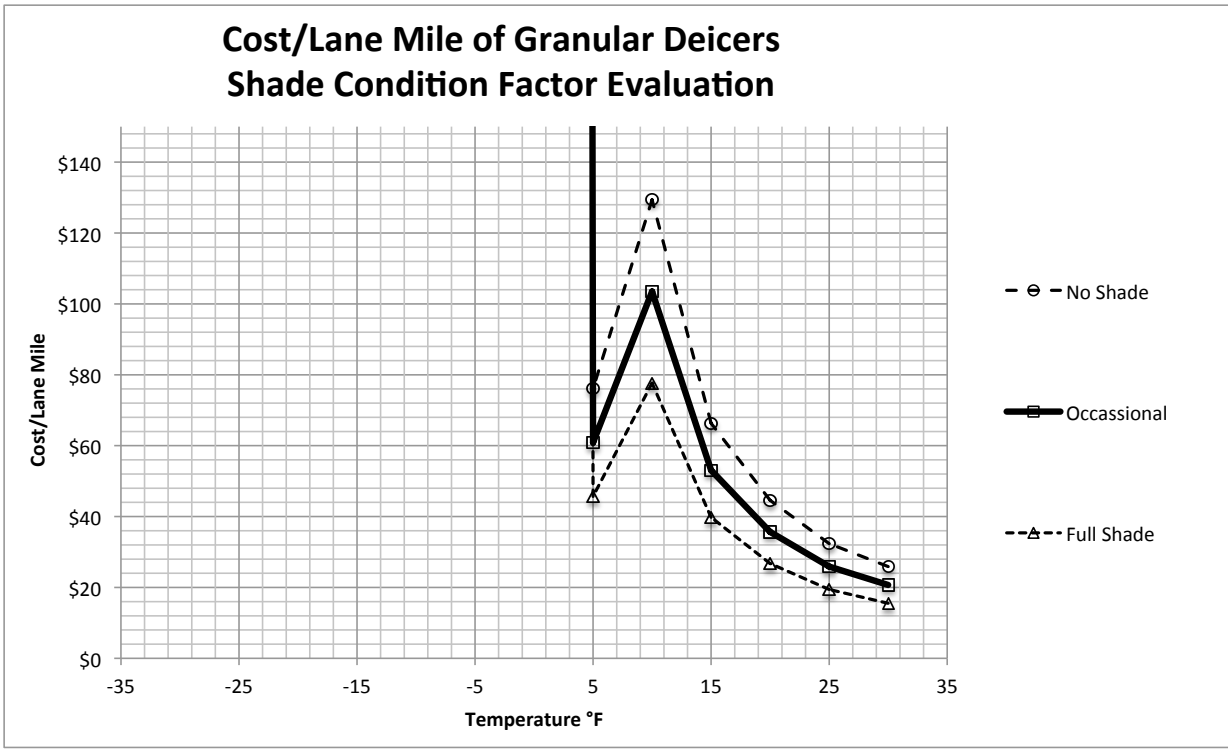
| **Roadway Volume (ADT)** | | | |
|---|---|---|---|
| Super Commuter (>30,000 ADT) | | | 2.5 |
| Urban Commuter (10,000-30,000 ADT) | | | 2.0 |
| Rural Commuter (2,000-10,000 ADT) | | | 1.5 |
| Primary (800-2000 ADT) | Y | ASSUMED LEVEL OF SERVICE | 1.0 |
| Secondary (<800 ADT) | | | 0.75 |
| Rural Low Volume | | | 0.50 |

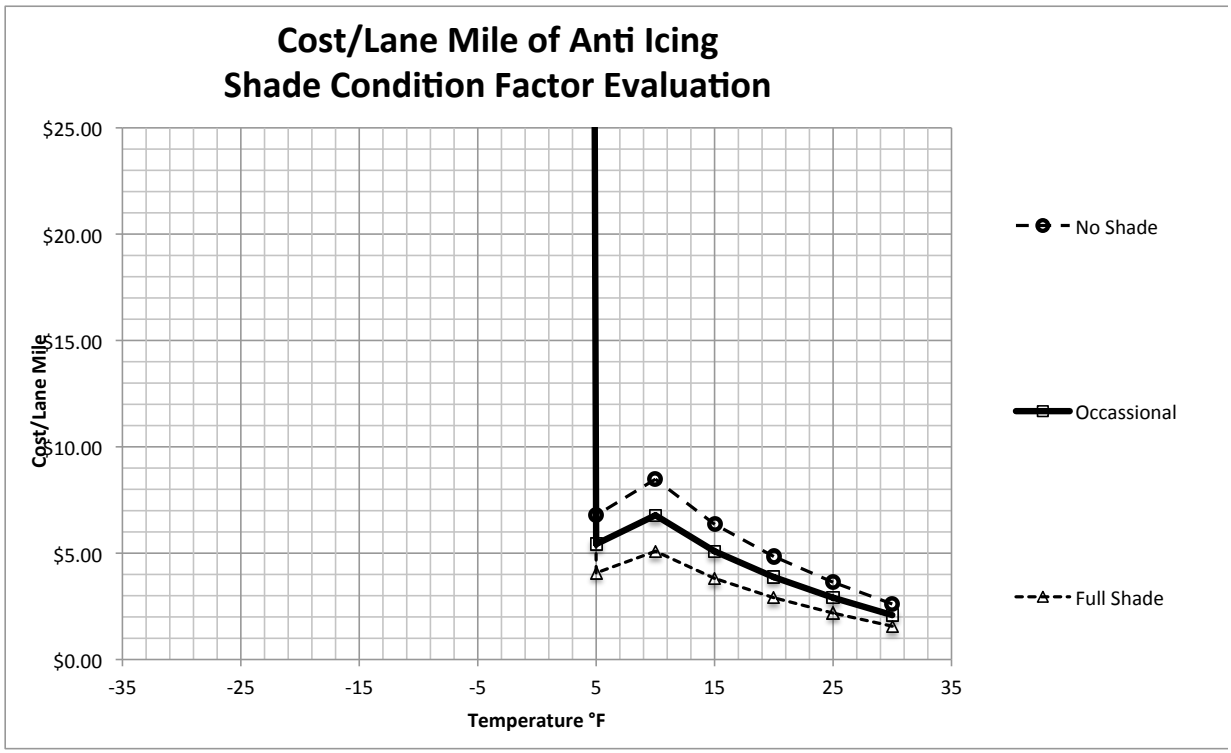
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Truck Proportion** | | >5% ADT | Y | 2-5% ADT | | <2% ADT | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | | | |
| Corrosion Sensitve Struct. | | Low | Y | Medium | | High | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | | Low | Y | Medium | | High | 1.25 | 1.00 | 0.75 |

| **Solid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | |
|---|---|---|---|---|
| Y | Rock Salt | NaCl | $75.00 | /ton |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

| **Liquid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | |
|---|---|---|---|---|
| Y | Salt Brine | NaCl | $0.11 | /gallon |
| | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Application Rate for Anti Icing | | 10 gal/LM | Y | 20 gal/LM | | 30 gal/LM | 10 | 20 | 30 |


Cost/Lane Mile of Granular Deicers
Shade Condition Factor Evaluation
$140
$120
$100
$80
$60
$40
$20
$0
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
No Shade
Occassional
Full Shade


Cost/Lane Mile of Anti Icing
Shade Condition Factor Evaluation
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
No Shade
Occassional
Full Shade

Deicing Cost Model
Mn/DOT Research Contract 96319

Name/Date: MSU Mankato Civil Engineering

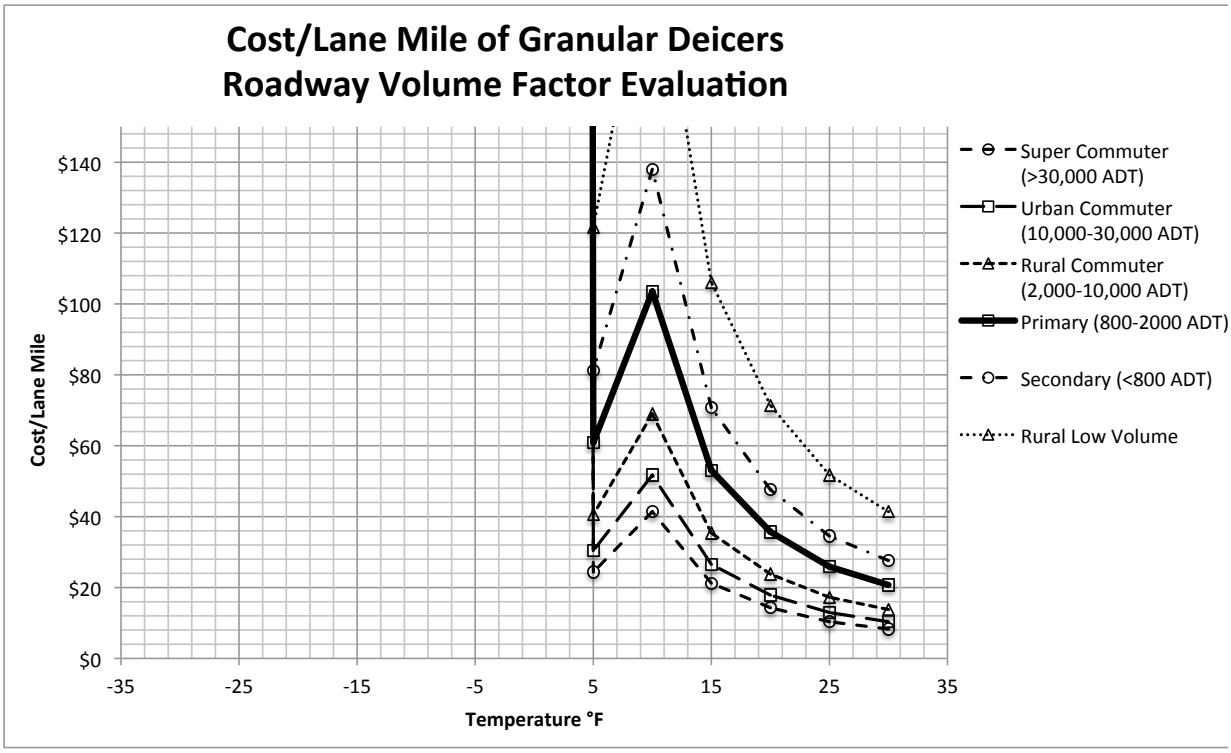
Roadway: Factor Evaluation

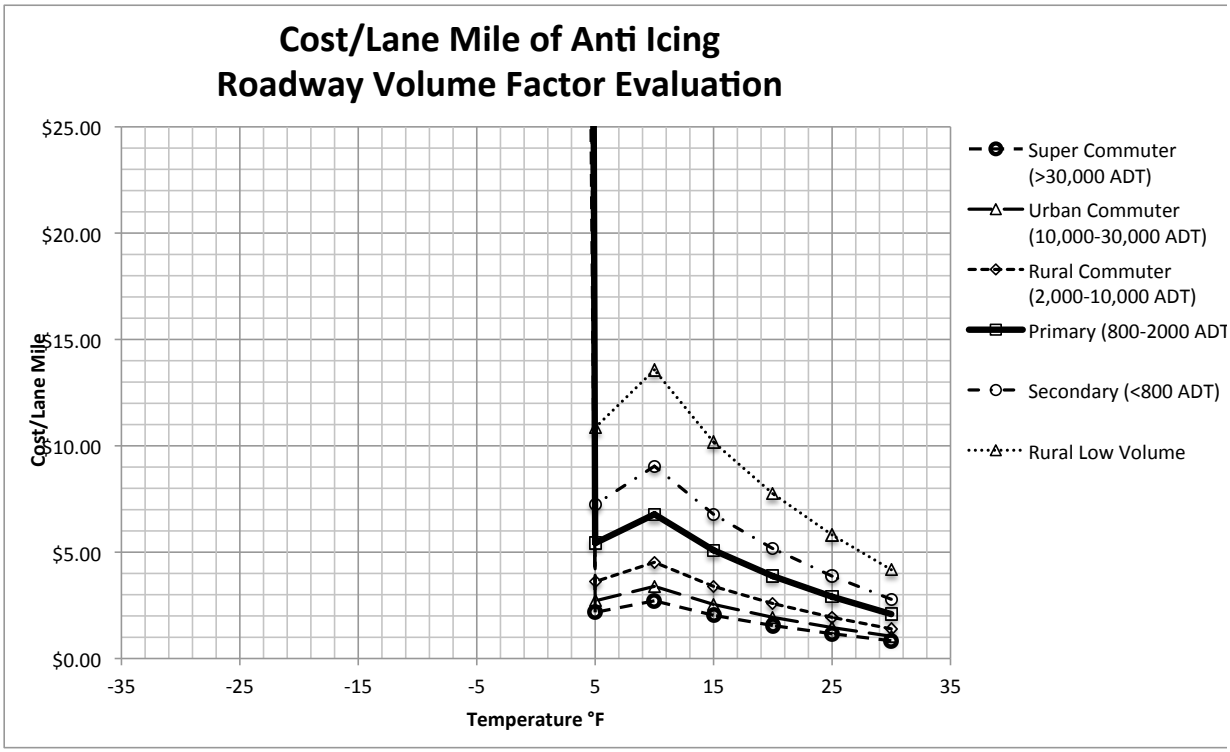
| **Application Factors - Select levels by placing a "Y" in the appropriate blocks.** | | | | | | Factors | | |
|---|---|---|---|---|---|---|---|---|
| Application Rate | | 300 lbs/LM | Y | 600 lbs/LM | | 900 lbs/LM | 300 | 600 | 900 |
| Ice Thickness (inches) | | < 1/16th | Y | 1/16-3/16th | | >1/4th | 1.5 | 1.0 | 0.5 |
| Temperature Movement | | Rising | Y | Steady | | Falling | 1.1 | 1.0 | 0.9 |
| Repeat Time | | 30-90 min | Y | 2-4 hr | | > 4 hrs | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | | | |
| Pavement Material | | Asphalt | Y | Concrete | | Open Graded/Porous | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | | 0 to 3 yrs | Y | 4 to 8 yrs | | 8 to 20+ yrs | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | | | |
| Sun Condition | | Bright Sky | Y | Overcast | | Dark | 1.5 | 1.0 | 0.5 |
| Wind Condition | | Calm | Y | Light | | Breezy | 1.25 | 1.00 | 0.75 |
| Roadway Shade | | No Shade | Y | Occassional | | Full Shade | 1.25 | 1.00 | 0.75 |
| **Roadway Volume (ADT)** | | | | | | | | | |
| Super Commuter (>30,000 ADT) | Y | | | | | | 2.5 | | |
| Urban Commuter (10,000-30,000 ADT) | Y | | | | | | 2.0 | | |
| Rural Commuter (2,000-10,000 ADT) | Y | | | | | | 1.5 | | |
| Primary (800-2000 ADT) | Y | ASSUMED LEVEL OF SERVICE | | | | | 1.0 | | |
| Secondary (<800 ADT) | Y | | | | | | 0.75 | | |
| Rural Low Volume | Y | | | | | | 0.50 | | |
| **Truck Proportion** | | >5% ADT | Y | 2-5% ADT | | <2% ADT | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | | | |
| Corrosion Sensitve Struct. | | Low | Y | Medium | | High | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | | Low | Y | Medium | | High | 1.25 | 1.00 | 0.75 |

| **Solid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | |
|---|---|---|---|---|
| Y | Rock Salt | NaCl | $75.00 | /ton |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

| **Liquid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | |
|---|---|---|---|---|
| Y | Salt Brine | NaCl | $0.11 | /gallon |
| | | | | |
| | Application Rate | 10 gal/LM | Y 20 gal/LM | 30 gal/LM |
| | for Anti Icing | | | |
| | | | | |
| | | | | |
| | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Application Rate | | 10 gal/LM | Y | 20 gal/LM | | 30 gal/LM | 10 | 20 | 30 |
| | for Anti Icing | | | | | | | | | |


Cost/Lane Mile of Granular Deicers
Roadway Volume Factor Evaluation
Cost/Lane Mile
$140
$120
$100
$80
$60
$40
$20
$0
-35
-25
-15
-5
5
15
25
35
Temperature °F
Super Commuter (>30,000 ADT)
Urban Commuter (10,000-30,000 ADT)
Rural Commuter (2,000-10,000 ADT)
Primary (800-2000 ADT)
Secondary (<800 ADT)
Rural Low Volume


Cost/Lane Mile of Anti Icing
Roadway Volume Factor Evaluation
Cost/Lane Mile
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
-35
-25
-15
-5
5
15
25
35
Temperature °F
Super Commuter (>30,000 ADT)
Urban Commuter (10,000-30,000 ADT)
Rural Commuter (2,000-10,000 ADT)
Primary (800-2000 ADT
Secondary (<800 ADT)
Rural Low Volume

Deicing Cost Model
Mn/DOT Research Contract 96319

Name/Date: MSU Mankato Civil Engineering

Roadway: Factor Evaluation

| **Application Factors - Select levels by placing a "Y" in the appropriate blocks.** | | | | | | Factors | | |
|---|---|---|---|---|---|---|---|---|
| Application Rate | | 300 lbs/LM | Y | 600 lbs/LM | | 900 lbs/LM | 300 | 600 | 900 |
| Ice Thickness (inches) | | < 1/16th | Y | 1/16-3/16th | | >1/4th | 1.5 | 1.0 | 0.5 |
| Temperature Movement | | Rising | Y | Steady | | Falling | 1.1 | 1.0 | 0.9 |
| Repeat Time | | 30-90 min | Y | 2-4 hr | | > 4 hrs | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | | | |
| Pavement Material | | Asphalt | Y | Concrete | | Open Graded/Porous | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | | 0 to 3 yrs | Y | 4 to 8 yrs | | 8 to 20+ yrs | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | | | |
| Sun Condition | | Bright Sky | Y | Overcast | | Dark | 1.5 | 1.0 | 0.5 |
| Wind Condition | | Calm | Y | Light | | Breezy | 1.25 | 1.00 | 0.75 |
| Roadway Shade | | No Shade | Y | Occassional | | Full Shade | 1.25 | 1.00 | 0.75 |

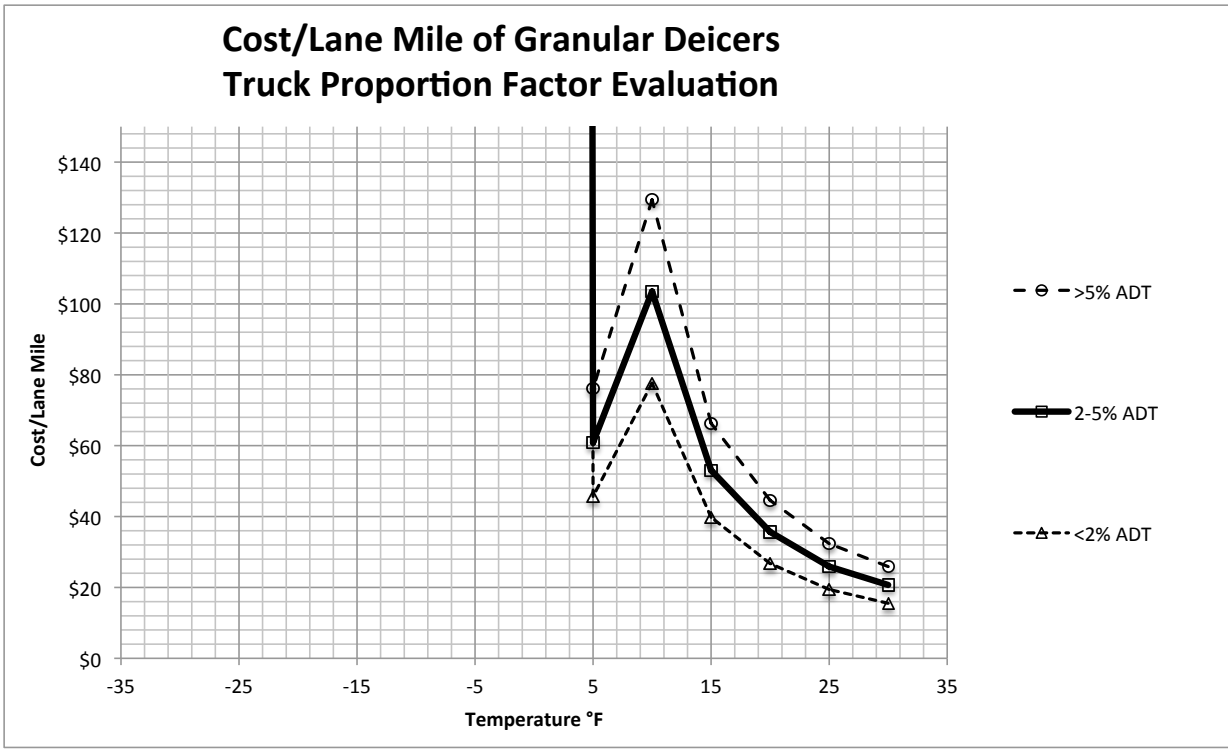
| **Roadway Volume (ADT)** | | | |
|---|---|---|---|
| Super Commuter (>30,000 ADT) | | | 2.5 |
| Urban Commuter (10,000-30,000 ADT) | | | 2.0 |
| Rural Commuter (2,000-10,000 ADT) | | | 1.5 |
| Primary (800-2000 ADT) | Y | ASSUMED LEVEL OF SERVICE | 1.0 |
| Secondary (<800 ADT) | | | 0.75 |
| Rural Low Volume | | | 0.50 |

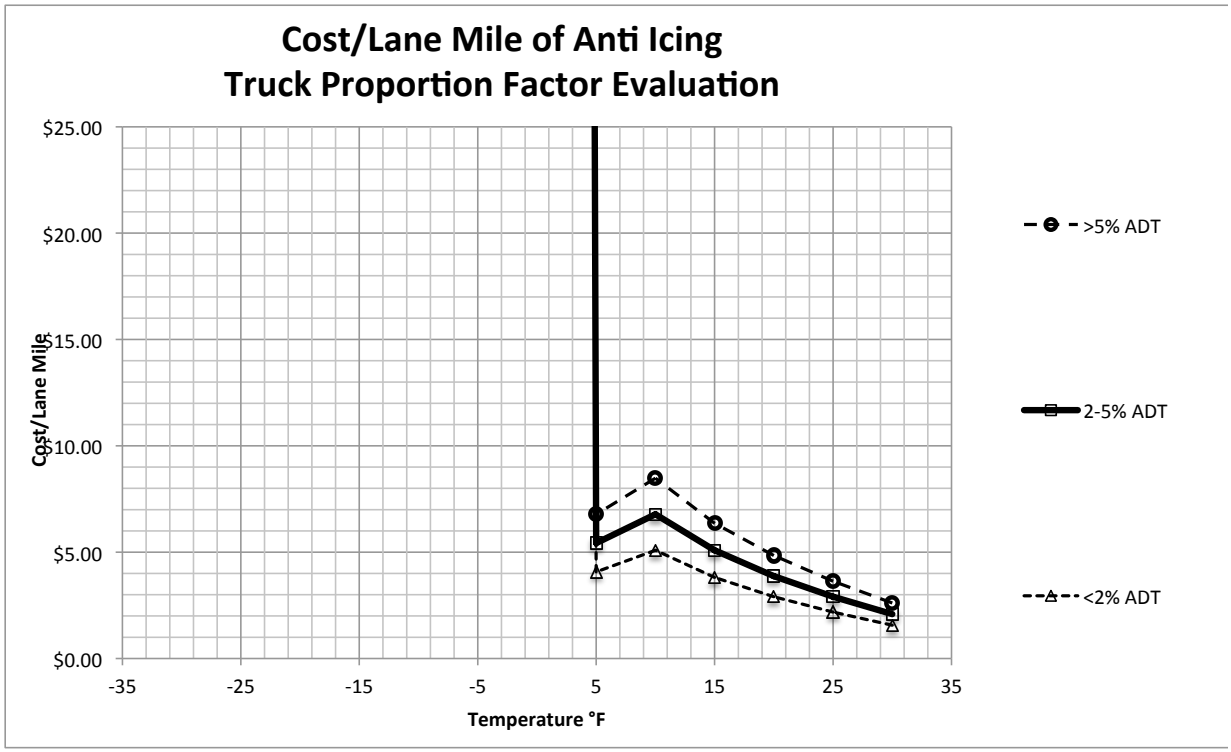
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Truck Proportion** | Y | >5% ADT | Y | 2-5% ADT | Y | <2% ADT | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | | | |
| Corrosion Sensitve Struct. | | Low | Y | Medium | | High | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | | Low | Y | Medium | | High | 1.25 | 1.00 | 0.75 |

| **Solid Deicers to Consider ("Y" to graph)** | | **Cost (Delivered)** | |
|---|---|---|---|
| Y | Rock Salt | NaCl | $75.00 /ton |

| **Liquid Deicers to Consider ("Y" to graph)** | | **Cost (Delivered)** | |
|---|---|---|---|
| Y | Salt Brine | NaCl | $0.11 /gallon |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Application Rate for Anti Icing | | 10 gal/LM | Y | 20 gal/LM | | 30 gal/LM | 10 | 20 | 30 |


Cost/Lane Mile of Granular Deicers
Truck Proportion Factor Evaluation
$140
$120
$100
$80
$60
$40
$20
$0
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
>5% ADT
2-5% ADT
<2% ADT


Cost/Lane Mile of Anti Icing
Truck Proportion Factor Evaluation
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
>5% ADT
2-5% ADT
<2% ADT

Deicing Cost Model
Mn/DOT Research Contract 96319

Name/Date: MSU Mankato Civil Engineering

Roadway: Factor Evaluation

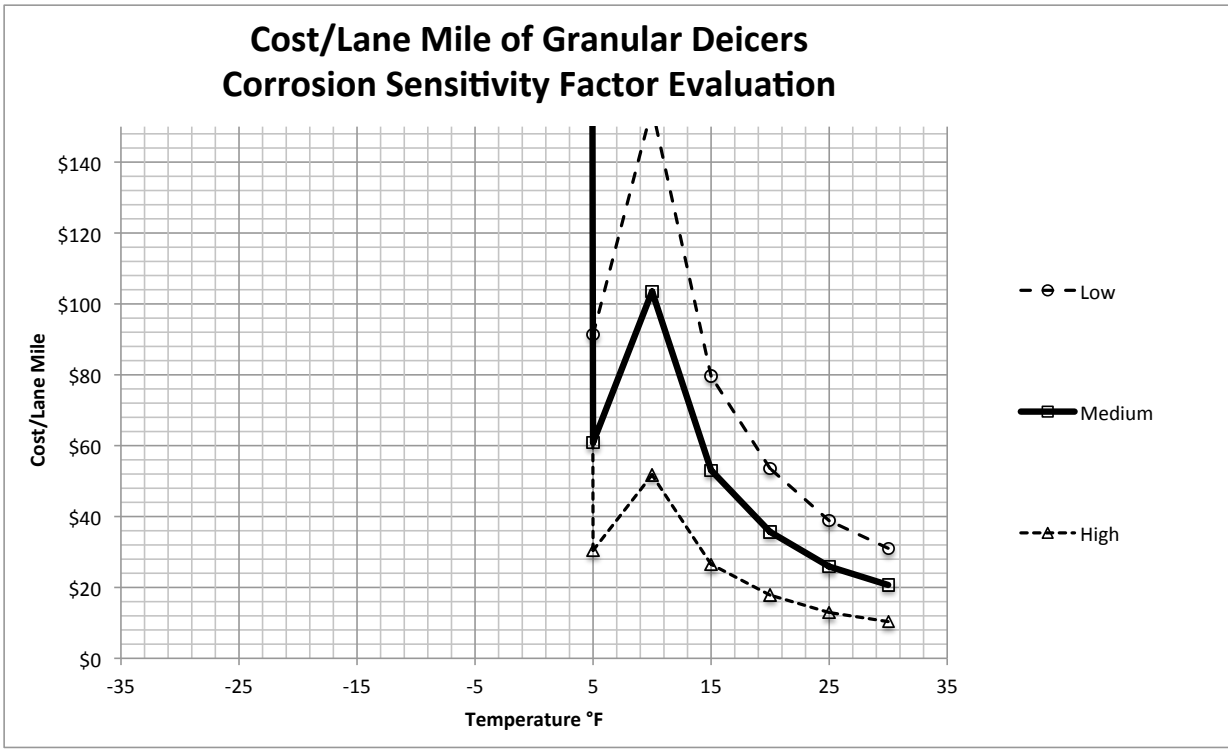
| **Application Factors - Select levels by placing a "Y" in the appropriate blocks.** | | | | | | Factors | | |
|---|---|---|---|---|---|---|---|---|
| Application Rate | | 300 lbs/LM | Y | 600 lbs/LM | | 900 lbs/LM | 300 | 600 | 900 |
| Ice Thickness (inches) | | < 1/16th | Y | 1/16-3/16th | | >1/4th | 1.5 | 1.0 | 0.5 |
| Temperature Movement | | Rising | Y | Steady | | Falling | 1.1 | 1.0 | 0.9 |
| Repeat Time | | 30-90 min | Y | 2-4 hr | | > 4 hrs | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | | | |
| Pavement Material | | Asphalt | Y | Concrete | | Open Graded/Porous | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | | 0 to 3 yrs | Y | 4 to 8 yrs | | 8 to 20+ yrs | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | | | |
| Sun Condition | | Bright Sky | Y | Overcast | | Dark | 1.5 | 1.0 | 0.5 |
| Wind Condition | | Calm | Y | Light | | Breezy | 1.25 | 1.00 | 0.75 |
| Roadway Shade | | No Shade | Y | Occassional | | Full Shade | 1.25 | 1.00 | 0.75 |

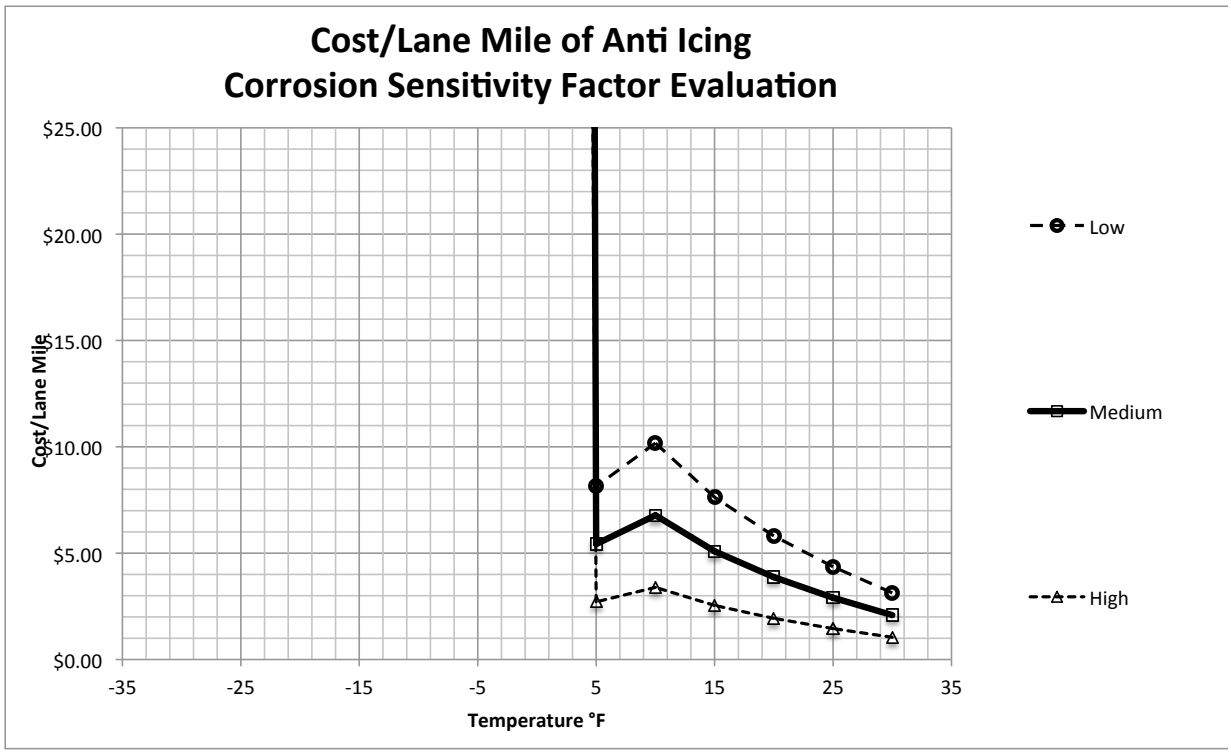
| **Roadway Volume (ADT)** | | | |
|---|---|---|---|
| Super Commuter (>30,000 ADT) | | | 2.5 |
| Urban Commuter (10,000-30,000 ADT) | | | 2.0 |
| Rural Commuter (2,000-10,000 ADT) | | | 1.5 |
| Primary (800-2000 ADT) | Y | ASSUMED LEVEL OF SERVICE | 1.0 |
| Secondary (<800 ADT) | | | 0.75 |
| Rural Low Volume | | | 0.50 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Truck Proportion** | | >5% ADT | Y | 2-5% ADT | | <2% ADT | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | | | |
| Corrosion Sensitve Struct. | Y | Low | Y | Medium | Y | High | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | | Low | Y | Medium | | High | 1.25 | 1.00 | 0.75 |

| **Solid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | |
|---|---|---|---|---|
| Y | Rock Salt | NaCl | $75.00 | /ton |

| **Liquid Deicers to Consider ("Y" to graph)** | | | **Cost (Delivered)** | | | | | |
|---|---|---|---|---|---|---|---|---|
| Y | Salt Brine | NaCl | $0.11 | /gallon | | | | |
| | Application Rate for Anti Icing | | 10 gal/LM | Y | 20 gal/LM | | 30 gal/LM | 10 | 20 | 30 |


Cost/Lane Mile of Granular Deicers
Corrosion Sensitivity Factor Evaluation
$140
$120
$100
$80
$60
$40
$20
$0
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
Low
Medium
High


Cost/Lane Mile of Anti Icing
Corrosion Sensitivity Factor Evaluation
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
Low
Medium
High

Deicing Cost Model
Mn/DOT Research Contract 96319

Name/Date: MSU Mankato Civil Engineering

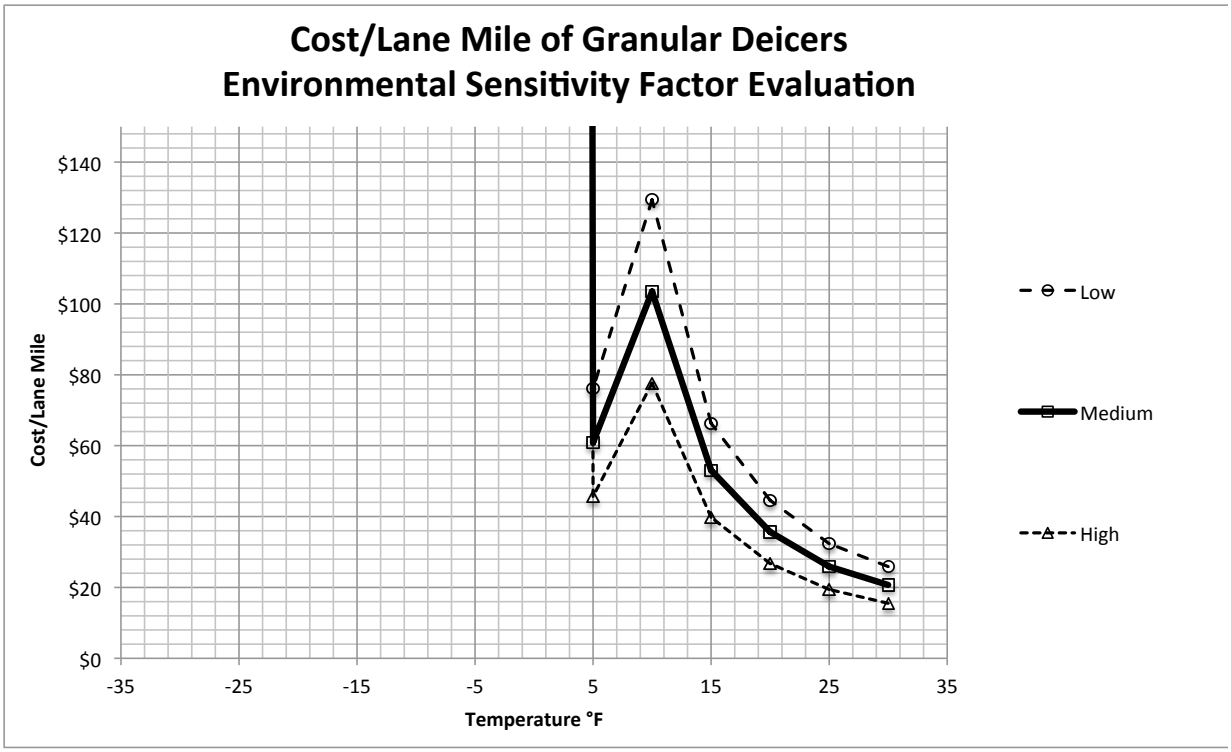
Roadway: Factor Evaluation

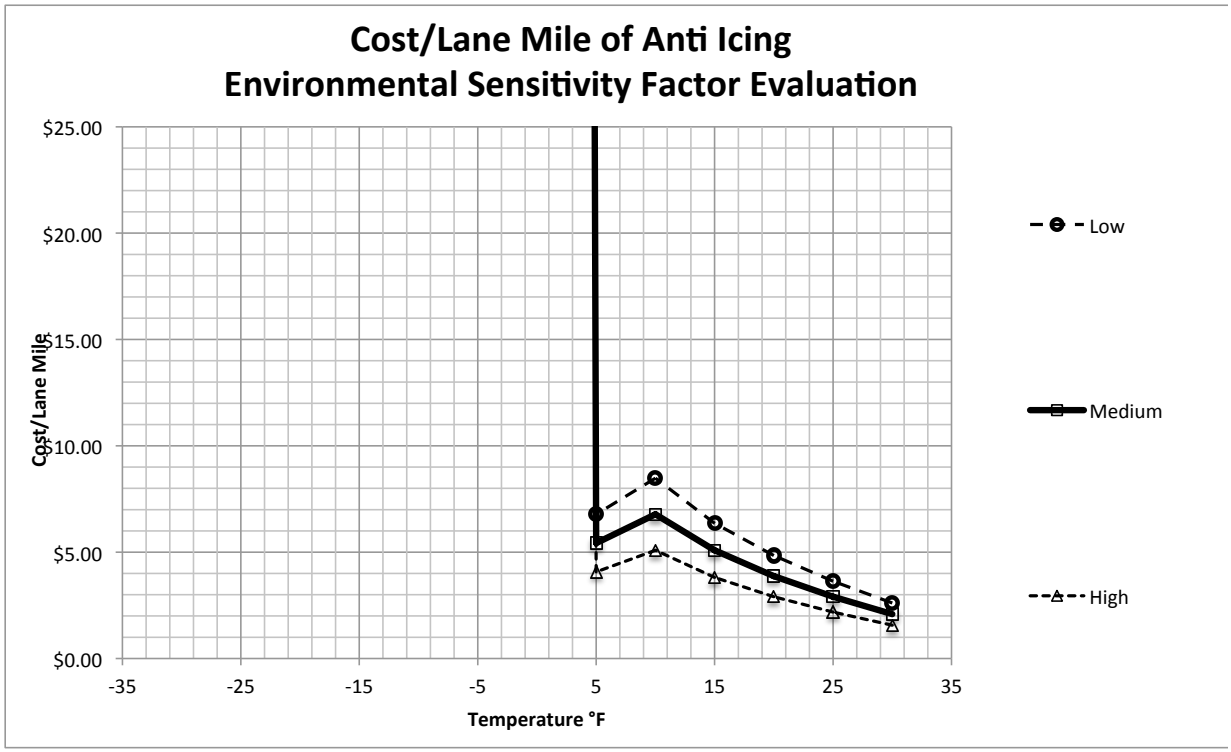
| **Application Factors - Select levels by placing a "Y" in the appropriate blocks.** | | | | | | Factors | | |
|---|---|---|---|---|---|---|---|---|
| Application Rate | | 300 lbs/LM | Y | 600 lbs/LM | | 900 lbs/LM | 300 | 600 | 900 |
| Ice Thickness (inches) | | < 1/16th | Y | 1/16-3/16th | | >1/4th | 1.5 | 1.0 | 0.5 |
| Temperature Movement | | Rising | Y | Steady | | Falling | 1.1 | 1.0 | 0.9 |
| Repeat Time | | 30-90 min | Y | 2-4 hr | | > 4 hrs | 1.25 | 1.00 | 0.75 |
| **Roadway Surface Factors** | | | | | | | | | |
| Pavement Material | | Asphalt | Y | Concrete | | Open Graded/Porous | 1.5 | 1.0 | 0.5 |
| Pavement Surface Age | | 0 to 3 yrs | Y | 4 to 8 yrs | | 8 to 20+ yrs | 1.25 | 1.00 | 0.75 |
| **Weather Factors** | | | | | | | | | |
| Sun Condition | | Bright Sky | Y | Overcast | | Dark | 1.5 | 1.0 | 0.5 |
| Wind Condition | | Calm | Y | Light | | Breezy | 1.25 | 1.00 | 0.75 |
| Roadway Shade | | No Shade | Y | Occassional | | Full Shade | 1.25 | 1.00 | 0.75 |
| **Roadway Volume (ADT)** | | | | | | | | | |
| Super Commuter (>30,000 ADT) | | | | | | | 2.5 | | |
| Urban Commuter (10,000-30,000 ADT) | | | | | | | 2.0 | | |
| Rural Commuter (2,000-10,000 ADT) | | | | | | | 1.5 | | |
| Primary (800-2000 ADT) | Y | ASSUMED LEVEL OF SERVICE | | | | | 1.0 | | |
| Secondary (<800 ADT) | | | | | | | 0.75 | | |
| Rural Low Volume | | | | | | | 0.50 | | |
| **Truck Proportion** | | >5% ADT | Y | 2-5% ADT | | <2% ADT | 1.25 | 1.00 | 0.75 |
| **Environmental Factors** | | | | | | | | | |
| Corrosion Sensitve Struct. | | Low | Y | Medium | | High | 1.5 | 1.0 | 0.5 |
| Environmentally Sensitive | Y | Low | Y | Medium | Y | High | 1.25 | 1.00 | 0.75 |

| **Solid Deicers to Consider ("Y" to graph)** | | **Cost (Delivered)** |
|---|---|---|
| Y Rock Salt | NaCl | $75.00 /ton |

| **Liquid Deicers to Consider ("Y" to graph)** | | **Cost (Delivered)** |
|---|---|---|
| Y Salt Brine | NaCl | $0.11 /gallon |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Application Rate for Anti Icing | | 10 gal/LM | Y | 20 gal/LM | | 30 gal/LM | 10 | 20 | 30 |


Cost/Lane Mile of Granular Deicers
Environmental Sensitivity Factor Evaluation
$140
$120
$100
$80
$60
$40
$20
$0
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
Low
Medium
High


Cost/Lane Mile of Anti Icing
Environmental Sensitivity Factor Evaluation
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
Cost/Lane Mile
-35
-25
-15
-5
5
15
25
35
Temperature °F
Low
Medium
High