DEPARTMENT OF TRANSPORTATION

Assessing the Effectiveness of Potassium Acetate to Control Snow and Ice on Minnesota Highways

Greg Waidley, Principal Investigator
CTC & Associates LLC

June 2020

Research Project
Final Report 2020-20

To request this document in an alternative format, such as braille or large print, call 651-366-4718 or 1-800-657-3774 (Greater Minnesota) or email your request to ADArequest.dot@state.mn.us. Please request at least one week in advance.

Technical Report Documentation Page

1. Report No.	2.	3. Recipients Accession No.	
MN 2020-20			
4. Title and Subtitle Assessing the Effectiveness of Potassium Acetate to Control Snow and Ice on Minnesota Highways		5. Report Date June 2020 6.	
7. Author(s) Greg Waidley, Brian Hirt, Ron Wright		8. Performing Organization Report No.	
9. Performing Organization Name and Address CTC & Associates LLC 4805 Goldfinch Drive Madison, WI 53714		10. Project/Task/Work Unit No. 11. Contract (C) or Grant (G) No. (C) 1030820	
12. Sponsoring Organization Name and Address Minnesota Department of Transportation Office of Research & Innovation 395 John Ireland Boulevard, MS 330 St. Paul, Minnesota 55155-1899		13. Type of Report and Period Covered Final Report (July 2018 - December 2019) 14. Sponsoring Agency Code	
15. Supplementary Notes http://mndot.gov/research/reports/2020/202020.pdf			

16. Abstract (Limit: 250 words)

As an alternative for snow and ice control, potassium acetate (KAc) has potential advantages compared with salt and brine—reduction of chlorides entering receiving waters, a lower effective deicing temperature, and reduction in corrosion impacts—but success in the field has been largely anecdotal. MnDOT District 1 worked with an investigator team to test KAc applied on four plow routes in the Duluth, Minnesota, area over the 2018–2019 winter season. Field trials protocols and data collection methods and forms were established to capture the following data during winter storms: vehicles and routes; material used; application rates, frequency, and timing; weather conditions; and pavement conditions. Due to issues beyond the control of MnDOT or the research team involving process gaps and data availability, a quantitative assessment of KAc could not be completed for this study. However, interviews with field crews yielded a wealth of useful observations and practical recommendations in the areas of training, liquid and sand concentrations, vehicles and equipment, snow removal procedures, application rates, and environmental concerns. The investigators also developed process recommendations for improving the chances of success for similar types of research studies in the future.

17. Document Analysis/Descriptors	18. Availability Statement		
Acetates, snow and ice control, winter maintenance	No restrictions. Document available from: National Technical Information Services, Alexandria, Virginia 22312		
19. Security Class (this report)	20. Security Class (this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	84	

ASSESSING THE EFFECTIVENESS OF POTASSIUM ACETATE TO CONTROL SNOW AND ICE ON MINNESOTA HIGHWAYS

FINAL REPORT

Prepared by:

Greg Waidley
Brian Hirt
Ron Wright
CTC & Associates LLC

June 2020

Published by:

Minnesota Department of Transportation
Office of Research & Innovation
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155-1899

ACKNOWLEDGMENTS

The authors thank the members of the project's Technical Advisory Panel, named in Section 1.3.1 of this report, for their time, guidance, and insight over the course of the project.

The authors also thank the maintenance staff members from the MnDOT district offices who participated in interviews for this project.

TABLE OF CONTENTS

LIST OF FIGURES

EXECUTIVE SUMMARY

The geography and climate of Duluth, Minnesota, make snow and ice control a challenge. Factors include heavy lake effect snows, steep road grades, and very low winter temperatures. In addition to plowing and using abrasives (such as sand), the Minnesota Department of Transportation (MnDOT) uses a variety of dry and liquid chemical deicers for snow and ice control.

MnDOT District 1 (D-1), which includes the Duluth area, has tried alternatives to traditional chlorides for snow and ice controls on roadways and has seen success with liquid potassium acetate (KAc). The potential advantages of KAc include the reduction of chlorides entering receiving waters, a lower effective deicing temperature (approximately -20° F) compared with salt or brine, and reduction in corrosion impacts.

However, the positive effects of KAc as a deicing material in the Duluth, Minnesota, area have been largely anecdotal based on its use in the following locations:

- US-2 Bong Bridge
- I-535 Blatnik Bridge
- I-35 tunnels
- MN-194 at Central Entrance

A MnDOT research study sought to document under controlled conditions the deicing effectiveness of KAc at selected locations in MnDOT D-1 Duluth subarea during the 2018–2019 winter season.

Prior to this study, MnDOT D-1 was already using equipment and personnel to apply KAc at measured application rates on four plow routes. For this study, D-1 was to conduct the field tests and gather the necessary data. MnDOT hired consulting firm CTC & Associates LLC to assist in designing the study, creating data gathering tools, monitoring data quality during the study, analyzing data gathered during the winter season, and writing a report to present the study conclusions. To address data gaps, a supplemental task to interview field practitioners on lessons learned was added partway through the process of conducting the study.

A Technical Advisory Panel (TAP) composed of personnel from across MnDOT was formed to provide oversight, guidance, and internal MnDOT perspective for the life of the project.

Literature search and survey

Two preparatory steps informed the efforts of MnDOT and the research team: a literature search and a survey of practice.

- The investigator team conducted a literature search to identify publicly available information on the national and international use of KAc as a deicing and anti-icing agent. The focus was on successful uses of the material by highway agencies and airports, including available information on concentrations, application rates, weather conditions, and timing. Each of the citations in the literature search includes a web link and an abstract or summary. The citations are grouped into

four topic areas of related resources, research-in-progress, state practices, and transferable practices from airports.

- The investigator team next conducted a survey of practice among the 36 member states of the Clear Roads Transportation Pooled Fund project. Among 25 respondents, 17 did not use KAc as an anti-icer or deicer. Of the remaining eight, three use it only on bridges. The survey asked agencies that do use liquid KAc about typical concentrations, costs, application rates, use scenarios, and weather factors.

Based on generally positive findings from the literature search and from other states, MnDOT proceeded with the study.

Study design and protocols

The investigator team worked with the TAP to outline the planned field trials and to set up data collection methods and forms to provide documentation of a controlled field trial of the performance and deicing efficacy of liquid KAc in the identified MnDOT D-1 locations.

Following are the key elements included in the study:

- Plow routes and trucks
- Number of trials
- KAc material/mixture with anti-skid used
- Application rates and frequency
- Application timing (anti-icing, deicing, pretreatment of sand)
- Application roadway condition (bare lanes, snow-covered, ice-covered)
- Application weather conditions (air temperature, humidity, precipitation, etc.)
- Observed pavement conditions pre- and post-application(s) and during the storms
- When bare lane condition was regained within the shift

“Bare lane,” a metric MnDOT uses to determine if a roadway has been regained, is defined as all driving lanes are 95 percent free of snow and ice between the outer edges of the wheel paths and have less than 1 inch of accumulation on the center of the roadway.

Data collection procedures included step-by-step instructions and screenshots of spreadsheet and web tools required for the collection and entry of data. Data were entered into a Microsoft Excel spreadsheet-based shift report.

Four routes were identified in D-1: Blatnik Bridge, Bong Bridge, I-35 Tunnels, and Central Entrance. The responsibilities for treating these routes were shared between two MnDOT truck sheds in Nopeming and Pike Lake.

Findings

A series of issues beyond the control of the MnDOT TAP and CTC & Associates confounded data collection efforts. These included process gaps and unavailable data. Moreover, a particularly severe winter made it impossible for existing staff to fill the role of on-site project coordinator. The research team's student intern and subject matter expert were challenged to adequately obtain the necessary data from the various MnDOT software programs and personnel and enter those data into the shift report form. Data anomalies experienced during the process of data collection further confounded efforts. As a result, the research team was not able to analyze the storms with temperatures below 0° F that were the focus of this project for their ability to test the effectiveness of KAc.

The research team focused on analyzing as well as possible the three storms for which team members felt they had the most complete and highest-quality data. Those were:

- December 26–28, 2018.
- February 22–24, 2019.
- March 9–10, 2019.

Ultimately, field data collected by MnDOT did not allow for a quantitative analysis on the effectiveness of KAc.

Due to the limited conclusions to be drawn from analysis of the field data, the TAP and the consultant team elected to interview MnDOT winter maintenance operators to learn about their experiences and empirical findings from using liquid KAc. This provided a wealth of information about the effectiveness and limitations of KAc.

Recommendations

Interviews yielded useful observations, recommendations and practical guidance in the following areas:

- Training
- Liquid and sand concentrations
- Vehicles and equipment
- Snow removal procedures
- Application rates

Practitioners also provided additional observations and general conclusions. Overall, the maintenance crews indicated that KAc was a good tool to have in the toolbox. It is not a tool that solves all problems, but under certain conditions, it can be effective at reducing the amount of salt required. The operators indicated that they would like training on the properties of KAc, the mechanisms of ice melting, and the use of alternative chemicals.

The investigator teams also developed recommendations about designing similar studies in the future. All participants—the sponsoring agency, the field staff, and the investigator team—should establish required time and effort for staff, confirm that data to be collected are necessary and sufficient, and establish checks in the field to assure that project data are collected as needed.

CHAPTER 1: PURPOSE AND OVERVIEW

1.1 SNOW AND ICE CONTROL IN DULUTH

Snow and ice operations can be difficult in the area of Duluth, Minnesota. Duluth is a port city located on Lake Superior; the inland Twin Cities of Minneapolis and St. Paul, by contrast, are situated on the Mississippi River (see Figure 1.1).

While less than two degrees latitude north of the Twin Cities, Duluth typically receives 30 more inches of snow per year (85 inches compared with 55 inches). Duluth is colder on average as well; the average February high and low are 19 and 2, compared with 24 and 8 for the Twin Cities.

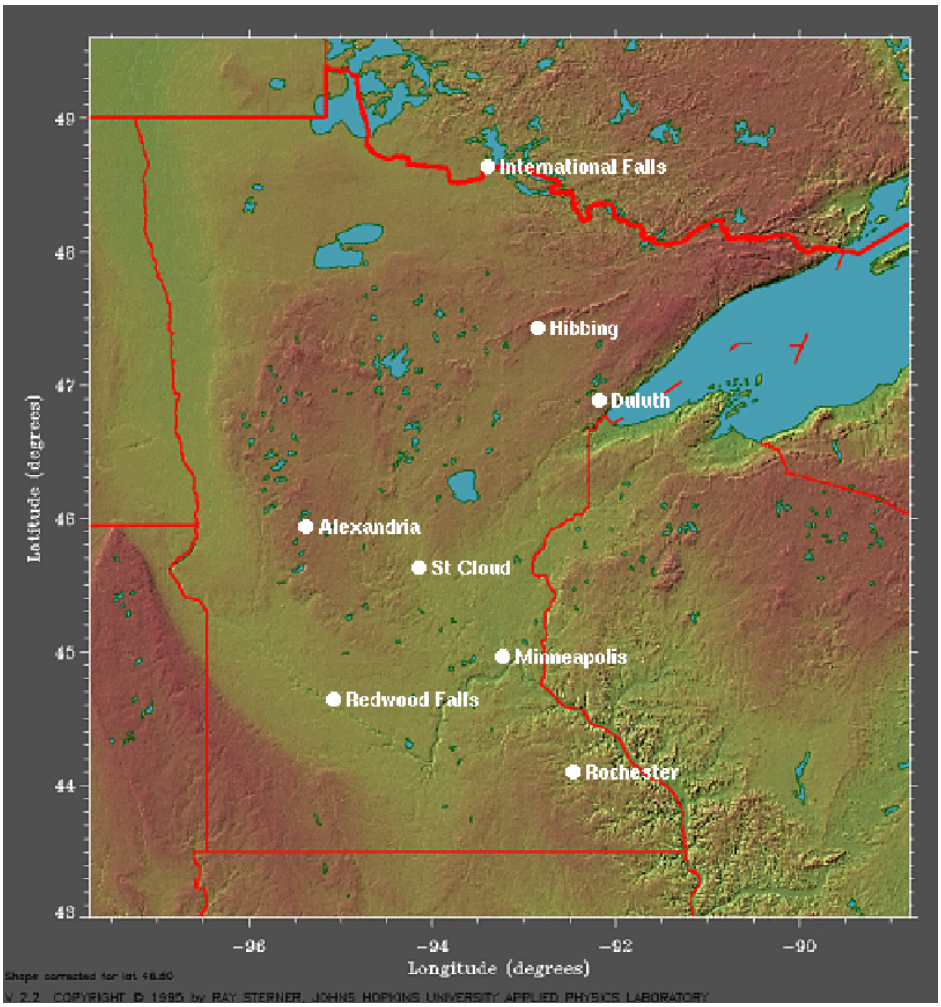


Figure 1.1. Geographical map of the state of Minnesota.
(Source: U.S. National Oceanic and Atmospheric Administration)

The excess of snowfall is compounded by other factors of Duluth's geography and topology. There are steep grades on the roads in the metropolitan area. As shown in Figure 1.2, from a harbor elevation near 600 feet above sea level, elevations can increase to 1,050 feet in less than a mile and to 1,428 feet at Duluth International Airport. Road grade percentages in the double-digits are common, with the steepest roads in excess of a 20-percent grade.

Figure 1.2. Topographical map of the city of Duluth and adjacent waterfront and communities. (Source: U.S. Geological Survey)

Other factors impacting snow and ice control in Duluth include high bridges and tunnels, steam and humidity from paper mills and other industry in the area, and snowmaking at a ski area adjacent to Interstate 35.

1.2 PROJECT GOALS

MnDOT District 1 (D-1), which includes Duluth, has tried alternatives to traditional chlorides for snow and ice controls on roadways, and has seen success with potassium acetate (KAc, which is shorthand and not a chemical formula).The potential advantages of KAc include the reduction of chlorides entering receiving waters, a lower effective deicing temperature (approximately -20° F, or -29° C) compared with salt brine (approximately 15° F, or -9° C), and reduction in corrosion impacts.

However, the positive effects of KAc as a deicing material in the Duluth area have been largely anecdotal based on use in the following locations (see Figure 1.3):

- US-2 Bong Bridge
- I-535 Blatnik Bridge
- I-35 tunnels
- MN-194 at Central Entrance

Figure 1.3. Areas of prior KAc use in Duluth.
(Source: MnDOT MnMap)

This study sought to document under controlled conditions the deicing effectiveness of KAc at selected locations in the D-1 Duluth subarea during the 2018–2019 winter season.

1.3 PROCESS

As noted, prior to this study, MnDOT D-1 was already using the equipment and personnel to apply KAc at measured application rates on four plow routes. For this study, D-1 was to conduct the field tests and gather the necessary data. MnDOT hired consulting firm CTC & Associates LLC to assist in designing the study, creating data gathering tools, monitoring data quality during the study, analyzing data gathered during the winter season, and writing a report to present the study conclusions. A supplemental task to interview field practitioners on lessons learned was added partway through the process of conducting this study to address data gaps.

1.3.1 Technical Advisory Panel

A Technical Advisory Committee (TAP) composed of personnel from across MnDOT was formed to provide oversight, guidance, and internal MnDOT perspective for the life of the project.

The TAP membership for this project included the following individuals:

- MnDOT Central Office:
    - Tara Carson, Office of Environmental Stewardship
    - Joseph Huneke, Office of Maintenance
    - Elizabeth Klemann, Office of Research and Innovation
    - Sue Lodahl, Office of Maintenance
    - Steve Lund, Office of Maintenance
    - Christina Markeson, Office of Environmental Stewardship
    - Tracy Olson, Office of Maintenance
    - Jay Pierzina, Office of Maintenance
    - Nicklas Tiedeken, Office of Environmental Stewardship
    - Bob Vasek, Office of Maintenance
- MnDOT D-1:
    - Steven Baublitz
    - Chris Cheney
    - Perry Collins
    - Mike Hedlund
    - Duane Hill
    - James Kielty
    - Shannon McIntyre
- Federal Highway Administration:
    - Gabriel Guevara

The TAP met regularly to review task activities, draft deliverables, and discuss next steps.

CHAPTER 2: LITERATURE SEARCH

As a first major step in this effort, the investigator team conducted a literature search to identify publicly available information on the national and international use of KAc as a deicing and anti-icing agent. The focus was on successful uses of the material by highway agencies and airports, including available information on concentrations, application rates, weather conditions, and timing.

Each of the citations in the literature search includes a web link and an abstract or summary. The citations are grouped into four topic areas:

Related Resources. Citations included completed research on the environmental risks and impacts of snow and ice control materials. It includes state research studies, a federal technology brief, and a MnDOT training video.

Research-in-Progress. Two additional citations address related research projects underway in Indiana and Colorado.

State Practices—Highway Agencies. Complementing research findings, these citations highlight documented practices in winter weather states. Citations draw from fact sheets, operations manuals, and reports. State practices are addressed in more detail in the survey of practice conducted for this project, detailed in Chapter 3.

Transferrable Practices from Airports. Two research citations address toxicity of snow and ice control runoff at airports; the results may be transferable in part to highway snow and ice operations.

The complete literature search is included as **Appendix A** to this report.

CHAPTER 3: SURVEY OF PRACTICE

To learn more about state practice specifically with KAc, the investigator team next conducted a survey of practice among the 36 member states of the Clear Roads Transportation Pooled Fund project (clearroads.org). This pooled fund constitutes most of the winter weather states in the United States. The complete findings of the survey of practice are included as **Appendix B** to this report

3.1 QUESTIONS

The survey asked respondents to indicate whether their agencies use liquid KAc as an anti-icer or deicer in winter road maintenance.

For those that did, a series of follow-up questions sought to determine:

- The typical concentration of KAc used.
- The agency's seasonal cost of using KAc.
- Use, application rates, and satisfaction with KAc for roadway anti-icing, roadway deicing, prewetting solid deicers, and automatic anti-icing systems/Fixed Automated Spray Technology (FAST).
- Additional scenarios for using KAc (frost control, before a weekend, holiday or increased traffic event, before a storm).
- The coldest temperature range that liquid KAc has been effective.
- Weather factors for selecting KAc.
- Frequency of KAc use and use with other liquids and solids.
- Plans for increased KAc use in the future and reasons for increased use.

The complete questions begin on page 15 of **Appendix B**.

3.2 RESPONSES

Twenty-five respondents participated in the survey. Participants included representatives from 21 state transportation agencies, two non-US transportation agencies and two consultants.

Seventeen respondents reported they did not use KAc. Eight said they used KAc and completed the entire survey, though among those, three respondents only use it on bridges.

The complete set of responses with detailed analysis appears in **Appendix B**; highlights of survey findings follow. Based on generally positive findings from other states, MnDOT proceeded with its own investigations.

- **Concentration.** Of the eight respondents indicating that they use KAc, all reported using a 50 percent concentration of KAc.
- **Cost.** The cost per gallon of KAc varied only slightly across the six respondents who answered this question, ranging from $4.50 to $5.12 per gallon.

- **Procedures.** Four of the eight respondents reported using KAc for anti-icing, five for deicing, and only one to prewet solid deicing materials. The use of KAc in FAST systems for bridges was reported by four respondents, three of which do not use KAc for highway applications.
- **Rates.** The respondents reported using rates varying from a low of 10 gallons per lane mile to a high of 40 gallons per lane mile for anti-icing and deicing. The respondent who reported using KAc to prewet deicing solids indicated that the agency uses 10 to 20 gallons per ton for this application.
- **Applications.** Respondents most commonly stated applications for KAc were for frost control and for use in advance of a storm.
- **Temperature range.** The reported coldest effective temperature for KAc anti-icing and deicing varied widely among respondents. Respondents were asked to select from one of seven ranges for coldest effective temperature (32 to 15°F, 15 to 0° F, 0 to -5°F, -5 to -15°F, -15 to -20°F, -20 to -25°F, Below -25°), and responses varied across the full range of options.
- **Supplementation materials.** For both anti-icing and deicing, respondents commonly supplement with another chemical: salt, salt/sand mix, brine, or another solid/liquid. Supplementing with salt only was less common. Two respondents always supplement, and four only supplement sometimes.
- **Future plans.** Three of eight respondents reported that they would use more liquid KAc in the future. Four respondents reported that their agencies did not plan to use more KAc in the future.
- **Resources. Appendix B**, the complete survey results, includes two resources:
    - An excerpt from Alabama Department of Transportation's (DOT's) Tuscumbia Area Winter Weather Plan 2017-18, which explains the decision to use KAc in its winter roadway maintenance plan and the weather conditions that would require its application.
    - Utah DOT's 2017 contract of purchase of KAc for winter maintenance, a pricing overview of a KAc contract for Utah DOT.

CHAPTER 4: STUDY DESIGN AND PROTOCOLS

The investigator team worked with the TAP to outline the planned field trials and to set up data collection methods and forms to provide documentation of a controlled field trial of the performance and deicing efficacy of liquid KAc in the identified MnDOT D-1 locations.

4.1 DATA ELEMENTS AND METRICS

Following are the key elements included in the study:

- Plow routes and trucks (see map, Figure 4.1 below).
- Number of trials.
- KAc material/mixture with anti-skid used.
- Application rates and frequency.
- Application timing (anti-icing, deicing, pretreatment of sand).
- Application roadway condition (bare lanes, snow-covered, ice-covered).
- Application weather conditions (air temperature, humidity, precipitation, etc.).
- Observed pavement conditions pre- and post-application(s) and during the storms.
- When bare lane condition was regained within the shift.

"Bare lane," a metric MnDOT uses to determine if a roadway has been regained, is defined as all driving lanes are 95 percent free of snow and ice between the outer edges of the wheel paths and have less than 1 inch of accumulation on the center of the roadway.

Procedures for data gathering are described in in **Appendix C** to this report. These include step-by-step instructions and screenshots of spreadsheet and web tools required for data collection and entry.

Data were entered into a Microsoft Excel spreadsheet-based shift report. The spreadsheet included multiple tabs for gathering data on up to four routes in a shift. The first tab of the shift report appears as **Appendix D** to this report.

4.2 STUDY ROUTES

Four routes were identified. Each was assigned a route identification (ID) number, shown in blue highlighting in Figure 4.1:

- Central Entrance: route ID TP1D1942.
- I-35 Tunnels: route ID TP1D0354.
- Bong Bridge: route ID TP1D0023.
- Blatnik Bridge: route ID TP1D5351.

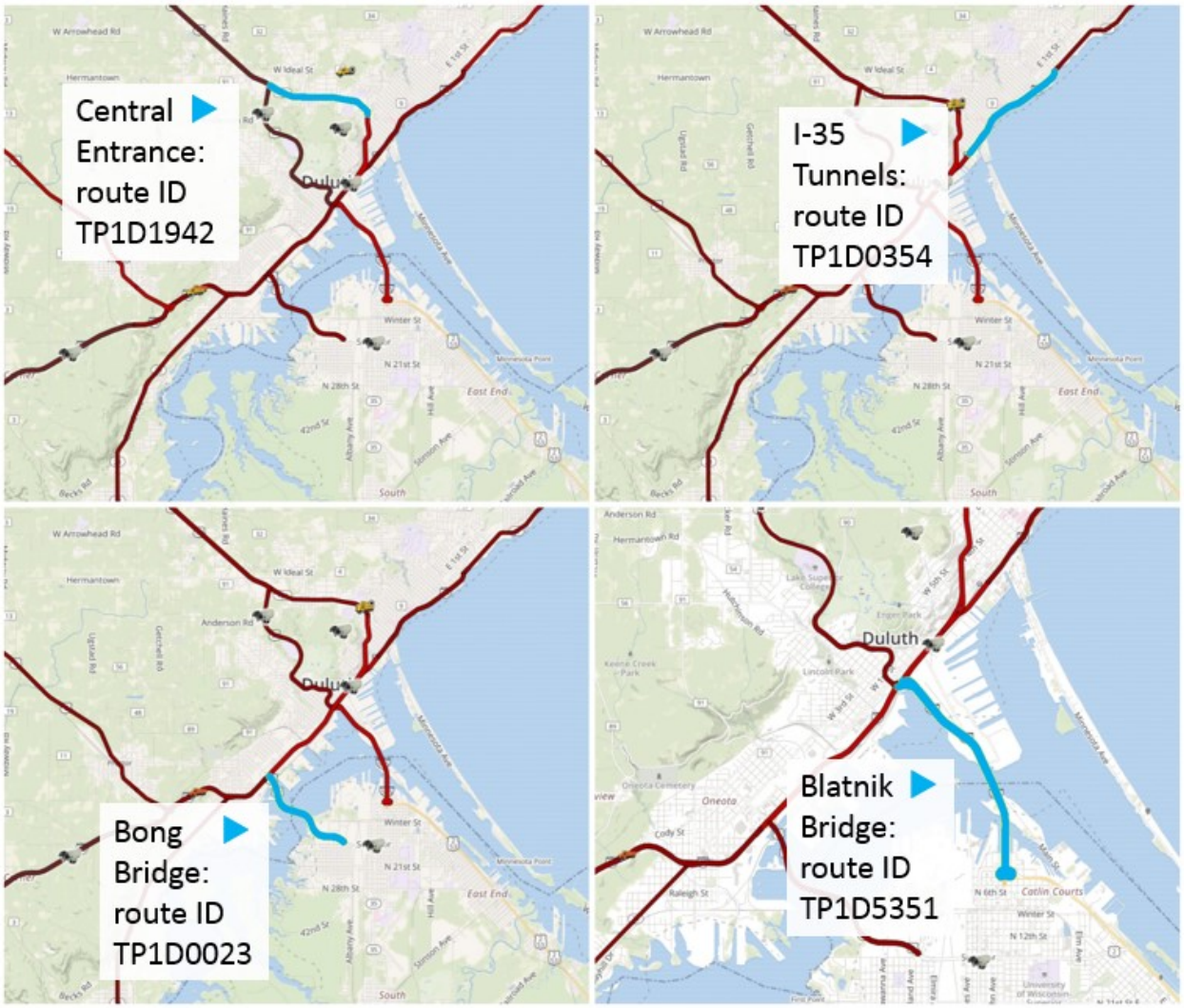


Figure 4.1. Winter maintenance routes. (Source: webMDSS)

4.3 TRUCK SHEDS

The responsibilities for treating these routes were shared between two MnDOT truck sheds:

- Nopeming: Bong Bridge and I-35 Tunnels.
- Pike Lake: Blatnik Bridge and Central Entrance.

4.4 EQUIPMENT

Following are the ID numbers of the vehicles used to apply KAc on the designated project routes, as well as a brief description of each piece of equipment's capacity for solid and liquid application.

- Vehicles:
    - Three Nopeming shed trucks: 210500, 212550, 215509.
    - Two Pike Lake shed trucks: 214500, 217502.
- Capacity:
    - Nopeming 210500 and Pine Lake 214500 were auger-equipped sanders with a 6-ton capacity.
    - Nopeming 215509 and Pine Lake 217502 were spray trucks with a 1,300-gallon capacity, stream or cone spray. The maximum application rate was 50 gallons per lane mile.
    - Nopeming 212550 was a sander/spray combination truck with a 1,100-gallon liquid capacity and 5- to 6-ton sand capacity, stream or cone spray patterns. Maximum application rates were 1,000 pounds per lane mile and 50 gallons per lane mile, respectively.

CHAPTER 5: FINDINGS

5.1 DATA COLLECTION

Issues beyond the control of the MnDOT TAC and CTC & Associates confounded data collection efforts.

5.1.1 Weather

Early in the project, a change in staffing assignment led to the D-1 supervisor stepping in to coordinate the data collection effort and provide required data to CTC.

However, the 2018–2019 winter was particularly severe in Minnesota, with Duluth experiencing unusually severe snow and ice conditions. According to the U.S. National Weather Service, a total of 107 inches of snow fell in Duluth in the 2018-2019 winter, well above the city's average of 85 inches. In addition, a late January artic weather system caused extremely low temperatures across Minnesota, with Cotton, Minnesota, outside Duluth recording a low of -56 °F.

Maintaining roads for traveler safety is the D-1 supervisor's first priority, and given these weather conditions, it was not possible for him coordinate the data collection for this project.

5.1.2 Data

In the absence of consistent data, the MnDOT Office of Research & Innovation project coordinator suggested that D-1 staff could use a student. CTC hired a student intern from the University of Wisconsin–Superior's Transportation & Logistics program.

Both the student intern and the subject matter expert on CTC's research team struggled to assist with data collection. It was a challenge to adequately obtain the necessary data from the various MnDOT software programs and personnel, and to enter those data into the shift report form. Data anomalies experienced during the process of data collection further confounded efforts. The research team experienced challenges in the following areas:

- Questions surrounding multiple locations of the equipment during a shift.
- Proper material identification.
- Reasonable application rates.
- Specific route material usage.
- Recorded or unrecorded pavement observations, including temperatures, weather data, and recorded times of road "lost" or "regained."
- Collection of key data elements to form conclusions on the effectiveness of the KAc applications, including visual observations.

5.2 QUANTITATIVE ANALYSIS

Due to missing data and data inconsistencies, the research team was not able to analyze the storms with temperatures below 0 °F that were the focus of this project with respect to the effectiveness of KAc. While there were a few of these storms, but for those, MnDOT plowed until snow was cleared and then applied KAc at the end.

As a result, the research team focused on analyzing as well as possible the three storms for which they felt they had the most complete and highest-quality data. Those were:

- December 26–28, 2018.
- February 22–24, 2019.
- March 9–10, 2019.

A new MnDOT D-1 maintenance staff member hired in March 2019 was instrumental in compiling the data for these three storms. A sample report for the December 26–28 storm is provided as **Appendix E** to this report.

The three primary sources of data for this report came from webMDSS (web-based maintenance decision support system), bare lane reports (from MnDOT's Business Intelligence data system), and end of shift reports completed by the operators. Available data from the bare lane reports and the end of shift reports sometimes did not match, leaving significant gaps in the data. Road weather information systems and National Oceanic and Atmospheric Administration (NOAA) were also used to provide missing data from webMDSS.

Ultimately, field data collected by MnDOT did not allow for a quantitative analysis on the effectiveness of KAc.

5.3 QUALITATIVE ANALYSIS

Due to the limited conclusions to be drawn from analysis of the field data, the TAP and the consultant team elected to interview MnDOT winter maintenance operators to learn about their experiences and empirical findings from using liquid KAc. This provided a wealth of information about the effectiveness and limitations of KAc.

The project investigators facilitated interview sessions with winter maintenance operators at D-1's Pike Lake and Nopeming locations on July 15, 2019, to learn about procedures for using liquid KAc for snow and ice removal in the Duluth subarea. The use of KAc was in the first year of implementation with the Pike Lake crews and in the second year with the Nopeming crews.

Detailed comments are provided in **Appendix F** to this report. Summary findings and recommendations appear in Chapter 6.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 INTERVIEW FINDINGS AND FIELD RECOMMENDATIONS

Recommendations about the use of KAc for snow and ice control are drawn from the follow-up interviews conducted for this study (Section 5.3 and **Appendix F**). Operators noted that KAc may be an effective tool when used in the right conditions, but it does not completely replace the use of other chemical and snow and ice control methods.

Summary findings and recommendations are grouped into eight themes:

- Training
- Project coordination
- Liquid and sand concentrations
- Vehicles and equipment
- Snow removal procedures
- Application rates
- Additional observations
- General conclusions

6.1.1 Training

Although newly hired operators are required to participate in MnDOT's Snowplow Operator Training (SPOT), there was not any formalized training with the use of KAc other than personnel protective standards to follow for safety. Some operators stated that KAc-specific training should be required.

6.1.2 Project Coordination

A dedicated MnDOT staff member should be assigned to manage data collection and staff interviews. That individual should have additional responsibility of being the overall field manager for the project.

6.1.3 Liquid and Sand Concentrations

KAc was applied in two different ways: as a liquid solution and as a treatment on sand. The concentration of the liquid KAc solution was 50 percent by weight. Sand was treated with 9 percent KAc by weight. Initially, a 10 percent mix for sand was used and found to be effective. However, the liquid KAc was observed to be leaching out of the sand mix and reducing the concentration. The 9 percent mix was more stable and worked as well as the 10 percent for removing snow and ice. A 7 percent mix was tested and found not to work as satisfactorily as the 9 percent. The term "sand" as used throughout this summary refers to 9 percent KAc treated sand.

6.1.4 Vehicles and Equipment

The subarea was assigned five snowplows for this study. These included two sanders equipped with saddle tanks, two liquid spray trucks, and one combination truck with the ability to apply either sand or liquid KAc. All sanding trucks had the ability to add KAc either to the roadway or to the spinner before being applied to the roadway. Equipment had the capacity to apply up to 50 gallons per lane mile of liquid and 1,000 pounds per lane mile of treated sand. The capacity for liquid trucks was 1,300 gallons, while sanders had a 5- to 6-ton limit. Saddle tanks on the sanders had a 150- to 250-gallon capacity. Liquid streamers were used for liquid delivery to the road surface.

6.1.5 Snow Removal Procedures

The standard procedure for snow removal consisted of plowing from the time snow began to accumulate on the roadway until the completion of the snow event. Gang plowing was used to limit snow accumulation in severe cases. Typical plowing started on the left side of the road, moving snow to the right side. Chemical application commenced after most of the snow was removed from the roadway. Standard material application was 20 gallons per lane mile mixed with 300 to 400 pounds per lane mile of treated sand. If conditions were more severe or the temperature was dropping, material application increased to 40 gallons per lane mile mixed with 500 to 700 pounds per lane mile of treated sand. Within trouble areas, in emergency situations, or with falling temperatures, treated sand applications would be made at rates up to 1,000 pounds per lane mile.

6.1.6 Application Rates

Operators made the decisions as to what applications of materials and rates would be applied to the roadway.

A “just-in-time” application process was adopted by one crew, where application of liquid KAc, at 20 gallons per lane mile, was applied at the start of a storm event. The results were very effective, with the crews reporting that the roads were regained faster with less chemical required.

During especially cold conditions, applications of 20 to 50 gallons per lane mile could cause the material to become slimy or cause freezing at colder temperatures, resulting in a lack of traction on the roadway. Out of urgency to regain the roadway, crews utilized an application of 600 pounds per lane mile using a 50/50 mix of salt and sand, followed by 40 gallons per lane mile of KAc. Crews noted that this quickly resolved traction issues and was very effective at removing ice buildup. This strategy worked effectively at temperatures down to -10° F and lasted for several days, thus reducing the need to apply additional chemicals.

Slurry mixes of KAc and sand were tried and found to be unsatisfactory, mainly due to equipment issues handling the material. Crews reported that KAc was effective and continued to reduce the amount of salt needed. The use of KAc and salt could be further investigated to establish effective combinations for use during cold weather.

The practice used at times of applying material on the centerline rather than in the travel lanes effectively cut the application rates in half.

6.1.7 Additional Observations

The following additional observations were noted:

- The use of KAc densified the residual snow on the side of the road. This densification prevented the snow blowers from loading snow into trucks properly. Snow blower breakdowns were more frequent in areas that used KAc. Shaded areas, such as in the tunnels, resulted in the snow continuing to melt on the edge of the roadway and forming large compacted "icebergs"—some as large as small cars—that needed to be broken down before loading.
- An application of 20 gallons per lane mile of KAc was extremely effective at controlling frost for three to five days with no re-freeze if no additional precipitation occurred. This was an improvement over salt brine and magnesium chloride.
- Information taken from the MDSS often was not reflective of what operators had seen or recorded.

6.1.8 Conclusions

Overall, the crews indicated that KAc was another good tool to have in the toolbox. It is not a tool that solves all problems, but under certain conditions, it can be effective at reducing the amount of salt used. The operators would like training on the properties, mechanisms of ice melting, and use of alternative chemicals.

6.2 PROCESS RECOMMENDATIONS

Challenges with data collection, as described in this report, led the research team to make the following recommendations about designing similar studies in the future. All participants—the sponsoring agency, the field staff, and the investigator team—would benefit from:

- Determining how much time and effort the project will take on the part of agency staff, and then judging whether that is realistic (particularly given that some data might need to be collected during winter storm emergency conditions).
- Confirming that all data to be collected are necessary. Inclusion of data that are interesting but not necessary to answer the research question should be considered carefully and removed from the project design if they do not provide useful context.
- Conversely, confirming that all data to be collected are sufficient to answer the research question. For this project, acquisition of comprehensive field performance data as a measure was vital.
- Establishing checks in the field to assure that project data are being collected. This should be done early enough in the project so that any deficiencies can be remediated.

It is impossible to plan for all contingencies, and unplanned staff vacancies are particularly difficult to work around. However, following recommendations like these would help improve the odds of collecting sufficient data to provide quantitative answers to future winter maintenance research questions.

APPENDIX A
LITERATURE SEARCH

MnDOT District 1 Potassium Acetate Field Study

Task 2: Literature Search

Prepared by CTC & Associates LLC
September 26, 2018

Description from the Work Plan:

TASK 2 Literature Search: CTC will review the MnDOT TRS on Field Usage of Alternative Deicers for Snow and Ice Control and identify any additional information that is publicly available regarding national and international use of KAc as a de-icing and anti-icing agent. The focus will be on successful uses of the material (material concentration and application rates, weather conditions, timing, etc.) by highway agencies or transferrable practices by airports.

1 Literature Search

1.1 Overview

A literature search of recent publicly available resources identified publications that are organized into four topic areas:

- Related Resources
- Research-in-Progress
- State Practices—Highway Agencies
- Transferrable Practices from Airports

1.2 Related Resources

Training Video for Implementation of Liquid-Only Plow Routes, Stonebrooke Engineering, Inc., Clear Roads and Minnesota DOT, May 2018, http://clearroads.org/project/16-06/.

From the abstract: Liquid-only plowing is a method of removing snow and ice on the road by applying liquid chemicals directly to the roadway surface. It also serves as an anti-icing tool. The goal of the Liquid-Only Plow Routes project was to create a set of training and promotional tools for the implementation of liquid-only roadway treatments. This information can serve as a resource for agencies seeking to gain buy-in within their organization for this type of winter maintenance, as well as for agencies already using these roadway treatments. It can also inform the general public while dispelling myths and misconceptions. The

tools created as part of this project include:

1. Literature Search Report: We researched the documented practices of liquid-only plow routes from agency and media sources, evaluated the applicability of the sources, and created a literature search report.
2. Survey of Practice: We compiled a list of 679 survey recipients from agencies in 27 US states and sent them an online survey to determine if their agency uses liquid-only roadway treatments, and if they would be interested in participating in a phone interview. We identified 22 recipients that agreed to be interviewed regarding their usage of these treatments. We performed the interviews and compiled the results into a report.
3. Quick Reference Guides: We created two quick reference guides for easy access to liquid-only plowing resources and information. The first guide, "Liquid-Only Road Treatments Start-Up Reference Guide," includes information on benefits, tips for gaining buy-in, and equipment recommendations. The second guide, "Liquid- Only Road Treatments Technical Reference Guide," includes usage parameters and application rates.
4. Videos: We produced two videos – a shorter video that focuses on benefits and dispelling myths, and a longer video that includes that information along with recommendations on how to start a liquid-only program, equipment guidelines, and usage parameters and application rates.

***Environmental Risks of Snow and Ice Control Materials,* Chapter 10** in **Sustainable Winter Road Operations,** Xianming Shi, Sen Du, Laura Fay, John Wiley & Sons Ltd, April 2018, 180-210**,** https://onlinelibrary.wiley.com/doi/abs/10.1002/9781119185161.ch10.

Summary: As abrasives and deicer products are widely used for snow and ice control, the past decade has seen increased concerns over the detrimental impacts on the surrounding environment. Generally, these snow and ice control materials can cause impacts to air quality, water quality, soil, flora, fauna, and human health. The added cost of clean-up and the paradigm shift from reactive to proactive snow and ice control strategies have resulted in growing use of chemicals instead of abrasives. Therefore, there is a need to better understand and assess the environmental impacts of deicers, in an effort to conduct sustainable winter road maintenance operations in an environmentally and fiscally responsible manner. This chapter will discuss relevant background information and provide a review of the environmental impacts of snow and ice control materials, including abrasives, chlorides, **acetates** and formates, glycols, urea, and agro-based deicers, according to a survey of published work particularly those over the last two decades.

Salt Brine Blending to Optimize Deicing, Anti-Icing Performance and Cost Effectiveness, Phase III, S. J. Druschel, Center for Transportation Research and Implementation, University of Minnesota, Mankato, November 2017, http://www.dot.state.mn.us/research/reports/2017/201745.pdf.
This study is a continuation of two previous phases of this deicing/anti-icing research (2012, 2014). On page 3 (page 18 of the PDF), the author reports on previous studies of deicing and anti-icing performance, including the use of potassium acetate (page 5, 91).

Chapter 4, the "Anti-icing Persistence Study" on pages 87–109 (102–124 of the PDF), presents and discusses methods and results of researchers' testing of many kinds of anti-icers on Minnesota highways.

Benefit-Cost Analysis of CDOT Fixed Automated Spray Technology (FAST) Systems, Anburaj Muthumani, David Veneziano, Jiang Huang, Xianming Shi, Colorado Department of Transportation: Applied Research and Innovation Branch, October 2014, https://www.codot.gov/programs/research/pdfs/2014/benefit-cost-analysis-of-cdot-fixed-automated-spray-technology-fast-systems/view.
The features, costs, advantages and disadvantages of potassium acetate (as one of many liquid chemical deicers) in FAST systems are reported throughout this study.

Abstract: The Western Transportation Institute (WTI) conducted research on behalf of the Colorado Department of Transportation (CDOT) to study the cost effectiveness of existing CDOT FAST systems. Both the national survey and the CDOT survey confirm the need for significant maintenance activities to ensure successful operation of FAST systems. Safety analysis of CDOT FAST system reveals a reduction in the number of annual crashes on multilane rural highways by 2 percent, urban interstates by 16 to 70 percent, rural interstates by 31 to 57 percent and interchange ramps between interstates by 19 to 40 percent. Overall, CDOT FAST systems included in the analysis have reduced crash severities at many sites resulting in potential safety benefits of $196,428 per winter season during the "after deployment" study period. Further, a benefit-cost excel sheet was developed based on the estimated crash reductions observed for each of the different roadway types.

The study found that FAST systems have demonstrated the potential to reduce the number of crashes and reduce the cost of winter maintenance activities, if sited at appropriate locations (e.g., high-traffic-volume ice-prone ramps). However, improved installation techniques and involvement of maintenance crews during FAST installation are necessary to further increase the cost-effectiveness of a FAST system deployment. Extra effort will be made in sharing the information gained from this research study by focusing on CDOT personnel involved in planning, design, construction, operation and maintenance of FAST systems.

Freeze-thaw Damage and Chemical Change of a Portland Cement Concrete in the Presence of Diluted Deicers, Xianming Shi, Laura Fay, Marijean M. Peterson, Zhengxian Yang, *Materials and Structures,* August 2010, Vol. 43, Issue 7, 933–946, https://link.springer.com/article/10.1617/s11527-009-9557-0.

From the abstract: The present study experimentally investigates the effect of different diluted deicers on concrete deterioration. Laboratory simulations of environmental freeze/thaw cycling were first conducted on Portland cement concrete specimens in the presence of various deicers (NaCl, K-formate, NaCl-based deicer, **K-acetate-based deicer**, Na-acetate/Na-formate blend deicer, CMA deicer, or $MgCl_2$ liquid deicer); and SEM/EDX measurements were then conducted for the concrete samples. Under the experimental conditions in this study, the CMA solid deicer and the $MgCl_2$ liquid deicer were benign to the concrete durability, whereas K-formate and the Na-acetate/Na-formate blend deicer showed moderate amount of weight loss and noticeable deterioration of the concrete. NaCl, the NaCl-based deicer, and the K-acetate-based deicer were the most deleterious to the concrete. In addition to exacerbating physical distresses, each investigated chemical or diluted deicer chemically reacted with some of the cement hydrates and formed new products in the pores and cracks. Such physiochemical changes of the cement paste induced by the deicers pose various levels of risks for the concrete durability.

Anti-icing in Winter Maintenance Operations: Examination of Research and Survey of State Practice, Minnesota Department of Transportation and Local Road Research Board, Transportation Research Synthesis (TRS) 0902, May 2009, https://www.lrrb.org/media/reports/TRS0902.pdf.
This synthesis examined publications addressing anti-icing from the following sources: national guidance, such as NCHRP and FWHA, handbooks and manuals (the Utah LTAP Center, Salt Institute, Minnesota Local Road Research Board) and state agency best practices (eight states and the Western Transportation Institute). The purpose of this synthesis was to provide foundational data for MnDOT's 2010 anti-icing guide (see this listing under **State Practices** below).

Within this literature search, references to potassium acetate occur in publications that appear on the following pages:

- Page 3 (as an alternative chemical for Michigan DOT)
- Page 11 (as an alternative chemical for Connecticut DOT)
- Page 12 (as an alternative chemical for roadways adjacent to bodies of water)
- Page 15 (in a study of alternative anti-icing and deicing chemicals)
- Page 22 (as an alternative chemical listed in state manuals)
- Page 24 (as a liquid chemical listed by Illinois DOT for use near waterways and in extreme cold).

FHWA Environmental Technology Brief: Is Highway Runoff a Serious Problem? FHWA-RD-98-079, Office of Infrastructure R & D, McLean, VA, 2008, updated March 8, 2016, https://www.fhwa.dot.gov/publications/research/infrastructure/structures/98079/runoff.cfm.

From the brief: Calcium Magnesium Acetate (CMA) and **Potassium Acetate** (KAc) are deicing chemicals most benign to the environment because they contain weak biodegradable acids. Sodium Chloride (NaCl), Calcium Chloride ($CaCl_2$), and Magnesium Chloride (MgCl2), on the other hand, leave residues of chloride ions on the highway surface that may not only contaminate surrounding ground waters, but that may also corrode motor vehicles and bridge structures.

This brief includes 22 footnotes.

Evaluation of Two Chemical De-Icers Used in Nebraska, Robert Rea, Lieska Halsey**,** Nebraska Department of Roads (NDOR) In-House Research, March 2006, https://dot.nebraska.gov/business-center/research/winter/.

From the research report: This study was initiated due to the growing concern that new liquid chemicals are being used as deicers, without knowing potential effects on the service life of Nebraska's concrete pavements. Currently, NDOR is using **magnesium chloride** and **potassium acetate** as liquid deicers in their winter maintenance program, as do many other states across the country. Each concrete sample will be taken from a NDOR construction project to ensure that the concrete samples are representative of the concrete pavement being placed in the field.
This study performed the following tasks:

1. Investigate the long-term effects of using 100 % magnesium sodium chloride and 50 % potassium acetate solutions on bridge decks and concrete pavement.
2. Evaluate accordance with ASTM C672 in order to quantify Scaling Resistance.
3. Evaluate the performance of three different cement types: IPF Inter-ground, IPF Blended and IPF with 10% Class C fly ash from two different sources.

1.3 Research-in-Progress

Evaluation of Our Current and Other Available Anti-Icing/De-Icing Products Under Controlled Environmental Conditions to Test Effectiveness (SPR-4321), Bob G. McCullouch, Zhi (George) Zhou, Purdue University/Indiana Department of Transportation JHRP, **Start date**: July 1, 2018; **Expected completion date**: June 30, 2019, https://trid.trb.org/Results?txtKeywords=anti-icing#/View/1531729.

Abstract: INDOT removes ice and snow from more than 28,000 lane miles of highways to protect public safety. This project will synthesize information from the literature and other agencies to evaluate effectiveness and environmental impacts of available anti-icing and de-icing products. The expected project deliverables include a summary report and recommendations on the most cost-effective anti-icing and de-icing products to support INDOT's efforts to improve highway safety.

Highway Anti-icing Products and Applications, Michelle Akin, Western Transportation Institute, Montana State University for Colorado Department of Transportation, **Start date**: December 2016; **Expected completion date**: December 2018, https://westerntransportationinstitute.org/research_projects/highway-anti-icing-products-and-applications/.
The objective of this project is to investigate road friction after deicing during winter storms.

Abstract: Colorado DOT Research Program is interested in addressing some concerns expressed by maintenance personnel regarding slippery road conditions that may develop after conducting anti-icing treatments prior to a forecasted winter storm. WTI is currently conducting a research project looking at road friction after deicing during winter storms. This project will enable additional field trials, and provide an opportunity to measure friction after anti-icing applications.

1.4 State Practices—Highway Agencies

"*Liquid Potassium Acetate Shows Promise in Reducing Chlorides*," *Newsline*, Minnesota Department of Transportation, January 10, 2018, http://www.newsline.dot.state.mn.us/archive/18/January/10.html#Z5.
This *Newsline* article discusses the winter maintenance chemicals used in District 1 (Duluth area) and the upcoming liquid potassium acetate field study planned for the winter of 2018-2019.

2017–2018 Winter Maintenance Fact Sheet: District 1—Duluth Office, Virginia Office, Minnesota Department of Transportation, http://www.dot.state.mn.us/d1/images/SnowIceFactSheet.pdf.

This document is a three-page overview of MnDOT District 1's methods of winter road maintenance. Potassium acetate is one of the materials winter road professionals use in this very cold area. Amounts used are listed on page 3.

Tuscumbia Area Winter Weather Plan 2017–18 Season: A complete review of the state of winter weather preparedness in the Tuscumbia Area, Tuscumbia Area Field Operations [Alabama], November 13, 2017, 66 pages. [No URL]

This document describes how the Tuscumbia Area prepared for the 2017–18 winter weather season. It includes an explanation (page 2) of its reasons for inclusion for the first time of potassium acetate (referred to as "PA" in this document) in its arsenal to combat ice on the highway system. It also describes how potassium acetate was included in preparations for use in managing roads affected by various kinds of winter storms.

> *From the weather plan, (page 4):* Potassium Acetate (PA) will be used this year. At the time of this report, we received the first of the PA shipments. It has been Area policy to refrain from chloride use and use only corrosively inert ice control materials on concrete structures due to the accelerated degradation of those structures. This policy could be considered more important today as it becomes more difficult to fund both the maintenance of existing bridges and the construction of replacements. PA is widely used in airport environments for snow and ice fighting because of its non-corrosive qualities. The FAA has approved its full exposure to aviation airframes, engines and other critical structural parts. PA is superior to the Area's existing inert bridge treatment, Calcium Magnesium Acetate (CMA) treatment in two ways. First, PA is a homogeneous premixed solution and is not subject to variations as is CMA, which is a mixture. Secondly, PA has a much lower potential flash-freeze temperature. In the accreting ice/low temperature example mentioned earlier, PA would have been instrumental in opening the Interstates due to the substantially lower eutectic temperature.

A discussion of management options, including pretreatment, included a comparison of potassium acetate with calcium magnesium acetate (page 21):

> Area bridge pretreatment has historically been accomplished with only corrosively inert chemicals or abrasives such as sand, fly ash, and larger gradations of commercially available aggregates. The only option to date has been Calcium Magnesium Acetate or CMA applied at a rate of 30 gallons per mile. Due to being a suspension as opposed to being dissolved in stable solution, CMA is prone to non-homogeneous concentrations. Flash freezing remains the primary concern for this type of application especially on raised structures like bridges. It has been Area policy to never apply this pretreatment below 25° F. Potassium Acetate (PA) to be tested this year will solve both problems as it is a solution whose eutectic temperature is -76° F.

[Note: this document is not accessible online and will be included in the appendix of the final research report for the **District 1 Field Study—Potassium Acetate**.]

North Dakota Anti-icing Facts, North Dakota Department of Transportation [n.d.] https://www.dot.nd.gov/divisions/maintenance/docs/anti-icingfacts.pdf.

A two-page informational document describes materials and methods of anti-icing performed by North Dakota Department of Transportation winter maintenance professionals. Potassium acetate is listed as an anti-icing chemical used in automated systems to keep bridges free of ice.

Winter Storm Management of Arizona State Highways Operations Manual, Arizona Department of Transportation, 2014.
https://www.azdot.gov/docs/default-source/environmental-planning-library/wsm-of-az-state-highways-september-2014.pdf?sfvrsn=2.
This operations manual discusses potassium acetate and other non-chloride road maintenance liquids. It explains why Arizona Department of Transportation does not use potassium acetate, (based upon a perception of its freeze-point depression limitations).

MnDOT Anti-Icing Guide, Gary Peterson, Paul Keranen, Rod Pletan, EVS, Inc. for Minnesota Department of Transportation, September 2010,
https://www.dot.state.mn.us/maintenance/pdf/research/AntiIcingGuide8Full.pdf.

Maine Winter Roads: Salt, Safety, Environment and Costs, Jonathan Rubin, Per E. Gårder, Charles E. Morris, Kenneth L. Nichols, John M. Peckenham, Peggy McKee, Adam Stern, T. Olaf, Johnson Margaret Chase Smith Policy Center, University of Maine, Feb. 2010,
https://mcspolicycenter.umaine.edu/wp-content/uploads/sites/122/2016/09/Winter-Road-Maint-Final.pdf.

From the Executive Summary: This report presents the results of a project by a research team from the University of Maine, in cooperation with the Maine Department of Transportation (MaineDOT), to examine the use of salts, equipment and personnel to control snow and ice on winter roads in Maine. The goal is to develop a common understanding among Maine residents of the relationships of cost, materials, research, policy priorities, and consequences.
In this report, we present background information on winter road maintenance, a description of current practices and policies in Maine, and summaries of the literature on environmental effects and corrosion. *We examine winter road practices in other selected states and provinces*. [Emphasis added].

New Hampshire, Minnesota, Ontario and Quebec road maintenance practices are examined in some detail. The discussion includes the use of **potassium acetate** in Minnesota's FAST (Fixed Automatic Spray Technology) systems for bridge treatment (page 43), and Ontario's use of FAST systems for treatment of bridges, ramps and tunnels (page 46).

1.5 Transferrable Practices from Airports (including RiP)

Determining Airfield Pavement Deicer and Anti-Icer Contributions to Airport Stormwater, Joseph D. Navarrete, Chris Cieciek; Airport Cooperative Research Program, Transportation Research Board, FAA, **Start date**: June 30, 2018; **Expected completion date**: May 31, 2019,
http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4424.

Abstract: The objective of this research is to develop a method to estimate the contributions of airfield pavement deicers and anti-icers to overall oxygen demand (BOD and COD) in stormwater discharges. The method should: (1) Account for sources, fate and transport of airfield pavement deicers and anti-icers; (2) Identify and quantify airfield pavement deicers and

anti-icers contained in discharged waters; (3) Account for contributions from other non-airfield pavement-related deicers and anti-icing activities; (4) Be adaptable to background water chemistry, various geographies, airport configurations, soils, topography, climate, weather, and hydrology; (5) Be scalable to levels of resource availability (e.g., data, time, money, personnel, expertise); and (6) Produce output expressed as a percentage of overall BOD and COD attributable to airfield pavement deicers and anti-icers with levels of confidence, and identify uncertainties.

***Aquatic Toxicity of Airfield-Pavement Deicer Materials and Implications for Airport Runoff*,** Steven R. Corsi, Steven W. Geis, George Bowman, Greg G. Failey, Troy D. Rutter, in *Environmental Science & Technology*, 2009, vol. 43 (1), 40-46. https://pubs.acs.org/doi/abs/10.1021/es8017732.

Abstract: Concentrations of airfield-pavement deicer materials (PDM) in a study of airport runoff often exceeded levels of concern regarding aquatic toxicity. Toxicity tests on Vibrio fischeri, Pimephales promelas, Ceriodaphnia dubia, and Pseudokirchneriella subcapitata (commonly known as Selenastrum capricornutum) were performed with **potassium acetate** (K-Ac) PDM, sodium formate (Na-For) PDM, and with freezing-point depressants (K-Ac and Na-For). Results indicate that toxicity in PDM is driven by the freezing point depressants in all tests except the Vibrio fisheri test for Na-For PDM, which is influenced by an additive. Acute toxicity end points for different organisms ranged from 298 to 6560 mg/L (as acetate) for K-Ac PDM and from 1780 to 4130 mg/L (as formate) for Na-For PDM. Chronic toxicity end points ranged from 19.9 to 336 mg/L (as acetate) for K-Ac PDM and from 584 to 1670 mg/L (as formate) for Na-For PDM. Sample results from outfalls at General Mitchell International Airport in Milwaukee, WI (GMIA) indicated that 40% of samples had concentrations greater than the aquatic-life benchmark for K-Ac PDM. K-Ac has replaced urea during the 1990s as the most widely used PDM at GMIA and in the United States. Results of ammonia samples from airport outfalls during periods when urea-based PDM was used at GMIA indicated that 41% of samples had concentrations exceeding the U.S. Environmental Protection Agency (USEPA) 1-h water-quality criterion. The USEPA 1-h water-quality criterion for chloride was exceeded in 68% of samples collected in the receiving stream, a result of road-salt runoff from urban influence near the airport. Results demonstrate that PDM must be considered to comprehensively evaluate the impact of chemical deicers on aquatic toxicity in water containing airport runoff.

APPENDIX B
SURVEY OF PRACTICE

MnDOT District 1 Potassium Acetate Field Study
MnDOT Contract No. 1030820

Task 2B: Survey of Practice

Prepared by CTC & Associates LLC
October 23, 2018

Survey of Practice

Survey Approach

A link to an online survey was distributed via email to the 36 Clear Roads member representatives and to the 15 members of the Technical Advisory Panel for this study. It was also posted on the Snow&Ice Listserv. The survey remained open for one week; the deadline was then extended one more week to allow for more participation. The survey gathered respondent information, then presented 15 questions about the use of potassium acetate (KAc) for winter road maintenance and two further places for participants to offer links to more information and final comments. A full text of the survey questions is included in Appendix A of this document. Full text of survey responses is available as an Excel file.

Twenty-five respondents participated in the survey. Participants included representatives from 21 state transportation agencies, two non-US transportation agencies and two consultants:

- Alabama
- Consultant: WVB East End Partners
- Consultant: Ice & Snow Technologies
- England
- Idaho
- Iowa
- Kansas
- Massachusetts
- Michigan
- Minnesota
- Montana
- Nevada
- New Hampshire
- North Dakota
- Ohio
- Oregon
- Pennsylvania
- Rhode Island
- Sweden
- Utah
- Vermont
- Washington State
- West Virginia
- Wisconsin
- Wyoming

Seventeen respondents reported they did not use KAc. The following eight said they used KAc and completed the entire survey, although Montana, Nevada and Utah only use it on bridges. Responses from the Consultant represented his prior experience at a state DOT (Washington State) as well as post-retirement work as consultant to others:

- Alabama DOT North Region
- Consultant: Ice & Snow
- Highways England
- Minnesota DOT Distr.1
- Montana DOT
- Nevada DOT
- Utah DOT
- Washington State DOT

Summaries of Survey Results

Survey Questions 3–4: Concentration, cost and use

These questions asked respondents about the potassium acetate concentration they used, the amounts of KAc applied and its cost for a winter maintenance season.

- What concentration of potassium acetate do you use? (Choices: 50%, 25% and Other.)
- What is your agency's seasonal cost of using potassium acetate? (Please indicate cost per gallon and number of gallons used or total cost and volume used.)

Concentration

Of the eight respondents indicating that they use potassium acetate (KAc), all reported using a 50 percent concentration of KAc.

Cost

The cost per gallon of potassium acetate varied only slightly across the six respondents who answered this question, ranging from $4.50 to $5.12 per gallon. The table below shows the cost per gallon and volumes of potassium acetate used for a winter season as reported for each respondent's agency. The far-right column also provides the total cost for the winter season.

Table 1: Cost and Quantities of Potassium Acetate Used for Winter Maintenance Season

Respondent	Cost per Gallon	Gallons Used in Winter Season	Total Cost for Winter Season
Alabama DOT	$4.97	50,000	$248,500
Highways England	$4.95/£3.78*	198,000	$980,100
Minnesota DOT	$4.50	30,000	$135,000
Montana DOT	$5.00	8,000	$40,000
Nevada DOT	$5.00	14,000	$70,000
Utah DOT	$5.1235**	8,700	$44,575

(*Currency conversion rate as of 10/08/2018: £1 = $1.31. ** Respondent provided season totals; price per gallon is approximate.)

Survey Questions 5–8: Winter maintenance procedures using KAc

This group of four questions asked respondents about which winter maintenance procedures in their agencies include the use of potassium acetate.

- Does your agency use liquid potassium acetate for roadway anti-icing? Application rate?
- Does your agency use liquid potassium acetate for roadway deicing? Application rate?
- Does your agency use liquid potassium acetate to pre-wet solid deicers? Application rate?
- Does your agency use liquid potassium acetate in automatic anti-icing systems such as those for bridge decks, also known as Fixed Automated Spray Technology (FAST)? Application rate?

Procedures

Four of the eight respondents reported using KAc for anti-icing, five for deicing and only one to pre-wet solid deicing materials (Washington State DOT). The use of KAc in FAST systems for bridges was reported by four respondents, three of which do not use KAc for highway applications (Montana, Nevada, Utah). See Table 2 below. Application rates were also provided by some respondents (rates are expressed in gallons per lane mile, gallons per ton or gallons per FAST sprayer/area or cycle).

Table 2: Winter Maintenance Procedures Using Potassium Acetate + Application Rates

Respondent	Anti-icing + Application rate	Deicing + Application rate	Pre-wetting + Application rate	Automatic Systems + Application rate
Alabama DOT	No	Yes 17 gal/lm	No	No
Highways England	Yes 20.8 gal/lm	Yes 29.8 gal/lm	No	No
Minnesota DOT	Yes 10 gal/lm	Yes 10–20 gal/lm	No	Yes 7.5 gal each spray/1000 ft
Montana DOT	No (just used on bridges)	No (just used on bridges)	No	Yes based on conditions
Nevada DOT	No	No	No	Yes
Utah DOT	No	No	No	Yes 22 gal/cycle
Washington State DOT	Yes 20–40gal/lm	Yes 20–40gal/lm	Yes 10–20 gal/ton	No
Consultant	Yes 25+gal/lm	Yes 25+gal/lm	No	No
TOTALS + RATES	4 10–40 gal/lm	5 10–40 gal/lm	1 10–20 gal/ton	4 varies

Rates

The respondents reported using rates varying from a low of 10 gallons per lane mile to a high of 40 gallons per lane mile for anti-icing and deicing. The respondent who reported using KAc to pre-wet deicing solids indicated that the agency uses 10–20 gallons /ton for this application.

Comparison of volumes of KAc used by respondents' agencies in FAST systems is not possible from the survey data: standard units, rates or areas covered were not provided. However, the Utah respondent noted that the agency only uses KAc in its FAST bridge deck systems and used 8,700 gallons for that purpose with a system "set at 22 gallons per cycle."

Survey Questions 9–11: Applications and satisfaction

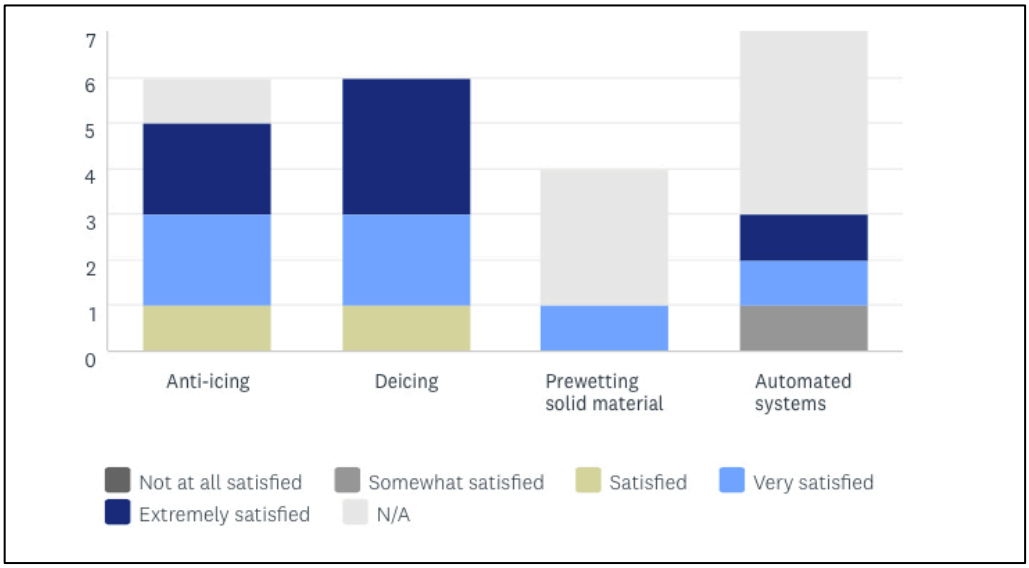
The next three questions examined the kinds of applications in which KAc was used, as well as levels of satisfaction with results in those applications:

- How satisfied is your agency with the use of liquid potassium acetate in the following applications: Anti-icing, Deicing, Pre-wetting, FAST systems?
- Please indicate whether your agency uses potassium acetate for any of the following applications: Frost control, Holding a pavement over a weekend, In advance of a holiday or other event, In advance of a storm and Other.
- Please indicate the coldest temperature range that liquid potassium acetate has been effective for anti-icing and deicing for your agency (choice of seven temperature ranges from 32 degrees F to minus 25 degrees F).

Satisfaction

The chart below graphically illustrates the respondents' ranking of their satisfaction with KAc results when used for anti-icing, deicing, pre-wetting and in FAST systems. The color key at the bottom of the chart indicates levels of satisfaction: Not at all Satisfied, Somewhat Satisfied, Satisfied, Very Satisfied and Extremely Satisfied. "Not Applicable" was also a choice.

Figure 1: Satisfaction with KAc Results Utilizing Four Application Practices
(Seven respondents)



Seven of eight respondents participated in some or all parts of this question. The respondents were generally more than satisfied with KAc performance in anti-icing, deicing, pre-wetting of solid materials and for use in FAST systems. Six of the seven respondents rated KAc for anti-icing and deicing, while only one offered a rating for pre-wetting solids. Three respondents rated KAc performance in automatic or FAST systems for bridge decks.

The table below further identifies individual responses as numerals from 1 to 5 in each application column (1 = Not Satisfied, 2 = Somewhat Satisfied, 3 = Satisfied, 4 = Very Satisfied, 5 = Extremely Satisfied or N/A = Not applicable). Respondents' comments follow the table.

Table 3: Individual Respondent Satisfaction of KAc Results in Four Applications Practices

Respondents	Anti-icing	Deicing	Pre-wetting	FAST systems
Alabama DOT	N/A	5	N/A	N/A
Highways England	4	4	N/A	N/A
Minnesota DOT	5	5	N/A	5

Respondents	Anti-icing	Deicing	Pre-wetting	FAST systems
Nevada DOT	N/A	N/A	N/A	2
Utah DOT	4	4	N/A	4
Washington State DOT	5	5	4	N/A
Consultant	3	3	N/A	N/A

Respondents from Minnesota, Utah and Washington State DOT indicated they were "Very Satisfied" or "Extremely Satisfied" with the results of KAc use in three out of four applications.

England's respondent reported they were "Very Satisfied" with KAc's results for anti-icing and deicing. England uses KAc to treat some tunnels and bridges, but this use involves the treatment of "only around 20 miles total of a 4300-mile network."

The Consultant respondent found KAc results for anti-icing and deicing "Satisfactory," and commented that it "does not melt like other deicer[s]. [It] makes it mealy and easy to plow off. [You] have to learn to use it or it will be overused. Good friction values from its correct use."

Alabama uses KAc only for deicing and indicated being "Extremely Satisfied" with the results, noting that the agency is replacing all use of CMA (calcium magnesium acetate) with potassium acetate. (Note that Alabama's respondent refers to potassium acetate as "PA" rather than "KAc." England's respondent also uses this initialization.)

Nevada's respondent reported the agency was "Somewhat Satisfied" with the use of KAc for FAST systems, though offered no comment to explain this relatively low rating for the application. Utah's respondent commented, "[w]e would use Potassium Acetate in spray trucks for anti-icing and deicing if it weren't so expensive."

Particular Applications

The next question asked respondents about their use of potassium acetate in a range of particular applications: Frost control, holding a pavement over a weekend, in advance of an event or holiday, in advance of a storm or other applications not included in the list. These applications can be understood as kinds of anti-icing.

Table 4: Use of KAc in Four Particular Application Events

Respondents	Frost Control	Holding Pavement over Weekend	In Advance of Holiday/ Event	In Advance of Storm	Other
Alabama DOT	X				Deicing during storm
Highways England	X		X	X	
Minnesota DOT	X	X			
Montana DOT	X				Automatic bridge system
Nevada DOT	X			X	Bridge system sprays based on moisture and temperature

Respondents	Frost Control	Holding Pavement over Weekend	In Advance of Holiday/ Event	In Advance of Storm	Other
Utah DOT	X			X	Bridge system sprays based on moisture and temperature
Washington State DOT	X	X	X	X	
Consultant				X	

All eight respondents participated in this question. All but one reported using potassium acetate for frost control. Two respondents (England and Washington State DOT) both reported using KAc to "hold a pavement over a weekend" and "in advance of a holiday or event." Five respondents indicated their use of KAc "in advance of a storm."

Washington State DOT's respondent alone indicated that potassium acetate was used by the agency for all four listed applications in this query. Alabama noted that potassium acetate was used for "deicing during [a] storm" rather than in advance of it. Three participants—Minnesota, Montana and Nevada—reported that KAc was always available in their automatic bridge systems and that spray application was triggered by changes in moisture and temperature.

Washington State DOT's respondent commented that the agency uses a product called "CF7 on the Tacoma Narrows Bridge" with good results "because of its limits to corrosion."

Temperature Range

The third of this group of questions asked respondents to indicate the coldest temperature range at which potassium acetate has been effective for anti-icing and for deicing. The two tables below show respondents' answers. A summary and respondents' comments follow.

Table 5: Coldest Effective KAc Temperature Range: Anti-icing

Coldest Effective KAc Temperature Range (°F): Anti-icing	Respondents
32 to 15°F	Highways England
15 to 0° F	None
0 to –5°F	Nevada DOT Washington State DOT
–5 to –15°F	Montana DOT
–15 to –20°F	Utah DOT
–20 to –25°F	None
Below –25°F	Consultant

Table 6: Coldest Effective KAc Temperature Range: Deicing

Coldest Effective KAc Temperature Range (°F): Deicing	Respondents
32 to 15°F	Highways England
15 to 0° F	None
0 to –5°F	Nevada DOT Washington State DOT
–5 to –15°F	Montana DOT
–15 to –20°F	Minnesota DOT Utah DOT
–20 to –25°F	None
Below –25°F	Alabama DOT Consultant

Respondents from Nevada, Washington State DOT, Montana, Minnesota and Utah reported effective use of KAc at temperatures ranging from 0 down to –20 degrees F.

England's respondent noted that the country does not generally experience temperatures below 14 degrees Fahrenheit. The respondent reported that potassium acetate has been effectively used in England for anti-icing and deicing from 32 degrees down to 15 degrees F.

The respondent identified as the Consultant commented that his answers do not apply solely to use in WSDOT but are, rather, "from an accumulation of experiences."

Alabama's respondent reported that temperature ranges and rates are being evaluated this year (2018).

Utah's respondent noted that although KAc is reported to function as a freeze-point depressant down to –70 degrees, since the FAST systems were installed in the state in 2003, "the lowest temperature recorded in Utah is –16 degrees."

Survey Questions 12–14: Supplementing KAc

Three questions asked about respondents' use of other materials to supplement the application of potassium acetate in anti-icing and/or deicing procedures, including types of materials added and conditions more effectively addressed with a combination of KAc and additional solids or liquids:

- What other liquid or solid materials do you use to supplement the use of liquid potassium acetate for anti-icing/deicing? Choose all that apply: Sand, Salt/Sand mixture, Salt, Brine, Other solid or liquid. N/A is also a choice.
- What anti-icing/deicing conditions determine your agency's use of other liquids or solids as supplements to liquid potassium acetate? Choose all that apply: Falling temperatures, Rising temperatures, Type of storm, Ice or snow on pavement, Traffic, Time of day. N/A is also a choice.
- How often does your agency supplement liquid potassium acetate with other liquid or solid materials to treat roadways?

Supplementation materials

One of the eight respondents (Minnesota DOT) reported that the agency does not supplement potassium acetate with any other solid or liquid in anti-icing or deicing operations. All other respondents indicated that other materials are used in conjunction with potassium acetate in anti-icing or deicing operations.

Four respondents—the particular four varying across material choices—indicated that their agencies use a salt/sand mixture, salt, brine, or other materials to supplement potassium acetate in their anti-icing operations.

Table 7 below shows which liquid or solid materials respondents reported using with potassium acetate for anti-icing. It is notable that the respondent from Alabama reported using every supplement listed in this question. Minnesota's respondent indicated this question was "not applicable" to the agency.

Table 7: Supplementing KAc: Anti-icing

Liquid or Solid Supplement	Respondents	Total
Sand	Alabama DOT	1
Salt/Sand mix	Alabama DOT, Montana DOT, Utah DOT, Washington State DOT	4
Salt	Alabama DOT, Highways England, Utah DOT, Washington State DOT	4
Brine	Alabama DOT, Highways England, Montana DOT, Nevada DOT, Utah DOT	4
Other solid or liquid	Alabama DOT, Highways England, Utah DOT, Washington State DOT	4

Six of the eight respondents reported using brine as a supplement to potassium acetate for deicing operations. Solid salt was used by five respondents; the same five reported using "other solids or liquids" in conjunction with KAc for deicing. Four respondents indicated they supplemented with a salt and sand mixture for deicing. Only the Alabama and Washington State DOT respondents reported using straight sand to supplement KAc for deicing.

Table 8 below shows which materials respondents' agencies used to supplement KAc for deicing operations.

Table 8: Supplementing KAc: Deicing

Liquid or Solid Supplement	Respondents	Total
Sand	Alabama DOT, Washington State DOT	2
Salt/Sand mix	Alabama DOT, Montana DOT, Utah DOT, Washington State DOT	4
Salt	Alabama DOT, Highways England, Utah DOT, Washington State DOT, Consultant	5
Brine	Alabama DOT, Highways England, Montana DOT, Nevada DOT, Utah DOT, Consultant	6
Other solid or liquid	Alabama DOT, Highways England, Utah DOT, Washington State DOT, Consultant	5

England's respondent commented that the majority of the nation's "4300 mile network is treated with pre-wetted rock salt (with brine), 30% liquid/70% solid." Calcium chloride may be used as a pre-wetting agent in extremely cold conditions.

Nevada's respondent commented that potassium acetate is only used on five bridges in the northwest third of the state. Utah's respondent added in a comment that "some of our sheds use cinders mixed with salt."

Conditions warranting supplementation

The next question asked about the conditions that would point to the use of potassium acetate combined with a supplementary liquid or solid for anti-icing and/or deicing operations.

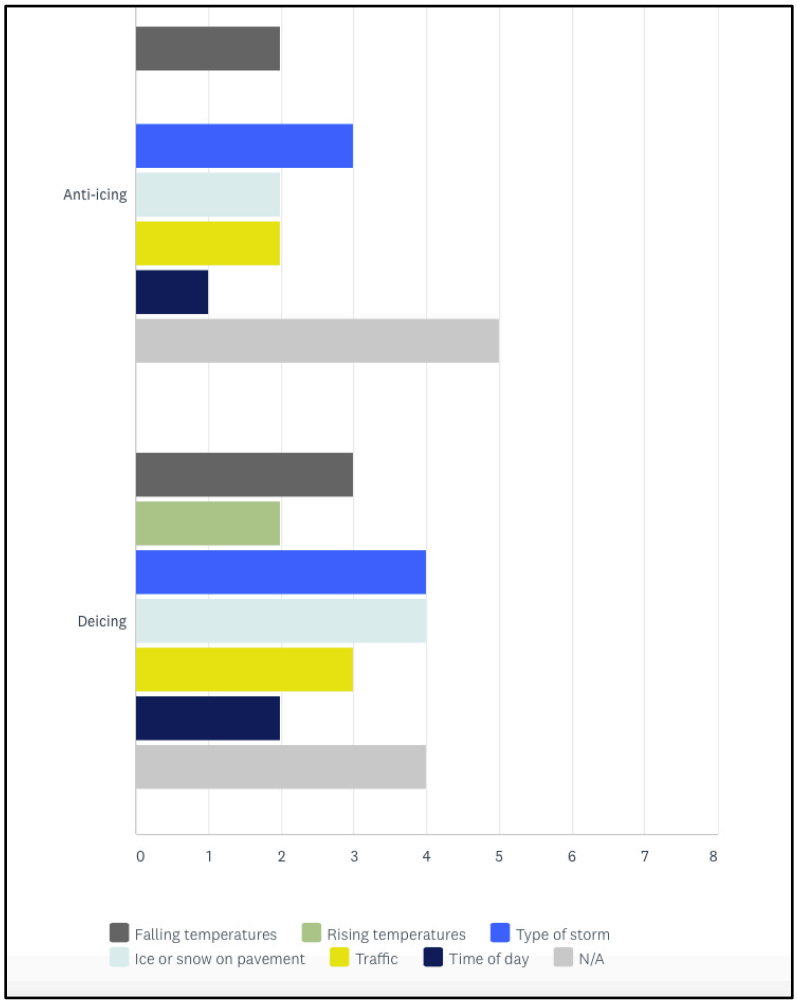
Anti-icing: Three of eight respondents indicated that some conditions would determine the use of supplemental materials with KAc for anti-icing. The Washington State DOT and the Consultant reported that falling temperatures, the type of storm and traffic were determining factors. The Washington State DOT respondent also indicated that the presence of ice or snow on the road would be a determining factor, while the Consultant included time of day as a condition to take into account.

The respondent from Montana reported that the type of storm and the presence of ice or snow on the road would determine whether or not to use supplemental materials with KAc for anti-icing.

Five participants indicated that none of these conditions was applicable to their decisions to use supplemental materials with KAc for anti-icing.

Deicing: Four respondents reported conditions that would influence their use of supplementary materials with KAc for deicing operations. Four other respondents chose "not applicable" as their answer to this part of the question. The chart below illustrates the distribution of conditions respondents considered relevant to deciding whether or not to supplement KAc with other liquids or solids for anti-icing and deicing:

Figure 2: Conditions Warranting Supplementing KAc: Anti-icing and Deicing
(Eight respondents)



Four respondents identified conditions relevant to them in deciding whether to supplement KAc with other liquids or solids for deicing operations:

- Alabama DOT
- Montana DOT
- Washington State DOT
- Consultant

Alabama's respondent as well as the Consultant both reported considering all six conditions listed as possibly warranting supplementing KAc with other liquids or solids for deicing.

Montana's respondent indicated that the type of storm and whether there was ice or snow on the pavement determined supplementation of KAc with other materials for deicing operations.

Washington State DOT's respondent indicated that falling temperatures, the type of storm, ice or snow on the pavement and traffic were considered when supplementation of KAc with other materials for deicing was evaluated.

Frequency of supplementation

The third question in this group asked respondents how often their agencies supplement KAc with other liquid or solid materials to treat roadways.

Table 9: Frequency of Supplementation of KAc

Frequency of Supplementation	Respondent
Every time	Minnesota DOT, Utah DOT
Sometimes	Highways England, Montana DOT, Nevada DOT, Washington State DOT
Never	Alabama DOT
Other (comment)	Consultant

All eight respondents provided an answer or comment on supplementation to KAc. Both Minnesota and Utah's respondents reported supplementing KAc "every time it is used." The Minnesota respondent qualified that answer by noting it is used on specified routes. Utah's respondent noted that "every time" refers to the KAc solution that is used in FAST systems.

The respondent from Alabama commented that the agency never uses supplemental materials with KAc.

Four respondents indicated that they "sometimes" use supplemental materials, and one more offered relevant comments. England's respondent indicated that "sometimes" a supplement is used, but that a potassium acetate solution with corrosion inhibitors is generally used without any additions.

Montana's respondent reported that supplementation is used "only as need to provide a safe surface."

Nevada's respondent explained that supplementation of KAc is used on bridge decks only when the FAST systems fail.

Washington State DOT's respondent noted that the agency uses potassium acetate in a limited role, supplemented with calcium chloride.

The Consultant noted that temperature defines the product selection: "At warmer temperatures when other less expensive products are effective [we] use them, if some other concern does not prevent it."

Survey Questions 15–16: Future use of KAc

The survey's last two questions asked about respondents' agencies likely future use of potassium acetate for winter roadways operations:

- Does your agency plan to increase its use of liquid potassium acetate in the future? Yes or No.
- Please rate these aspects of liquid potassium acetate regarding how they may determine your agency's use of it in the future:
    - Effective when other materials are not effective
    - Allows use of less chloride/salt
    - Current or future regulation concerning salt/chloride use
    - Cost
    - Uncertainty about effectiveness
    - Uncertainty about equipment needs
    - Uncertainty about changing established procedures
    - Environmental concerns about salt/chloride

- Environmental concerns about potassium acetate

Respondents applied a five-point rating scale to each of these aspects of liquid potassium acetate:

- 1: Not important
- 2: A concern but not a deciding factor
- 3: Important when combined with other factors
- 4: Very important
- 5: Extremely important
- N/A (not applicable)

More KAc in the future?

Three of eight respondents (Alabama, England, Minnesota) reported that they would use more liquid potassium acetate in the future. Alabama's respondent commented that other non-corrosives are being phased out, while England's respondent explained, "usage will be expanded to include more key structures." Minnesota's respondent indicated that KAc would be used on more routes.

Four respondents reported that their agencies did not plan to use more KAc in the future. Montana's respondent noted that it is only used on one bridge system in the state. Nevada's respondent reported no plan to increase use. Utah's respondent explained that the agency was "not actively planning on installing any other FAST systems." Washington State DOT's respondent cited the high cost as the reason for its current limited use; there was no plan to increase using KAc.

The Consultant noted that use "depends on the customer, their needs and goals."

Aspects of KAc influencing future use

The final survey question asked participants to rate characteristics of liquid potassium acetate that would determine their agency's future use for winter roadway maintenance. The question, described in detail above, elicited responses from all eight respondents. The table below shows individual respondents' determinations of the importance of nine considerations in choosing to use potassium acetate:

Table 10: Importance of Nine Considerations in Choosing KAc: Individual Responses

Key: 1 = Not Important, 2 = A concern but not a deciding factor, 3 = Important when combined with other factors, 4 = Very important, 5 = Extremely important, N/A = not applicable

Considerations	Respondents							
	Alabama DOT	Highways England	Minnesota DOT	Montana DOT	Nevada DOT	Utah DOT	Washington State DOT	Consultant
n	4	3	5	5	N/A	4	4	5
Use less chloride/salt	5	5	5	3	N/A	N/A	4	5
	2	1	4	3	N/A	N/A	3	3
Cost	2	3	3	5	4	5	5	5

Uncertainty: effectiveness	1	4	3	3	4	4	1	N/A
Uncertainty: equipment	1	3	3	4	4	4	1	No response
Uncertainty: change procedures	3	2	3	2	N/A	2	2	No response
Environment: chloride/salt	1	2	4	3	No response	3	2	5
Environment: KAc use	1	2	2	3	N/A	3	1	4

The table shows that three considerations ranked very highly in importance for the majority of the respondents:

- Effectiveness of potassium acetate when other materials are not effective.
- The ability to use less chloride/salt.
- The cost of potassium acetate.

Rankings of the importance of other considerations showed more variation across the participants' responses.

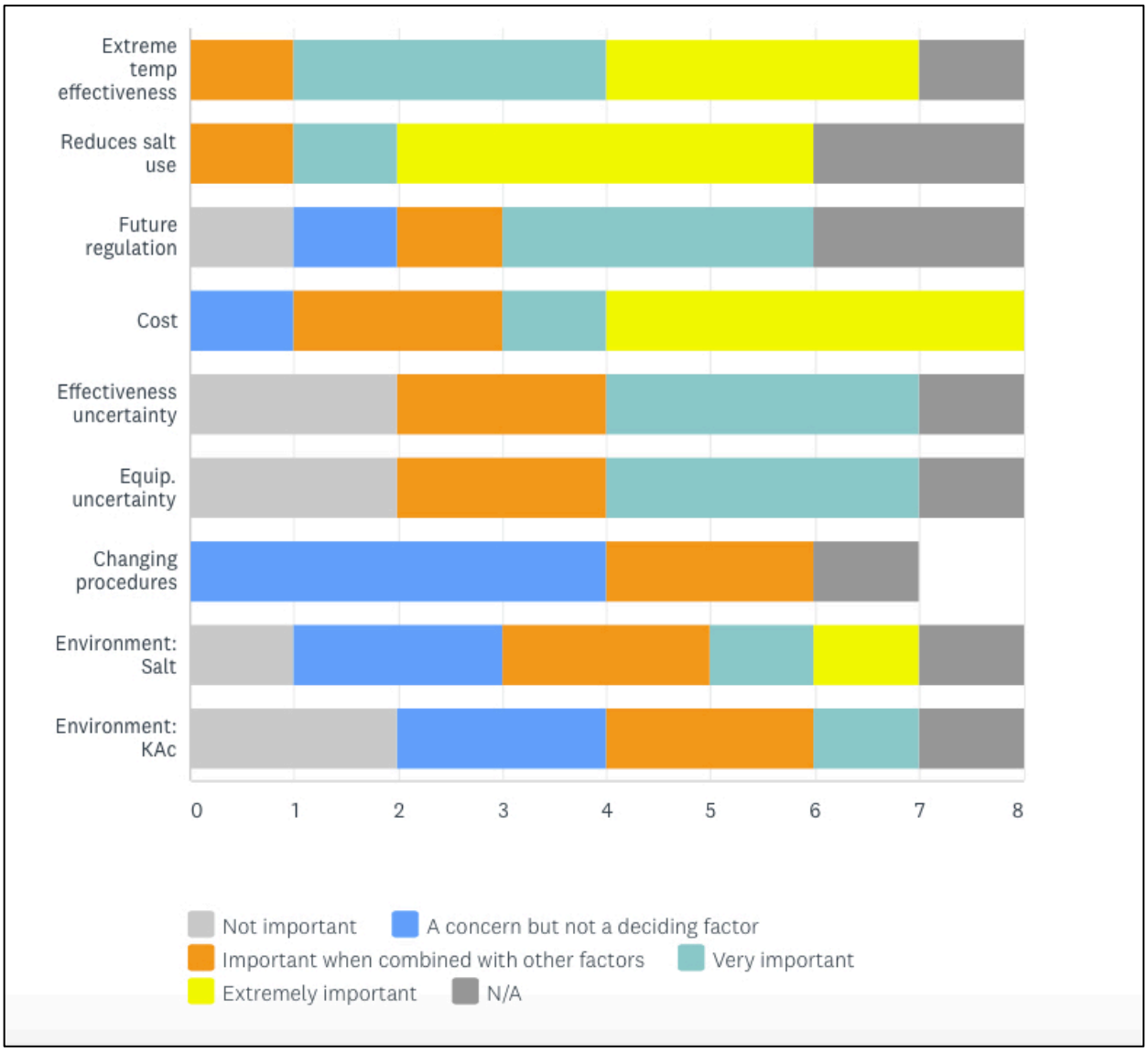
Three respondents offered comments after completing this question. Montana's respondent noted that they were "still early in the evaluation process." The Consultant reiterated that his answers "in many cases do not apply to WSDOT but are from an accumulation of experiences."

The respondent from England described the situation in his country concerning the use of salt and other anti-icers/deicers:

> A significant program of structural repairs to ageing major infrastructure in England has been ongoing for a number of years and will continue for many more to come. It is clear that salt corrosion has exacerbated the damage and costs and therefore the use of alternative, less corrosive materials on those sections of key infrastructure susceptible to salt damage is likely to increase.

The chart below graphically illustrates the overall range of importance for each of the nine considerations ranked by the respondents:

Figure 3: Importance of Nine Factors in Choosing KAc: Overview



Additional Information and Closing Comments

The final survey requests were for additional information and closing comments. Two respondents sent documents that included information about their agencies' use of potassium acetate: Alabama's respondent sent the Tuscumbia Area Winter Weather Plan: 2017–18 Season. This document is not available online. A description of it appears in the Literature Search section of this study and a portion related to potassium acetate use is provided in Appendix B of this section. Utah's respondent sent the UDOT contract for purchase of potassium acetate for winter roadway maintenance. A selection from that document is provided in Appendix C.

Five respondents offered closing comments:

England's respondent commented, "Extreme temperatures are unusual in the UK."

Montana's respondent described KAc use on bridges:

> We have used [potassium acetate] for one season (2 seasons on half the bridge). It is used in an automated spray system. We are still in the early stages of evaluating its effectiveness. Its effectiveness is tied to the operation of the automated system.

Nevada's respondent also described the agency's potassium acetate use on bridges:

> Potassium acetate is only used on a few bridges [through] an automated spraying system. The system has proven to be unreliable, and we have had to revert back to using brine and salt sand mixtures.

Utah's respondent described its KAc use on bridges: "All of our FAST systems are on bridge decks located on curves that are prone to black ice."

The Consultant offered a summation: "Very good product when used correctly and with understanding. Cost of use can be high."

Washington State DOT's respondent reiterated those views: "The product works very well. [We have] limited use because of [the] cost to apply. Average cost to apply is $6.00 [per] gallon without labor cost.

Appendix A

District 1 Potassium Acetate Field Study: Survey Questions

The following survey was distributed as a link via email to the 36 Clear Roads member representatives and to the 15 members of the MnDOT Technical Advisory Panel for this study. It was also posted on the Snow&Ice Listserv.

Concentration, cost and use

1. What concentration of potassium acetate do you use? (50%, 25%, Other)
2. What is your agency's seasonal cost of using potassium acetate? (Please indicate cost per gallon and number of gallons used or total cost of potassium acetate used per season and approximate volume used.)

Winter maintenance procedure using KAc

1. Does your agency use liquid potassium acetate for roadway anti-icing? Y/N Application rate?
2. Does your agency use liquid potassium acetate for roadway deicing? Y/N. Application rate?
3. Does your agency use liquid potassium acetate to pre-wet solid deicers? Y/N. Application rate?
4. Does your agency use liquid potassium acetate in automatic anti-icing system, such as those for bridge decks, also known as Fixed Automatic Spray Technology (FAST)? Y/N. Application rate?

Application and satisfaction

1. How satisfied is your agency with the use of liquid potassium acetate in the following applications: anti-icing, deicing, pre-wetting solid material, automated spray systems/FAST? (Rating scale: 1 = Not at all satisfied, 2 = Somewhat satisfied, 3 = Satisfied, 4 = Very satisfied, 5 = Extremely satisfied, N/A = not applicable.)
2. Please indicate whether your agency uses potassium acetate for any of the following applications (choose all that apply): Frost control, Holding a pavement over a weekend, In advance of holiday or other event of increased traffic, In advance of a storm, Other.
3. Please indicate the coldest temperature range that potassium acetate has been effective for anti-icing and deicing for your agency: 32 to 15°F, 15 to 0° F, 0 to –5°F, –5 to –15°F, –15 to –20°F, –20 to –25°F, Below –25°, N/A.

Supplementing KAc

1. What other liquid or solid materials do you use to supplement the use of liquid potassium acetate for anti-icing/deicing? Choose all that apply: Sand, Salt/Sand mixture, Salt, Brine, Other solid or liquid. Choose N/A if you do not supplement.
2. What anti-icing/deicing conditions determine your agency's use of other liquids or solids as supplements to liquid potassium acetate? Choose all that apply: Falling temperatures, Rising temperatures, Type of storm, Ice or snow on pavement, Traffic, Time of day. Choose N/A if you do not supplement.

3. How often does your agency supplement liquid potassium acetate with other liquid or solid materials to treat roadways?

Future use

1. Does your agency plan to increase its use of liquid potassium acetate in the future? Y/N.

2. Please rate these aspects of liquid potassium acetate regarding how they may determine your agency's use of it in the future:
    - Effective when other materials are not effective
    - Allows use of less chloride/salt
    - Current or future regulation concerning salt/chloride use
    - Cost
    - Uncertainty about effectiveness
    - Uncertainty about equipment needs
    - Uncertainty about changing established procedures
    - Environmental concerns about salt/chloride
    - Environmental concerns about potassium acetate

    Respondents applied a five-point rating scale to each of these aspects of liquid potassium acetate:
    1. Not important
    2. A concern but not a deciding factor
    3. Important when combined with other factors
    4. Very important
    5. Extremely important

    N/A (not applicable)

Additional information and closing comments

1. Please provide links to any manuals or guidance that your agency uses for application of liquid potassium acetate. Please email guidance documents not available online to sharon.vansluijs@ctcandassociates.com.

2. Please use this space to provide any comments or additional information about your agency's use of liquid potassium acetate, particularly in extreme temperatures.

Appendix B

Alabama: Tuscumbia Area Winter Weather Plan 2017-18

The following selection of 13 pages from this 66-page document explains the area's decision to use potassium acetate in its winter roadway maintenance plan and the weather conditions that would require its application.

Tuscumbia Area Winter Weather Plan

The Tuscumbia Area winter weather response has evolved over the last decade to the plan which follows. The evolution of the ALDOT response, to date, has progressed from an abrasive only approach to the application of various chemical deicers and pretreatment of the road/precipitation interface and finally, a geographic approach. This plan represents the accumulation of data, wisdom and knowledge in the Tuscumbia Area.

WINTER WEATHER SETTING

With the mass Interstate strandings associated with a winter storm in central Alabama in 2014, Director Cooper has asked that the Area pay particular attention during winter events to I-65 and I-565. There is also an expectation of the public traveling south on I-65 from Tennessee that conditions will improve as they travel south. Due to these considerations, it is the intent and policy of the Tuscumbia Area to expend any and every resource so that those facilities remain open and passable.

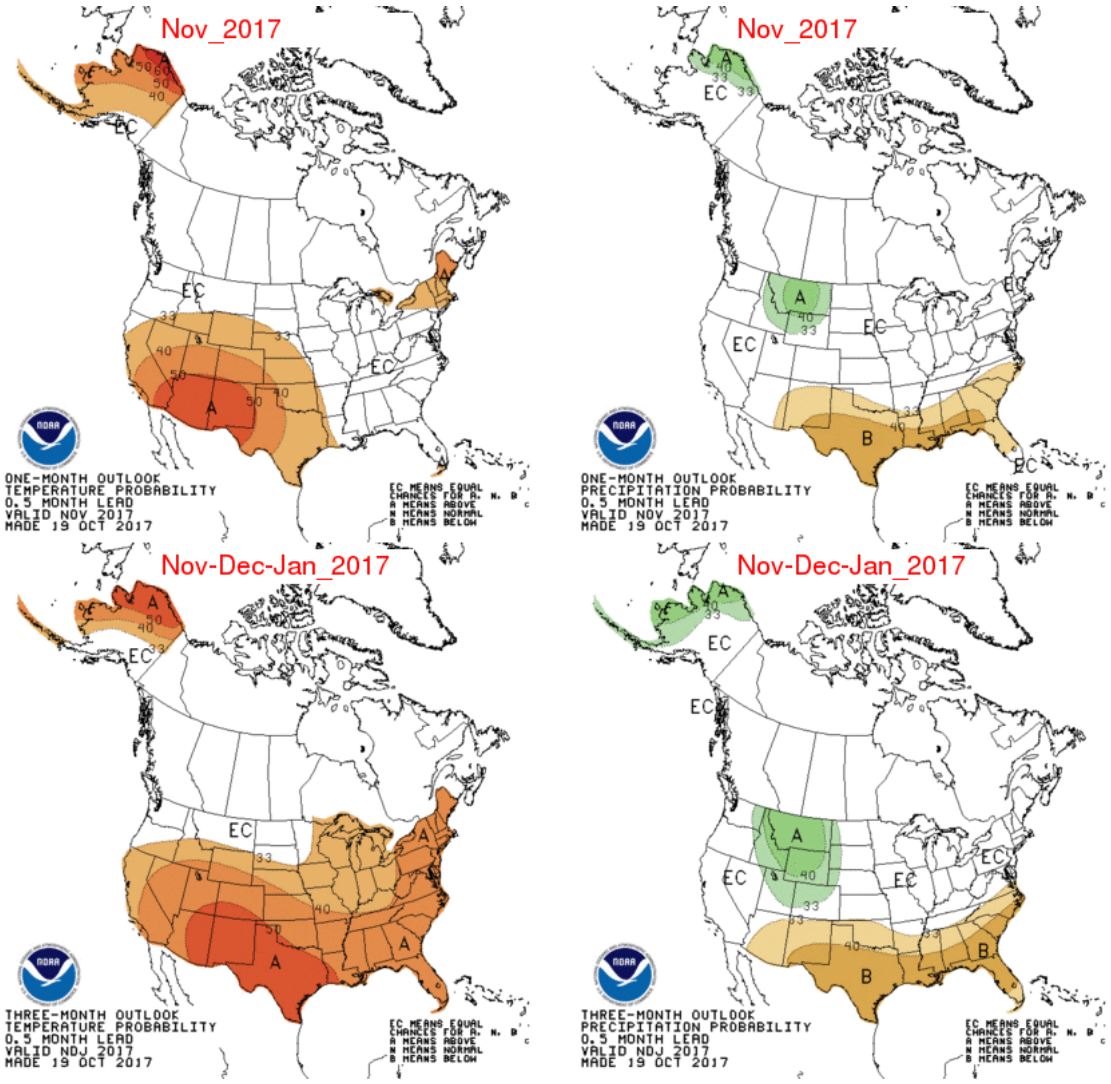
With the exception of one freezing-rain ice accretion event in the 2014-15 season, Priorities 1, 2, and 13 (see Priorities Chart of page 30) have not been impassable in the last 4 years. During that event, accretion had reached near ¼ inch and ground temperatures had dropped below the effective melting points of all of the chemical deicers in use by the Area at that time. Interface bonding had occurred and it had become treacherous for Area winter weather operations. This year's plan finally addresses that shortcoming with the added capability of Potassium Acetate.

NOAA has released its long range predictions for the 2017-18 season. The three-month outlook for precipitation probability is equal to all other years. The three-month probability for temperature is above normal. However, a La Nina watch exists for the Pacific Ocean;

> *"…A LA NINA WATCH CONTINUES, AS ATMOSPHERIC AND OCEANIC CONDITIONS, TAKEN IN TOTALITY, REMAIN CLOSEST TO ENSO-NEUTRAL CONDITIONS THROUGH EARLY OCTOBER. OCEANIC CONDITIONS CONTINUE TO MOVE QUITE CLOSE TO THE LA NINA STATE AS EQUATORIAL SEA SURFACE TEMPERATURE (SST) DEPARTURES FROM NORMAL ARE NEGATIVE TO A MAGNITUDE OF -0.5 DEGREES C FROM ABOUT 150W TO THE SOUTH AMERICAN COAST WITH A HORSESHOE OF ABOVE NORMAL SSTS TO THE NORTH AND SOUTH OF THIS REGION AND ACROSS THE FAR WESTERN PACIFIC (TYPICAL OF DEVELOPING/ESTABLISHED LA NINA CONDITIONS). OCEANIC HEAT CONTENT (OCEAN TEMPERATURES ACROSS THE PACIFIC BASIN FROM THE SURFACE TO 300 METERS DEPTH) SHOW A CONSIDERABLE RESERVOIR OF COLDER THAN NORMAL WATER, OFTEN A PRECURSOR FOR THE DEVELOPMENT OF MORE ESTABLISHED LA NINA CONDITIONS.*
>
> *IN TERMS OF THE ATMOSPHERE, SUPPRESSED CONVECTION REMAINS OBSERVED ACROSS MUCH OF THE CENTRAL EQUATORIAL PACIFIC WHILE ENHANCED RAINFALL CONTINUES ACROSS THE MARITIME CONTINENT REGION. ALTHOUGH GENERALLY WEAK OVERALL, THE TRADE WINDS IN THE PACIFIC HAVE BEEN ENHANCED AND UPPER-LEVEL WESTERLY WIND ANOMALIES ARE CURRENTLY OBSERVED IN THE REGION AS WELL. AN ADDITIONAL FACTOR TO BE COGNIZANT OF IN THE COMING MONTH IS THE CURRENT DEVELOPING MJO WHICH HAS, AND WILL LIKELY CONTINUE TO, MODULATE SST, WINDS AND CONVECTION ON THE SUBSEASONAL TIME SCALE ACROSS THE PACIFIC BASIN AS IT PROGRESSES ACROSS THE PACIFIC TO THE WESTERN HEMISPHERE, AS CURRENTLY PREDICTED…"*
>
> ***PROGNOSTIC DISCUSSION FOR LONG-LEAD SEASONAL OUTLOOKS***
> ***NWS CLIMATE PREDICTION CENTER COLLEGE PARK MD***
> ***830 AM EDT THU OCT 19 2017***

Even with the La Nina watch outlined above, the more accurate one-month climate forecast seems to indicate almost "equal chance" of precipitation and temperature outlooks for the Tuscumbia Area. This indicates both

outlooks will probably not vary from previous years. The three-month climate forecast seems to indicate above average temperatures and below normal precipitation through December. In general, La Nina years tend toward the three-month forecast throughout the winter. ***These climate forecasts indicate the current trend of mild temperatures may extend for the fourth year.***



The 2015-16 winter was extremely mild; however, the 14-15 season was characterized by a sustained period of below freezing temperatures. There were five events that required mobilization that year. Almost 3,000 tons of salt was utilized during these events which was rationed heavily during the final two events. Any subsequent events would have been treated with abrasives only because additional salt and liquid calcium purchases were impossible. For the 15-16 season, road salt was purchased entirely before the season started due to the purchasing experience gained in the previous year.

Area policy today, is to assume additional chloride products will not be available after winter weather begins in the northern United States.

THIS YEAR'S INNOVATIONS

Every effort has also been made to maximize the efficiency of the much smaller budget available for winter weather in Alabama relative to Tennessee. The relative efficiency of most any deicing effort is exponentially related to absolute distance to the treated area (See Figure 1). By the preplacement of materials and equipment along I-65 at Mileposts 318, 363 and the existing Tanner District, the Area has reduced replenishment travel time to any point from Exit 310 (Cullman) to the Tennessee state line to less than 16 minutes. Other prepositioned materials are located south of Russellville. Although above a 100-year flood elevation the prepositioned materials west of Rogersville were removed this year due to flooding potential and numerous complaints.

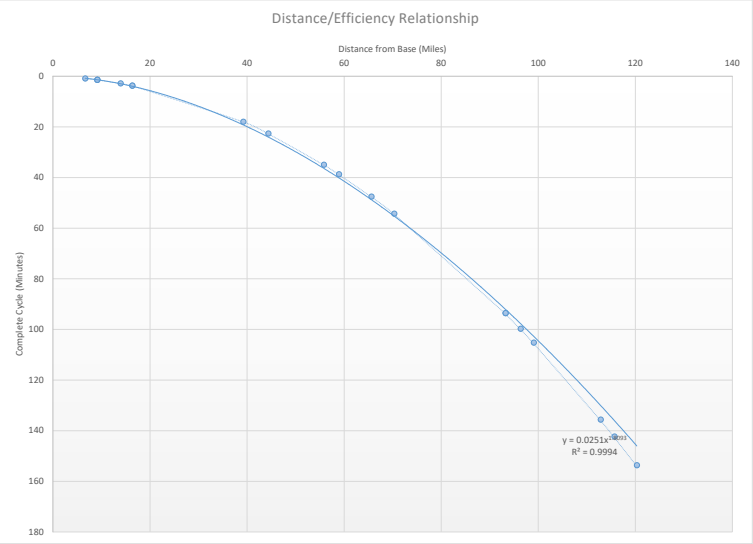


Figure 1

We will continue to experiment with different mechanical equipment to overcome limitations with an emphasis on granular solid distribution rates. In furtherance of this purpose we will continue to work with purchasing limitations to obtain *Ground Oriented Control Technology*. This technology varies, both the conveyor speed and the spinner, based on actual vehicle speed to control the rate of distribution. To date, distribution rates have been merely a function of the size of the opening which allows materials to be spilled onto the spinner. According to DOT officials at the Minnesota, Wyoming and the New York, using openings to control distribution rates is not effective.

Potassium Acetate (PA) will be used this year. At the time of this report, we received the first of the PA shipments. It has been Area policy to refrain from chloride use and use only corrosively inert ice control materials on concrete structures due to the accelerated degradation of those structures. This policy could be considered more important today as it becomes more difficult to fund both the maintenance of existing bridges and the construction of replacements. PA is widely used in airport environments for snow and ice fighting because of its non-corrosive qualities. The FAA has approved its full exposure to aviation airframes, engines and other critical structural parts. PA is superior to the Area's existing inert bridge treatment, Calcium Magnesium Acetate (CMA) treatment in two ways. First, PA is a homogeneous premixed solution and is not subject to variations as is CMA, which is a mixture. Secondly, PA has a much lower potential flash-freeze temperature. In the accreting ice/low temperature example mentioned earlier, PA would have been instrumental in opening the Interstates due to the substantially lower eutectic temperature.

1. Weather Condition One

An overtopping cold front approaches typically from the northeast over a warm moist existing air mass. This situation typically produces a widespread event beginning with frozen precipitation.

This condition will begin with pretreatment protocol. Based on temperature and timing, the following possible responses are available to ALDOT management:

A. PROCEEDURE ONE- 24-48 hour advance notice and above freezing temps more than 25^{o} F.

EXECUTION

-48 Hours

- Check fuel stocks-Order tank wagons if necessary
- Area Warehouse will obtain 3-day menu
- Brine manufacturing begins (If recent winter activity has prevented top off procedure)
- Each District will load 3 spreaders, 2 brine tank skids and 1 CMA/PA skid
- All plows will be mounted
- Notify all support personnel for alert in next 48 hours

-24 Hours

- Pre-treatment begins (Priority 1-25)
- Brine tankers top off districts (If recent winter activity has prevented top off procedure)

-12 Hours

- Small crew left to remove all liquid skids, replace with spreaders and obtain food stocks from warehouse and store at district office
- Remaining crews sent home

-3 Hours

- Crews recalled granular salt loaded
- Support crews called and arrive
- Crews dispatched to county preposition locations (See Table 1, Page 6)

0 Hour

- Notify EMA, Area, Region that DOT operations active

+1 Hour

- Notify Region, Area of measurable winter precipitation
- Begin reconnaissance of road conditions
- Monitor developing weather conditions with TV, department weather contractors and area weather stations
- Adjust de-icing activities
- Field Operations distributes SITREP to region and Montgomery
- Serve 2 hot meals and 1 bag lunch to crews as appropriate
- Repair equipment as needed

+24 Hours

- Clean and spray protectorant on all equipment
- Open and operate brine facility until all tanks have been topped off
- Reorder/redistribute liquid calcium, potassium Acetate and solid Calcium Magnesium Acetate

B. PROCEDURE TWO-Less than 24 hour notice with existing freezing temps more than 25^{o} F

EXECUTION

-12 Hours

- Check fuel stocks-Order tank wagons if necessary
- Area Warehouse will obtain 3-day menu
- Brine manufacturing begins (If recent winter activity has prevented top off procedure)
- Each District will load 3 spreaders, 2 brine tank skids and 1 CMA/PA skid
- All plows will be mounted
- Notify all support personnel for alert in next 12 hours
- Pre-treatment begins (To Priority 25)

-6 Hours

- Small crew left to remove all liquid skids and replace with spreaders
- Remaining crews sent home

-1 Hour

- Crews recalled granular salt loaded
- Support crews called and arrive
- Crews dispatched to county preposition locations (See Table 1, Page 6)

0 Hour

- Notify EMA, Area, Region that DOT operations active
- Begin surveillance

+1 Hour

- Notify region
- Begin reconnaissance of road conditions
- Monitor developing weather conditions with TV, department weather contractors and area weather stations
- Adjust de-icing activities
- Distribute SITREP to region and Montgomery
- Serve 2 hot meals and 1 bag lunch to crews as appropriate
- Repair equipment as needed

+24 Hours

- Clean and spray protectorant on all equipment
- Open and operate brine facility until all tanks have been topped off
- Reorder/redistribute liquid calcium, potassium Acetate and solid Calcium Magnesium Acetate

C. PROCEDURE ONE- 24-48 hour advance notice with existing below freezing temperatures between 20^{o} and 25^{o} F.

EXECUTION

-48 Hours

- Check fuel stocks-Order tank wagons if necessary
- Area Warehouse will obtain 3-day menu
- Brine manufacturing begins (If recent winter activity has prevented top off procedure)
- Each District will load 3 spreaders, 2 brine tank skids and 1 CMA/PA skid
- All plows will be mounted
- Notify all support personnel for alert in next 48 hours

-24 Hours

- Pre-treatment begins with 15% Liquid Calcium (Roadway Only)
- Brine tankers top off districts (If recent winter activity has prevented top off procedure)

-12 Hours

- Small crew left to remove all liquid skids, replace with spreaders and obtain food stocks from warehouse and store at district office
- Remaining crews sent home

-3 Hours

- Crews recalled granular salt loaded and abrasives for bridges
- Support crews called and arrive
- Crews dispatched to county preposition locations (See Table 1, Page 6)

0 Hour

- Notify EMA, Area, Region that DOT operations active
- Begin surveillance

+1 Hour

- Begin reconnaissance of road conditions
- Monitor developing weather conditions with TV, department weather contractors and area weather stations
- Adjust de-icing activities
- Field Operations distributes SITREP to region and Montgomery
- Serve 2 hot meals and 1 bag lunch to crews as appropriate
- Repair equipment as needed

+24 Hours

- Clean and spray protectorant on all equipment
- Open and operate brine facility until all tanks have been topped off
- Reorder/redistribute liquid calcium, potassium Acetate and solid Calcium magnesium Acetate

D. PROCEDURE TWO- Less than 24 hour notice with existing freezing temperatures between 20^{o} and 25^{o} F.

EXECUTION

-12 Hours

- Check fuel stocks-Order tank wagons if necessary
- Area Warehouse will obtain 3-day menu
- Brine manufacturing begins (If recent winter activity has prevented top off procedure)
- Each District will load 3 spreaders, 2 brine tank skids and 1 CMA/PA skid
- All plows will be mounted
- Notify all support personnel for alert in next 12 hours
- Pre-treatment begins with 15% Liquid Calcium (Roadway Only)

-6 Hours

- Small crew left to remove all liquid skids and replace with spreaders
- Remaining crews sent home

-1 Hour

- Crews recalled granular salt and abrasives for bridges loaded
- Support crews called and arrive
- Crews dispatched to county preposition locations (See Table 1, Page 6)

0 Hour

- Notify EMA, Area, Region that DOT operations active
- Begin surveillance

+1 Hour

- Begin reconnaissance of road conditions
- Monitor developing weather conditions with TV, department weather contractors and area weather stations
- Adjust de-icing activities
- Field Operations distributes SITREP to region and Montgomery
- Serve 2 hot meals and 1 bag lunch to crews as appropriate
- Repair equipment as needed

+24 Hours

- Clean and spray protectorant on all equipment
- Open and operate brine facility until all tanks have been topped off
- Reorder/redistribute liquid calcium, potassium Acetate and solid Calcium Magnesium Acetate

E. Existing extreme cold less than 20^{o} F with approaching cooler front.
ALDOT MANAGEMENT SHOULD CONSIDER RESTING IN PLACE

- Apply abrasives on roadways and bridges
- Apply PA to critical roadways and bridges

2. Weather Condition Two

Existing precipitation is overtopped by marginally freezing upper air.

This event starts with rain then typically changes to sleet then snow. It is presumed rain volumes will be high enough (more than 1/8th-inch per hour) that **pretreatment concentrations will not be effective**. The ALDOT management reaction to this condition should be driven by anticipated precipitation volumes. Presumably, ground temperatures allow for initial melting on contact with lower volume events of less than ½-inch per hour. Accumulation can occur at volumes exceeding ½ inch. This accumulation will begin on elevated structures and be characterized by a liquid interface with frozen accumulation on top. The removal by plowing of these accumulated materials should be the priority. Granular salt on roadways, once plowed, lower freezing points extending drying time for the remaining accumulation. Acetate products on bridges accomplish similar results.

ALDOT management reaction to the extended rain events of low volume should be approached with the protocol above. It however, should be repeated with attention to both ambient air, structure and ground temperatures. As ambient air temperatures fall, structure and ground temperatures should follow. Ambient temperatures should be considered when applying liquid deicers due to the potential of flash freezing.

During high volume events, plowing should be the first reaction followed by the protocol above.

B. PROCEDURE ONE- 24-48 hour advance notice and above freezing temps more than 25^{o} F.

EXECUTION

-48 Hours

- Check fuel stocks-Order tank wagons if necessary
- Area Warehouse will obtain 3-day menu
- Brine manufacturing begins (If recent winter activity has prevented top off procedure)
- Each District will load all spreaders and 1 CMA/PA skid
- All plows will be mounted
- Notify all support personnel for alert in next 48 hours

-12 Hours

- Small crew left to check spreaders and obtain food stocks from warehouse and store at district office
- Remaining crews sent home

-3 Hours

- Crews recalled granular salt loaded
- Support crews called and arrive
- Crews dispatched to county preposition locations (See Table 1, Page 6)

0 Hour

- Notify EMA, Area, Region that DOT operations active
- Begin surveillance

+1 Hour

- Begin reconnaissance of road conditions

- Monitor developing weather conditions with TV, department weather contractors and area weather stations
- Adjust de-icing activities
- Field Operations distributes SITREP to region and Montgomery
- Serve 2 hot meals and 1 bag lunch to crews as appropriate
- Repair equipment as needed

+24 Hours

- Clean and spray protectorant on all equipment
- Open and operate brine facility until all tanks have been topped off
- Reorder/redistribute liquid calcium, potassium Acetate and solid Calcium Magnesium Acetate

C. PROCEDURE TWO- Less than 24 hour notice with existing freezing temps more than 25^{o} F

EXECUTION

-12 Hours

- Check fuel stocks-Order tank wagons if necessary
- Area Warehouse will obtain 3-day menu
- Brine manufacturing begins (If recent winter activity has prevented top off procedure)
- Each District will load All spreaders and 1 CMA/PA skid
- All plows will be mounted
- Notify all support personnel for alert in next 12 hours

-6 Hours

- Small crew left to check spreaders and obtain menu supplies
- Remaining crews sent home

-1 Hour

- Crews recalled granular salt loaded
- Support crews called and arrive
- Crews dispatched to county preposition locations (See Table 1, Page 6)

0 Hour

- Notify EMA, Area, Region that DOT operations active
- Begin surveillance

+1 Hour

- Begin reconnaissance of road conditions
- Monitor developing weather conditions with TV, department weather contractors and area weather stations
- Adjust de-icing activities
- Field Operations distributes SITREP to region and Montgomery
- Serve 2 hot meals and 1 bag lunch to crews as appropriate

- Repair equipment as needed

+24 Hours

- Clean and spray protectorant on all equipment
- Open and operate brine facility until all tanks have been topped off
- Reorder/redistribute liquid calcium, potassium Acetate and solid Calcium Magnesium Acetate

D. PROCEDURE ONE-24-48 hour advance notice with existing below freezing 20^{o} to 25^{o} F.

EXECUTION

-48 Hours

- Check fuel stocks-Order tank wagons if necessary
- Area Warehouse will obtain 3-day menu
- Brine manufacturing begins (If recent winter activity has prevented top off procedure)
- Each District will load 3 spreaders, 2 brine tank skids and 1 CMA/PA skid
- All plows will be mounted
- Notify all support personnel for alert in next 48 hours

-12 Hours

- Small crew left to check spreaders and obtain food stocks from warehouse and store at district office
- Remaining crews sent home

-3 Hours

- Crews recalled granular salt loaded (Pre-wetting systems loaded)
- Support crews called and arrive
- Crews dispatched to county preposition locations (See Table 1, Page 6)

0 Hour

- Notify EMA, Area, Region that DOT operations active
- Begin surveillance

+1 Hour

- Begin reconnaissance of road conditions
- Monitor developing weather conditions with TV, department weather contractors and area weather stations
- Adjust de-icing activities
- Field Operations distributes SITREP to region and Montgomery
- Serve 2 hot meals and 1 bag lunch to crews as appropriate
- Repair equipment as needed

+24 Hours

- Clean and spray protectorant on all equipment
- Open and operate brine facility until all tanks have been topped off

- Reorder/redistribute liquid calcium, potassium Acetate and solid Calcium Magnesium Acetate

E. Existing extreme cold less than 20^{o} F with approaching cooler front.
ALDOT MANAGEMENT SHOULD CONSIDER RESTING IN PLACE
    - Apply abrasives on roadways and bridges
    - Apply PA to critical roadways and bridges

3. Weather Condition Three

Ambient air, structure and ground temperatures are all below freezing. A moist front producing precipitation traverses the area.

In all cases except extreme cold, condition 3 should be approached similarly to Condition 2. During extreme cold, this condition usually yields super-cooled surfaces and **flash freezing should be carefully considered**.

PRIORITIES

In general, priorities will not be changed from previous years (Table 6). When time is compressed for winter operations for uncertainty in the forecast or other reasons, single lane treatment is reflected in the Area priorities. This plan is based on the following criteria:

1. Interstates will be treated first for reasons stated earlier
2. Routes within city centers where access to medical facilities is involved.
3. US high volume routes
4. Urban state high volume routes
5. Rural state high volume routes
6. Rural state routes

Appendix C

Utah: Contract of Purchase of Potassium Acetate for Winter Maintenance: 2017

The following page is a pricing overview of a potassium acetate contract for UDOT, including prices and quantities.

Potassium Acetate Pricing Information

Attachment D
Pricing
Potassium Acetate

Location	Base Price		Base Price	
UDOT Provo Canyon Maintenance Shed 3741 E. Provo Canyon Orem, UT 84604	Delivered Price Per Gallon 500-Gallon Lot	**$6.00**	Delivered Price Per Gallon 4500-Gallon Truck Load	**$4.30**
Morgan Maintenance Station 476 N. Industrial Rd. Morgan, UT 84050	Delivered Price Per Gallon 500-Gallon Lot	**$6.00**	Delivered Price Per Gallon 4500-Gallon Truck Load	**$4.30**
I-84 milepost 90 Westbound West of Mountain Green, UT	Delivered Price Per Gallon 500-Gallon Lot	**$6.00**	Delivered Price Per Gallon 2500-Gallon Lot Delivered Price Per Gallon 4500-Gallon Lot	**$4.50** **$4.30**
Location	**Optional Price**		**Optional Price**	
UDOT Central Maintenance 4501 South 2700 West Salt Lake City, UT 84114	Delivered Price Per Gallon 500-Gallon Lot	**$6.00**	Delivered Price Per Gallon 4500-Gallon Truck Load	**$4.30**
FOB Origination -94 North 400 West North Salt Lake, Utah 84054	500-Gallon Lot	**$5.00**	4500-Gallon Truck Load	**$4.30**
Delivery Charge	500-Gallon Lot	$Prepaid and add per mile from Vendor Plant (FOB Origination)		
	4500-Gallon Truck Load	$Prepaid and add per mile from Vendor Plant (FOB Origination)		

APPENDIX C
PROCEDURE FOR GATHERING DATA

Procedure for Gathering Data

For Collection of Route/Truck Data

- https://www.webmdss.com/ (End of Shift Report & Detailed storm Report)
- MnDOT Bare Lane Reports

For Collection of Current/Past Weather Data

- https://www.webmdss.com/
- http://www.rwis.dot.state.mn.us
- https://www.ncdc.noaa.gov/cdo-web/datasets/LCD/stations/WBAN:14913/detail

General Information:

Trucks #: *217502, 215509, 214500, 212550 and 210500*

Routes ID:	Begin:	-	End:	Total Miles:	Total Lane Miles:
TP1D5351	*0.00*	-	*1.547*	*1.547*	*6.16*
TP1D0023	*263.085*	-	*264.089*	*1.004*	*4.016*
TP1D0354	*256.816*	-	*259.657*	*2.841*	*11.364*
TP1D1942	*13.569*	-	*16.00*	*2.431*	*9.724*

To complete a shift report for CTC:

1. Open Shift Reports Ver 8.0.xlsx (Current Version of CTC Shift Report)
2. Open MnDOT Bare lane report (Supplied by MnDOT Personnel)
3. Open webmdss.com
4. Utilize data from MnDOT Bare lane report to enter data into the Shift report Ver 8.0.xlsx.

   **Note that each shift report represents a specific truck and that each route number the truck was on corresponds with a separate sheet within the excel document.*
5. Run an "End of Shift Report" through maintenance reports in MDSS. Enter data obtained through this report such as truck number, route location and total material used on route into the Shift report Ver 8.0.xlsx.

6. With information gathered from the End of Shift Report, open a new session of MDSS in a separate tab/window. In this session of MDSS run a "Detailed Storm Report" to complete the following information needed on the Shift Report Ver 8.0.xlsx.
7. If weather information is not available through MDSS, utilize RWIS or NOAA (or other reputable sources) to complete the missing information for the excel document.
8. Name the file appropriately for easier referencing and submit the document.

Collect event begin and end times as well as roadway lost and regain times of routes:

After obtaining the bare lane report from MnDOT District 1

- Open the Excel document and locate the specific Project ID
  Project ID's to be used are: TP1D5351, TP1D0023, TP1D0354 and TP1D1942.
- The date of the event will be located at the top left corner of the document, followed by the Even Begin and End time, the time that bare lane was lost and also the time of regain and lastly the event type.

Nopeming Bare Lane Report										
1-6 & 1-7-19	*Bare Lane Lost?*	yes						*no >>>>>*	*Post Storm Meeting?*	
Project ID	**BEGIN**	**END**	**LOST**	**REGAIN**	**EVENT TYPE**	**TARGET**	**OPERATOR**	**MDSS Rec.**	**Actual App.**	**COMMENTS**
TP1D0391	9:30pm	11:00am	10:30pm	11:00am	snow,freezing rain, rain	4-9 Hours				
TP1D0231	9:30pm	11:00am	10:30pm	11:00am	snow,freezing rain, rain	4-9 Hours				
TP1D0355	9:30pm	11:00am	10:00pm	11:00am	snow,freezing rain, rain	0-3 Hours	V43,61	100	100-300	
TP1D0023	9:30pm	11:00am	10:30pm	11:00am	snow,freezing rain, rain	2-5 Hours				
TP1D0022	9:30pm	11:00am	10:00pm	11:00am	snow,freezing rain, rain	2-5 Hours				
TP1D0352	9:30pm	11:00am	10:00pm	11:00am	snow,freezing rain, rain	0-3 Hours				
TP1D0351	9:30pm	11:00am	10:30pm	11:00am	snow,freezing rain, rain	0-3 Hours				
TP1D0354	9:30pm	11:00am	10:30pm	11:00am	snow,freezing rain, rain	0-3 Hours				
TP1D0611	9:30pm	11:00am	10:30pm	11:00am	snow,freezing rain, rain	2-5 Hours				

With this report we can identify the following information about Project ID/Route ID TP1D0354:

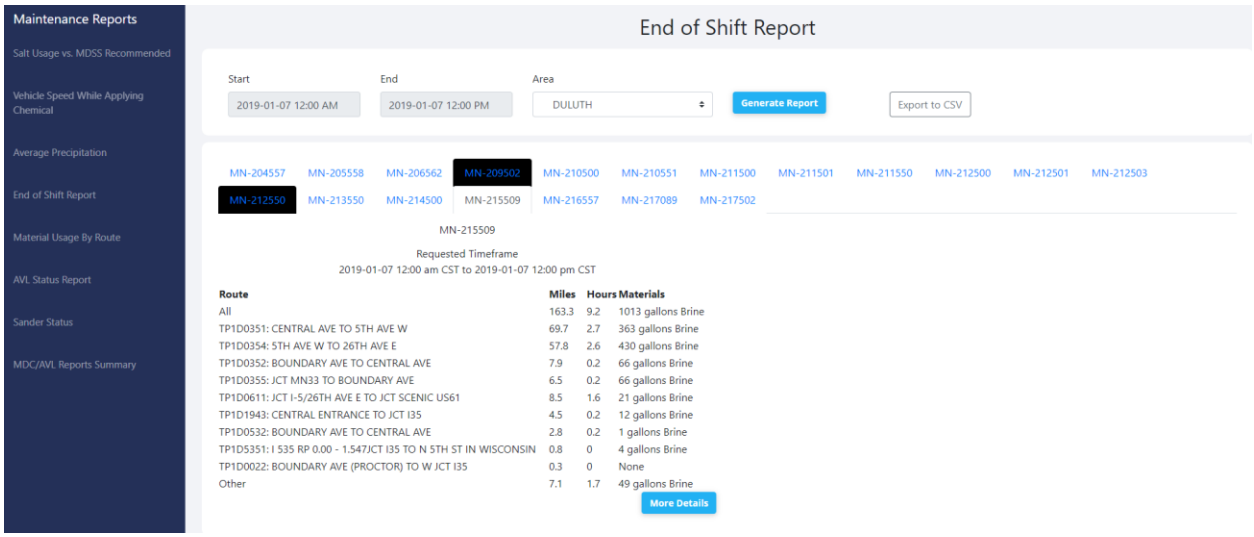
- *The event began at: 9:30 PM on 01-06-19*
- *The event ended at 11:00 AM on 01-07-19*
- *Bare lane was lost at 10:30 PM on 01-06-19*
- *Bare lane was regained at 11:00 AM on 01-07-19*

For information about total materials used during the Shift and or day.

- Open www.webmdss.com
- Select "tools" and then click on "Maintenance Reports"
- Under Maintenance reports, select "End of shift report" located on the left side of the website.
- Enter in the start date and end date, Select "Duluth" as the area, then generate the report. The report can be narrowed down further to "Nopeming" or "Pike Lake" as well.

After the report is generated you will be able to select a reporting truck within the Duluth area.

- After selecting a truck, the following information will be displayed:

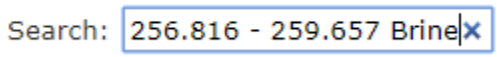


**By generating reports this way, you can more efficiently switch between trucks and total materials applied as well as type of material being applied which will be useful later. On 01-07-2019 truck # 215509 applied 430 gallons on route TP1D0354. By Clicking on truck # 217502, I can see that this specific truck applied 214 gallons on route TP1D5351 and 215 gallons on TP1D1942. Although the material is listed as "Brine", because these routes are within the study, they will only have Potassium Acetate.*

Because of the information obtained in the "End of Shift report", completing the "detailed storm report" will be easier**.**

<u>For information about material usage/application rate, weather conditions and temperature.</u>

- Open www.webmdss.com
- On the top navigation tools, highlight "tools", then select "AVL/MDC Tools"
- Select "Detailed Storm Report", Enter in your start date and time as well as your end date and time followed by the truck number. (Instead of scrolling through the truck list, start typing the truck number and then select it).
- Select "Generate Report"
- Since we are only looking at certain routes/mile points, utilize the search function to narrow the data down to pertinent information.
    - Under search enter "256.816 – 259.657" to display information for TP1D0354.
    - If you want to look at just times of application, further your search by entering "Brine" (or other chemical that the specific truck was applying) after your location.



- With the data narrowed down, we can tell that Truck 215509, on 01-07-2019 was applying at a rate of 20/gal ln mi on route TP1D0354.

Local Time	MDSS Segments	Direction	Speed (mph)	Plows Down	Applications	Weather Conditions	Road Conditions	Road Temp (°F)	Air Temp (°F)	Images	Local Time
1-08-19 9:53:11 AM CST	I35 - RP 256.816 - 259.657		37		Brine 20 gals / ln mi	snow		27			1-08-19 9:53:11 AM CST

**If there is no weather information or road condition on the "Detailed storm report", utilize other reputable sources to obtain conditions. Some options to consider are other trucks reporting weather/road conditions, NOAA and RWIS.*

How to access past weather data utilizing www.rwis.dot.state.mn.us:

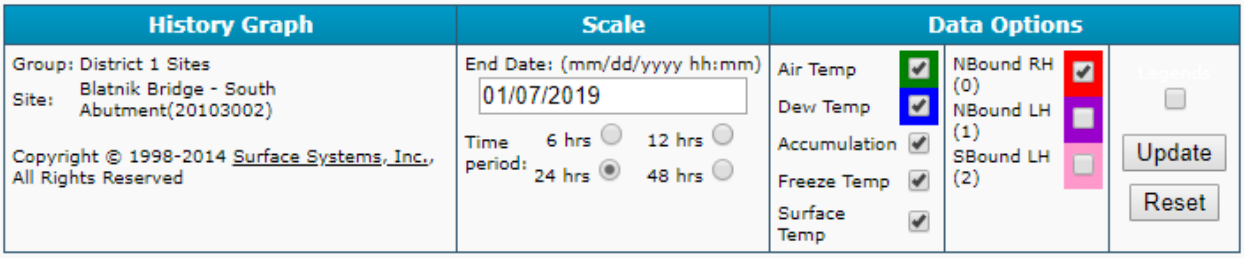
(This is location based data, not route/truck based)

- From the main homepage on the map, click on St. Louis County (1).
- The District 1 Sites page will allow the user to see current conditions of RWIS locations throughout District 1. Locate the area that you would like to view past data. (Ex: Blatnik Bridge – South Abutment NBound RH") Click on History.

District 1 Sites (3)
Site Summary Page
(Selected surface sensor may change based on conditions)
Current Time: 04/18/2019 07:24 CDT

Status	Sfc	Sub	Air	RH	Dew	BaroPs	Precip	Intens	Rate	Vis	SpdAvg	DirAvg	
-	Bigfork Municipal Airport (20101057)							04/18/2019 07:13 (CDT)					History
	-	-	37F	100%	37F	28.4 in	-	-	-	9.9 mi	Calm	N	
Dry	Blatnik Bridge - Pier 20 - Pier 20 SB (20103001.1)							04/18/2019 07:20 (CDT)					History
	39.0F	-	41F	80%	35F	-	Yes	-	-	-	4 mph	NW	
Dry	Blatnik Bridge - South Abutment - NBound RH (20103002.0)							04/18/2019 07:20 (CDT)					History
	39.2F	-	41F	80%	35F	-	None	None	0.0 iph	1.2 mi	Calm	NW	

- On the bottom of the VAISALA/Scan Web webpage that loads, Under the "Scale" tool, Select the date that you would like to view (Hours are optional, but will default to 00:00 if not selected), and the time period that you want to cover. (Ex: 24 Hrs.)
- Under Data Options, Select the atmospheric conditions that you want to display, Air Temp, Dew Temp, Accumulation, Freeze Temp, Surface temp. After your scale date range and data options are selected, click update.



- After selecting update, at the top of the page, select "Precip Table". When the first graph loads, select "Surface/ Atmospheric History" at the top. This will give your Precipitation Type, Wind Speed, Air temp, and surface pavement temperatures and conditions.

District 1 Sites
Blatnik Bridge - South Abutment - NBound RH (20103002.0)
Surface/Atmospheric History

01/06/2019 00:00 to 1/7/2019 00:00

Surface/Precip. History | Surface History Graph | Atmospheric History | Precip. History | Export

Change End Date: 1/7/2019 00:00 Go <-- -->

Date/Time (CDT)	Surface				Air			Wind			Precip	
	Status	Sfc	Pvt	Sub	Air	RH	Dew	Avg	Gust	Dir	Type	Intens
01/06/2019 23:45	Snow Watch	28.8F	28.9F	-	30F	-	-	14 mph	18 mph	NE	Snow	Slight
01/06/2019 23:40	Snow Watch	28.6F	28.9F	-	30F	-	-	13 mph	16 mph	NE	Snow	Slight
01/06/2019 23:35	Snow Watch	28.8F	28.9F	-	30F	95%	29F	13 mph	19 mph	NE	Snow	Slight
01/06/2019 23:30	Snow Watch	28.6F	28.8F	-	30F	87%	27F	16 mph	23 mph	NE	Snow	Slight
01/06/2019 23:25	Snow Watch	28.6F	28.9F	-	30F	92%	28F	15 mph	20 mph	NE	Snow	Slight
01/06/2019 23:20	Snow Watch	28.6F	28.9F	-	30F	91%	28F	12 mph	17 mph	NE	Snow	Slight
01/06/2019 23:15	Trace Moisture	28.6F	28.9F	-	30F	83%	26F	15 mph	20 mph	NE	Snow	Slight
01/06/2019 23:10	Trace Moisture	28.4F	28.9F	-	30F	88%	27F	17 mph	22 mph	NE	Snow	Slight
01/06/2019 23:05	Trace Moisture	28.2F	28.9F	-	31F	-	-	14 mph	18 mph	NE	Snow	Slight
01/06/2019 23:01	Trace Moisture	28.8F	28.9F	-	31F	-	-	12 mph	17 mph	NE	Snow	Slight
01/06/2019 22:55	Trace Moisture	28.6F	28.9F	-	31F	85%	27F	14 mph	17 mph	NE	Snow	Slight

Complete Shift Report Ver8.0.xlsx

APPENDIX D
SHIFT REPORT

SHIFT REPORT Main / Route 1

Require Manual Data Entry

Multiple Reports Multiple Routes/Shift

Date
Start Time
End Time

Truck Station

Equipment Number

Route Number(s)
Route 1
Route 2
Route 3
Route 4

Number of Laps During Shift

OBSERVATIONS DURING SHIFTS

	Start of Shift	Middle of Shift	End of Shift
Time			
Air Temp °F			
Pave Temp °F			
Weather Conditions			
% Bare Pavement			
Road Conditions			

OBSERVATIONS DURING KAC APPLICATIONS

Time of Application			
Applied KAc Full Route			
Applied KAc Partial Route			
Partial Route Location(s)			
Application Rate - KAc (gal/lm)			
Application Rate KAc/Antiskid (lb/lm)			
Location 1			
Location 2			
Location 3			

BARE LANE REGAINED DURING THIS SHIFT

(Date) (Time)

Date and Time Storm Started
Date and Time Storm Ended
Date and Time Bare Lane was Lost
Date and Time Regain was Completed

TOTAL KAC MATERIALS APPLIED

KAC Applied (gals)
KAc/Antiskid Mix Applied (lbs)
KAc mixed with Antiskid (Gal/Ton)

PRECIPITATION REPORT

Type of Precipitation
Rate of Accumulation (in/hr)
Accumulated Precipitation (In)

AVERAGE WEATHER DATA OVER SHIFT TIME

Wind Speed (mph)
Wind Direction
Relative Humidity(%)
Dew Point °F

How did the storm arrive?

How did the storm end?

Comments

APPENDIX E
STORM EVALUATION

12-26-18 AM | 12 AM -12 PM

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Bong 023				X		1													48								
Start of Shift							12:00 AM	23	21	No Precipitation	100	Dry	3:39 AM	yes			15							9	W	79	14
Mid Shift							6:00 AM	18	19	No Precipitation	100	Dry													W		
End of Shift							12:00 PM	21	25	No Precipitation	100	Dry													W		

Dawn Patrol Applied material

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Tunnels 0354				X		1													10								
Start of Shift							12:00 AM	23	21	No Precipitation	100	Dry	3:18 AM	No	Yes		15							9	W	79	14
Mid Shift							6:00 AM	18	19	No Precipitation	100	Dry													W		
End of Shift							12:00 PM	21	25	No Precipitation	100	Dry													W		

Dawn Patrol applied material

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Central 1942																											
Start of Shift																											
Mid Shift																											
End of Shift																											

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Blatnick 5351				X		1													69								
Start of Shift							12:00 AM	23	21	No Precipitation	100	Dry	3:04 AM	Yes			15							9	W	79	14
Mid Shift							6:00 AM	18	19	No Precipitation	100	Dry													W		
End of Shift							12:00 PM	21	25	No Precipitation	100	Dry													W		

Storm arrived later in day. Dawn Patrol used material to spray bridge decks for frost possibility. Looks like one pass was made NW down centerline at 15 Gal/lm and one pass was made SE down centerline at 15 Gal/lm. Bare lane was not lost-no event yet.

Regain Times from Business Intellegence Report

TP1D0023 Bong Bridge			
Date and Time Storm Started	12/27/2018	12:00	AM
Date and Time Storm Ended	12/28/2018	5:00	AM
Date and Time Bare Lane was Lost	12/27/2018	12:30	AM
Date and Time Regain was Completed	12/28/2018	9:00	AM

TP1D0354 Tunnels			
Date and Time Storm Started	12/27/2018	23:00	AM
Date and Time Storm Ended	12/28/2018	5:00	AM
Date and Time Bare Lane was Lost	12/27/2018	1:00	AM
Date and Time Regain was Completed	12/28/2018	9:00	AM

TP1D1942 Central			
Date and Time Storm Started	12/26/2018	11:00	PM
Date and Time Storm Ended	12/28/2018	6:00	AM
Date and Time Bare Lane was Lost	12/27/2018	12:00	AM
Date and Time Regain was Completed	12/30/2018	9:00	PM

TP1D5351 Blatnik Bridge			
Date and Time Storm Started	12/26/2018	11:00	PM
Date and Time Storm Ended	12/28/2018	6:00	AM
Date and Time Bare Lane was Lost	12/27/2018	12:00	AM
Date and Time Regain was Completed	12/30/2018	12:00	PM

12-27-18 AM | 12 AM -12 PM

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Bong 023		X				29														19079							
Start of Shift							12:00 AM	29	27	Snow		Dry	2:47 AM	Yes				400			Snow	0.28	11.82	9.6	NNE	93.91	28.66
Mid Shift							6:00 AM	30	29	Snow		Dry	4:14 AM	Yes				400									
End of Shift							12:00 PM	33	32	Rain/Snow Mix		Wet	9:13AM	Yes				400									

Total Precip by end of storm: 11.82". MDSS is reporting 74 units unrecognized for material usage in addition to the 9.54 Tons of "sand". Multiple Applications, only listed 3

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Tunnels 0354				X		7													110								
Start of Shift							12:00 AM	31	27	Snow		Dry	7:36 AM	Yes			25				Snow	0.38	11	14.91	NE	90.75	29.33
Mid Shift							6:00 AM	33	29	Rain/Snow Mix		Compacted Snow															
End of Shift							12:00 PM	34	32	Rain/Snow Mix		Wet															

Total Precip accumulated by end of storm : 10.95"

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Central 1942			X			2														1251							
Start of Shift							1:30 AM	27	28	Snowing & Blowing	50	Blowing Snow	6:44 AM	Yes				300 to 700			Snow	0.3	13.07	14	NE	93	29
Mid Shift																											
End of Shift																											

Second application: Made one loop applying 200 lbs l/m, followed by second loop applying 300 lbs l/m.

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Blatnick 5351			X			10														5751							
Start of Shift							1:30 AM	27	28	Snowing & Blowing	50	Blowing Snow	3:00 AM	Yes				40			Snow	0.3	11.5	15	NE	93	29
Mid Shift							6:00 AM	32	30	Snowing & Blowing	0	Snow	4:44 AM	Yes				200 & 300									
End of Shift							12:00 PM	34	32	Snowing & Blowing	0	Snow	7:38 AM	Yes				200 & 300									

Total Precip accumulated by end of storm: 11.53". Second application: Made one loop applying 200 lbs l/m, followed by second loop applying 300 lbs l/m.

12-27-18 PM | 12 PM -12AM

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Bong 023																											
Start of Shift																											
Mid Shift																											
End of Shift																											

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Tunnels 0354	X					9.8														2312							
Start of Shift							1:26 PM	33	29	Snow		Wet															
Mid Shift							5:00 PM	34	30	Rain/Snow Mix		Wet															
End of Shift							10:19 PM	33	28	Rain/Snow Mix		Slush	10:19	Yes				600									

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Central 1942			X			10														18100							
Start of Shift							12PM	32	33	Snow	0	Compacted Snow	2:41 PM	Yes				300			Snow	0.38	13.07	9.75	NNW	95	31
Mid Shift							6PM	32	33	Snow	0	Compacted Snow	6:12	Yes				400									
End of Shift							12:00 AM	31	31	Snow	0	Compacted Snow	10:44 PM	Yes				800									

Wind switches from NNE to N at 5pm then to NNW at 8PM. Wind speed starts at 12 mph, then slowly decreases throughout the afternoon to 7 mph then increases around 11 pm back into 10-14 mph. Snow accumulation by end of storm: 13.07"

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Blatnick 5351			X			3														5796							
Start of Shift							12:00 PM	32	33	Snow	0	Compacted Snow	7:45 PM	Yes				500-700			Snow	0.3	11.53	9.5	NNW	96	32
Mid Shift							6PM	32	33	Snow	0	Compacted Snow															
End of Shift							12:00 AM	31	31	Snow	0	Compacted Snow															

Total snow accumulation by end of storm 11.53". Wind direction was NNE until 3pm then switched to N and then to NNW after a few hours. Application: 1 pass going SE then NW at 700 lbs/lm then 1 pass going SE and then NW at 500 lbs/lm

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Blatnick 5351					X	21														5796							
Start of Shift							12:00 PM	33	33	Snow		Wet						500-700			Snow	0.3	11.53	9.5	NNW	96	32
Mid Shift							6PM	32	33	Snow	0	Compacted Snow															
End of Shift							12:00 AM	31	31	Snow	0	Compacted Snow	11:01 PM														

Total snow accumulation by end of storm 11.53". NE wind switching to NW around 6PM. Only 1 application of material

12-28-2018 AM | 12 AM -12PM

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Bong 023				X		5													791								
Start of Shift							12:00 AM	30	30	Snow		Compacted Snow	3:51 AM	Yes			40				Snow	0.1	11.82	6.25	WNW	85.25	17.08
Mid Shift							6:00 AM	19	22	Snow		Compacted Snow	6:26 AM	Yes			40										
End of Shift							12:00 PM	15	21	Snow		Compacted Snow															

Total accumulation by end of storm: 11.82"

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Tunnels 0354				X		3													335								
Start of Shift							12:00 AM	31	31	No Precipitation		Compacted Snow	2:44 AM	Yes			40				Snow	0.06	11	8	NW	82.25	17.58
Mid Shift							6:00 AM	21	23	Snow		Compacted Snow															
End of Shift							12:00 PM	16	22	No Precipitation		Compacted Snow															

total accumulation by end of storm: 10.95"

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Tunnels 0354	X					4.4														23011							
Start of Shift							2:32 AM	26	24	Snowing & Blowing		Blowing Snow	3:15 AM	Yes				600									
Mid Shift							6:28 AM	21	18	Snowing & Blowing		Blowing Snow	6:28 AM	Yes				600									
End of Shift							10:39 AM	18	17				9:26	Yes				600									

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Central 1942					X	4													863								
Start of Shift							12:00 AM	29	29	Rain/Snow Mix		Compacted Snow	3:33 AM	Yes			40				Snow	0.08	13.07	9.8	NW	83.25	15.41
Mid Shift							6:00 AM	18	21	Snow		Compacted Snow	5:07	Yes			40										
End of Shift							12:00 PM	14	21	Snow		Compacted Snow	9:54 AM	Yes			40										

Total precip by end of storm: 13.07". wind gusts15-25 mph throughout shift

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Central 1942			X			3														4515							
Start of Shift							12:00 AM	29	28	Snow		Compacted Snow	3:34 AM	Yes				400			Snow	0.1	13.07	14.8	NNW	83	15.08
Mid Shift							6:00 AM	21	20	Snowing & Blowing		Compacted Snow	4:47	Yes	Yes			300-500									
End of Shift							12:00 PM	12	17	Snowing & Blowing		Compacted Snow	9:55 AM	Yes				50									

Parital Route* Only 1 pass in each direction. Total accumulation at end of storm 13.07".

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gal/lm	Total lb/lm	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Blatnick 5351			X			9														9997							
Start of Shift							12:00 AM	29	28	Snow		Compacted Snow	2:50 AM	Yes				400-500			Snow	0.1	11.5	8	NW	83.66	17.66
Mid Shift							6:00 AM	21	20	Snowing & Blowing		Compacted Snow	7:15 AM	Yes				500-1000									
End of Shift							12:00 PM	12	17	Snowing & Blowing		Compacted Snow	8:44 AM	Yes				20-50									

Total snow accumulation by end of storm: 11.53"

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Blatnick 5351					X	9														541							
Start of Shift							12:00 AM	31	30	Snow		Compacted Snow	2:50 AM	Yes			30				Snow	0.1	11.5	8.08	NW	83.66	17.66
Mid Shift							6:00 AM	20	20	Snow		Ice	4:28 AM	Yes			30										
End of Shift							12:00 PM	16	22	Snow		Ice	8:34 AM	Yes			30										

Total snow accumulation by end of storm: 11.53". wind gusts were between 15-25 mph

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Blatnick 5351	X					2														2785							
Start of Shift							3:48 AM	26	21	Snowing & Blowing		Blowing Snow															
Mid Shift							8:43 AM	17	13			Compacted Snow	7:43 AM	Yes				600									
End of Shift							9:08 AM	17	15			Compacted Snow	9:02 AM	Yes				800									

12-28-2018 PM | 12 PM -12AM

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Bong 023					X	4													506								
Start of Shift							12:00 PM	15	21	Snow		Compacted Snow	2:25 PM	Yes			30				Snow	0.006	11.82	4.4	WNW	78	2
Mid Shift							6:00 PM	6	10	No Precipitation		Compacted Snow	5:13 PM	Yes			30										
End of Shift							12:00 AM	-1	4	No Precipitation		Compacted Snow															

Total precip accumulation by end of storm: 11.82"

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Tunnels 0354					X	1													127								
Start of Shift							12:00 PM	16	22	Snow		Compacted Snow	1:19 PM	Yes			20						10.95	5.33	WNW	74.58	3.83
Mid Shift							6:00 PM	9	11	No Precipitation		Compacted Snow															
End of Shift							12:00 AM	5	6	No Precipitation		Compacted Snow															

total precip accumulation by end of storm: 10.95"

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Central 1942					X	2													153								
Start of Shift							12:00 PM	14	21	Snow		Compacted Snow	10:23 PM	Yes			20						13.07	5.83	NW	75.83	1
Mid Shift							6:00 PM	6	10	No Precipitation		Compacted Snow															
End of Shift							12:00 AM	-1	4	No Precipitation		Compacted Snow															

Total precip accumulation by end of storm: 13.07". end of snow, temps dropped.

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Central 1942			X			6														23155							
Start of Shift							12:00 PM	14	21	Blowing Snow		Compacted Snow	3:21 PM	Yes				1000				0	13.07	5.8	NW	75	-1
Mid Shift							6:00 PM	6	10	No Precipitation		Compacted Snow	5:24 PM	Yes				1000									
End of Shift							12:00 AM	-1	4	No Precipitation		Compacted Snow	10:23 PM	Yes				600									

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Blatnick 5351			X			8														16148							
Start of Shift							12:00 PM	16	22	Blowing Snow		Ice	1:28 PM	Yes				500				0	11.53	5	WNW	75.75	3.25
Mid Shift							6:00 PM	8	10	No Precipitation		Compacted Snow	4:51 PM	Yes				1000									
End of Shift							12:00 AM	3	5	No Precipitation		Compacted Snow	8:38 PM	Yes				300									

Total snow accumulation by end of storm: 11.53"

Route	210500 Sand	212550 Sand/Spray	214500 Sand	215509 Spray	217502 Spray	Laps	Shift Time	Air Temp	Road Temp	Weather Condition	% Bare Pavement	Road Condition	Time of Appl.	App. Full Route	App. Partial Rte.	Partial Rte Loc.	Rate gal/lm	Rate lb/lm	Total gals	Total lbs	Type of Precip	Rate of Accumulation	Accumulated Precipitation	Wind Speed	Wind Direction	Rel Humd	Dew Pt
Blatnick 5351					X	7													613								
Start of Shift							12:00 PM	16	22	Snow		Compacted Snow	2:01 PM	Yes			30						11.5	5.75	WNW	82	4
Mid Shift							6:00 PM	8	10	No Precipitation		Compacted Snow	4:59 PM	Yes			20-30										
End of Shift							12:00 AM	3	5	No Precipitation		Compacted Snow	9:15 PM	Yes			20										

total precip by end of storm: 11.53"

APPENDIX F
OPERATOR INTERVIEWS

MnDOT Contract No. 1030820
District 1 Alternative De-Icing Chemical - Potassium Acetate

Experiences of Winter Maintenance Operators on the Use of Liquid Potassium Acetate in the Duluth Sub Area for the Winter of 2018-2019

The project investigators facilitated interview sessions with winter maintenance operators at MnDOT District 1's Pike Lake and Nopeming locations on July 15, 2019, to learn about procedures for using liquid potassium acetate (KAc) for snow and ice removal in the Duluth sub area. The use of KAc was in the first year of implementation with the Pike Lake crews and in the second year with the Nopeming crews.

The winter maintenance operators from the two locations were divided into separate interview groups to provide their experiences with the use of liquid KAc.

- Summary findings are presented in the report, *Assessing the Effectiveness of Potassium Acetate to Control Snow and Ice on Minnesota Highways*.
- This Appendix presents detailed comments and questions-and-answers captured during these sessions.

Detailed Comments and Questions-and-Answers

Operators and Routes
Operators from Pike Lake treated the routes of Blatnik Bridge (TP1D5351) and Central (TP1D1942), while operators from Nopeming treated the routes of Bong Bridge (TP1D0023) and the Tunnels (TP1D0354).

Equipment
Listed below are the equipment vehicle numbers used for the application of KAc on the designated project routes and a brief description of the equipment and their capacity for solid and liquid application.

- Nopeming Shed Trucks - 210500, 212550, 215509.
- Pike Lake Shed Trucks - 214500, 217502.
    - 210500 and 214500 are auger equipped sanders with a 6-ton capacity.
    - 215509 and 217502 are spray trucks with 1300 gallons capacity, stream or cone spray. Max application rate of 50 gal/lane mile.
    - 212550 is a sander/spray combo truck, 1100-gallon capacity, 5-6 tons sand, stream or cone spray patterns. Max application rates of 1000 lb/lane mile and 50 gal/lane mile.
- Equipment numbers with 500-549 are single axle vehicles, 550+ are tandem axles.
- All trucks are equipped with a single plow.

General discussion (storm description, training, experiences, and practices) based on interviews with both groups of operators.

- How does a storm typically start on this section of roadway?
    - Snow events typically move in from the lake traveling in an east to west direction.
    - Weather conditions vary from the waterfront areas to the higher elevations of the sub area.
    - Lake effect conditions are prevalent with higher moisture content within the snow.
- When does the snow removal process begin?

    - Plowing begins when snow is accumulating on the roadway.
- When are shifts called into service?
    - It depends on snow accumulation.
    - Truck operators and supervisors are in contact with each other and are continuously relaying the conditions of the road during the shifts.
    - Dawn patrol and afternoon shift can make applications and determine when to call out additional operators.
- Who judges when the bare lane is lost, and how is it reported?
    - Operators and the dawn and afternoon patrols call in to make reports on the road conditions and will report when bare lane is lost.
- Describe how snow removal practices begin, including plowing techniques, patterns, and application of materials.
    - Single front-end plows are utilized within the area.
    - Operators begin removal of the snow plowing from the left side to the right side of the highway.
    - Gang plowing is used to clear the roadways as the snow rates elevate.
    - Snow is plowed to the edge of the roadway, where it is later removed using loaders, snow blowers and trucks.
    - Spray equipment applications are typically applied at 20 gal/lm. Equipment has the capacity to apply up to 50 gal/lm. The maximum typically used was 40 gal/lm.
    - Applications are made with streamer tubes.
    - Sanders can apply at maximum of 1000-1200 lb/lm and are also equipped with a 150-gallon saddle tank. Gravity feed into the sanders.
    - Treated sand is typically a 9% mix of liquid KAc to sand. Tried a 7% mix and determined it was not effective. That pretreated sand was then additionally pre-wetted at a rate of 150 gallons per 6 tons of pretreated sand from the saddle tanks.
    - Treated sand applied at 300-400 lb/lm is typical in 25 °F weather; 600-700 lb/lm is applied in colder weather.
    - Just-in-time application of the liquid KAc was being experimented with by one of the crews: 20 gal/lm application of the liquid KAc just prior to the storm beginning. The application resulted in the road being regained quicker and with less chemical than areas where the practice was not being used.
    - With compaction already on the road, crews experimented with a narrow pattern of granular salt application right down the skip-stripe at 600 lb/lm. This was then followed up with a mini spray bar (concentrated pattern) of KAc at 30 gal/lm (both solid and liquid applications were done at vehicle speeds of 20 mph). Doing this causes the KAc to adhere the salt to the roadway creating a sandpaper-like surface. Shift temperature started out at 10 degrees above and ended at 12 below. By the time the weather warmed up again the next day, the roads were about 90% clear, which freed up equipment that would normally be applying material to haul snow. This experiment was conducted on less critical routes west of the district.
- Who judges when the bare lane is regained, who and how is it reported?
    - Dawn and afternoon patrols.
    - Operators on patrol call in at the time that bare lane is regained on roadway sections.
- How much KAc was used this winter season?
    - 6 tankers at 4,400 gallons per tanker. About 6,000 gallons are currently left. Therefore, about 20,400 gallons were used.

Training

- What level of training have operators received with the use of deicer chemicals including KAc?
    - Basic training through MnDOT's Snowplow Operating Program (SPOT). Depends when an employee is hired to what amount and level of training can be achieved.
    - No specific training with the KAc product.
    - Would encourage more training with specific products. Additional education on the chemicals and handling practices would be welcome.
    - Experience primarily gained through on-the-job training.
- Did training include any do's or don'ts?
    - Only what was observed and communicated to other operators during a storm event, and at the end of storm meetings.
- Is on-the-job training included?
    - Yes, this was the primary method for training on snow removal practices and the use of chemicals.

Experiences

- Do the operators have experience using other deicing materials such as liquid sodium chloride (brine), magnesium chloride, calcium chloride, solid sodium chloride, pretreated solid sodium chloride or antiskid? Any other materials or chemicals?
    - Liquid sodium chloride has been used by most of the operators.
    - Most operators have experience with solid sodium chloride through direct application and with it added to sanding material. Solid salt is typically prewet with salt brine at the spinner and is MnDOT's most common practice.
    - Would use 10-12% salt mixed with sand. Operator can increase the mix depending upon the conditions of the roadway.
    - A few operators have had experience with liquid magnesium chloride and liquid calcium chloride several years ago.
    - KAc is new to the sub area with this being the first year it was used in Pike Lake and second year for Nopeming.
    - Ten gallons of liquid KAc added per ton of dry sand on the stockpile in the shed.
- What application rates and experiences can you share with the use of each of these materials, assuming 25 °F (temperatures dropping to zero) and compacted snow on ground?
    - Liquid sodium chloride (brine): Do not have good control on flow rate, was set by a ball valve position.
    - Increased application rates with liquid salt brine. Don't apply on compacted snow. Better luck with applying the material in each lane and not down the centerline.
    - Solid salt applied at 200 lb/lm on asphalt on a well scraped down roadway and 350-500 lb/lm on concrete. Applications depended upon conditions and typically range from 200-500 lb/lm.
    - If using KAc, then apply at 20-30 gal/lm and up to 50 gal/lm. Use the traffic to help burn off the snow and ice.
    - Sand, pretreated with liquid KAc, should be applied at about 450 lb/lm.
    - Do not plow off the materials to soon. Let the material work on the road and not on the edge of the road.
- For cold temperatures, does the application rate increase?
    - Yes. Salt has been increased at colder temperatures. Typically used in salt-sand mixes.

- 40-50 gal/lm of liquid KAc in conjunction with a 50/50 mix of salt and sand used at 600-800 lb/lm was very effective in removing compacted snow or ice at cold temperatures.
- Used 9% KAc treated sand rather than 10% treated sand. 10% mixture caused the KAc to leach out of the sand. Effectiveness of using the 9% was essentially the same as the 10% material.
- Can apply additional KAc to the treated sand at the spinner head, if required, from KAc in the saddle tanks of the sanders.
- Slurry mix of KAc and sand was not satisfactory. Adopted the current methods after the initial slurry mix trials were unsuccessful. Applied spray bars to trucks to apply the liquid onto the sand on the roadway to replicate the slurry mix. Recommend not less than 30 gal/lm application.
- Traffic at lower temperatures helps move the material around and results in clearing the roadway quicker.
- Application of the pretreated sanding material was made, followed by the liquid KAc truck applying liquid at up to 40 gal/lm. Applications were typically made on the center line rather than in the travel lanes, allowing the material to move on the traffic lanes better and not migrate off the shoulder of the road.
- 600 lb/lm of solid salt followed by an application of 30-40 gal/lm of KAc was found to work considerably faster at -10 °F for clearing the roadway.
  - This application appeared to fuse to the road and provided additional protection for several days. Provided a longer lasting chemical application than other methods.

- How would you compare the use of potassium acetate to other liquid chemicals for effectively clearing the roadway during winter conditions?
  - Extended cold Temperatures?
    - Crews work toward achieving regain prior to cold temperatures setting in and creating a denser compacted ice or snow with the use of KAc. However, if temperatures drop before regain has been achieved, crews have successfully used KAc with treated sand in clearing the roadway for regain. Especially in trouble spots or in case of emergencies.
    - KAc was better than salt.
  - As a pretreatment to antiskid?
    - Works well.
  - Frost control?
    - Works extremely well. Able to hold the road frost free for three to five days.
    - KAc had a better longevity than both salt brine and magnesium chloride.
- Is there a positive experience you can relate regarding the use of potassium acetate over other deicers?
  - Focused on using a minimum amount of material for maximum effectiveness.
  - Time to bare lane regain using a standard application rate of 15-25 gal/lm applied after plowing and at different temperatures resulted in the following:
    - 1 hour until wet and regained at temperatures from 10 °F to 32 °F,
    - 2 hours until wet and regained at temperatures of 0 °F to 10 °F,
    - Several hours until regain at temperatures below zero.
  - Able to use the material on the centerline for maximum effectiveness across both lanes of traffic.
  - Liquid application prior to snow accumulating on the roadway provided satisfactory results and early regain periods.

    - KAc should be considered when the goal is to reduce the amount of salt being used.
    - KAc mixed with salt was felt to be three times quicker than solid calcium chloride at melting snow and ice.
    - More environmentally compliant (friendly).
- Is there a negative experience you can relate regarding the use of potassium acetate over other deicers?
    - Experienced slime and building of slick roads with high application rates or multiple applications, especially on snow-compacted roads. (Related that the material turned fuzzy in appearance, possible freezing)
    - Using KAc during the storm caused denser compaction of snow and ice onto the roadway which resulted in more plowing to regain the roadway.
    - With the Blatnik Bridge at temperatures below zero in the morning, a KAc application resulted in no traction. Continued to add KAc, which resulted in no improvement, and actually made the road worse. Be very careful with over-applications.
    - Need to focus on the minimum amount of material to use in an application.
    - More difficulty with hauling the snow away after KAc application. The snow becomes denser and increases the strain on the snow blowers. This likely increased the amount of equipment failures this last year.
    - The snow and ice in the tunnels became like icebergs being set up as hard as concrete paste.
- For potassium acetate, what are the most frequent application rates for liquid, pretreated antiskid materials, or both materials used in combination?
    - Straight liquid application rates are 15-25 gal/lm, most frequent is 20 gal/lm, 25-50 gal/lm being used as needed for spotting and final clearance applications.
    - Pretreated antiskid using a 9% KAc, 300-500 lb/lm, with 600 to 1000 lb/lm in trouble spots.
- Describe your experience in increasing or decreasing an application rate?
    - Did not increase above the 50 gal/lm application rates.
    - No experience increasing rates at below zero temperatures.
    - Understanding the eutectic curve better would help in understanding the physical characteristics and effective use of the material.
    - Limits were established for the maximum and minimum amounts of KAc that could be used on an application.
- Describe your experience in the use of a higher percentage mix of potassium acetate in the antiskid?
    - Higher percentages of KAc in the pretreated sand mix allowed the KAc to leach out of the material.
- Describe your experience in varying the timing of an application of material?
    - Making just-in-time applications was experimented with and showed that regain times could be achieved faster.
    - No other varying of the time was made.
- Does a variation in application rate or time of application require authorization from the Supervisor?
    - No.
- Can the variation be made by the operator while on the roadway?
    - Yes, application rates are determined by the operator depending upon conditions and operator experience.

- Describe your successes or failures when an application rate or timing has been varied.
    - Just-in-time was successful.
    - Increasing application rates or frequency of applications in certain weather conditions can create a slick road.
- Based on your experience as an operator, please describe the most effective time(s) to make an application of potassium acetate to the roadway.
    - Just-in-time application at the start of a storm.
    - At the end of the storm, while temperature conditions are favorable, without additional snow accumulation.
    - Quicker melting times achieved with the use of salt.

Practices

Provide application rates for the following conditions using liquid only, pretreated antiskid, liquid and pretreated antiskid in combination, or other:

- Before the storm as an anti-icing practice?
    - One area does not employ the practice with any chemical, except for frost prevention on the bridges.
    - Second area used 20 gal/lm in a just-in-time practice to reduce the bond of the snow and ice to the pavement surface.
- During the storm event while continuing to plow?
    - Continue to plow until the end of the storm and no further snow accumulation.
- At the end of the storm with compacted snow on the roadway?
    - Apply 9% treated sand, 300 to 600 lb/lm.
- Temperatures dropping and compacted snow on the roadway?
    - Continue to plow.
    - No increase in application rates or additional pretreated sand used above previous ranges.
- Frost control?
    - Liquid applications of KAc, 20 gal/lm was typical. Note: 15 gal/lm applied down the center line has shown to be effective. Without additional moisture in the form of snow or rain, one liquid KAc application would prevent road frost for 3-5 days.
- Extended cold temperatures?
    - No, unless there is an emergency, then treat with pretreated sand.
    - Continue to treat trouble spots as needed with pretreated sand.
- Roadway showing patches of compacted snow and the temperature dropping below zero?
    - No, unless an emergency, and then apply pretreated sand.
- All granular materials are applied down the skip-stripe.

Observations or Recommendations

Is there any other information related to the use of potassium acetate as a liquid or a pretreatment to antiskid that you feel is valuable to share?

- Encourage the continued use of KAc as a tool in the toolbox.
- Need more evaluation of KAc with salt and salt/sand mix. Estimated that the use of the combination of the two chemicals could result in a 50% reduction in salt.
- Experiment with various application rates.
- Recommend a study be conducted in areas that have absolutely no interaction with other chemical applications, especially at intersections and with other agencies.

- Run trials, analyze results, report results, and make recommendations for changes during the season.
- Crews reported that MDSS records are not in line with shift records. MDSS did not accurately record gallons used on 217500 during the route. Therefore, operators used the amount of liquid used to fill the tank and then divided that amount into the amount of sand used on the route. That info was then reported out in the Resource Consumption Application system by route.
- Operator in the 217502 truck (from beginning of winter season until mid-February) often over applied material and did not regularly record material applied.
- Confirmed that additional non-designated (non-project) trucks applying KAc material were used on the project routes.
- Confirmed that non-designated (non-project) trucks applying non-KAc materials were used on the project routes.
- Suggested that a controlled research study with various scenarios being tested with different chemicals and mixtures would be valuable. Would also need a designated person (outside of operators) to assist with communication, documentation and observation.