Clear Roads Study

Establishing Effective Salt and Anti-icing Application Rates

Revised Summary Report

Task 1: Collection of Information

MnDOT Contract No. 02000
Fed. Project No. TPF – 5(218)

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Summary of Task 1 Findings

This report contains a brief summary of the Task1 findings for MnDOT Contract No. 02000 dealing with "Establishing Effective Salt and Anti-icing Application Rates." The Task 1 activities, identified as the collection of information, included the collection of information regarding anti-icing and deicing materials including blends, from: 1) past research testing since 2004; 2) from producers of enhanced brine blends; and 3) from winter maintenance experts regarding their use and experiences with anti-icing and deicing materials. The objective of the Task 1 activity was to collect as much information as possible and initially analyze the data in regards to chemical performance observation made under a variety of circumstances. These results will be incorporated in the development of the Task 2 activities.

This summary report is divided into three main sections. Section I describes the Search of Databases regarding studies of field-based tests that have been conducted on snow and ice control chemicals during the past 15 years. Section II describes the Contact of Manufacturers and producers of deicer products and product blends of ice control chemicals to obtain Manufacturer's Safety Data Sheets (MSDS) and technical reports that describe the chemical compositions, laboratory performance data, specification and field performance data they are willing to share with the study and obtain the identity of users of their products. Finally Section III, describes the Expert Interview conducted with winter maintenance experts regarding the anti-icing and deicing ice control chemicals they use and their experiences with those products.

I. Search of Databases

Computerized literature searches were conducted using the following four databases to determine what laboratory or field-based tests have been conducted on snow and ice control chemicals since 1999.

- Joint Transport Research Center's International Transport Research Documentation
  Web site: **http://trid.trb.org/**

- Canada Institute for Scientific and Technical Information (NRC-CISTI)
  Web site: **http://cisti-icist.nrc-cnrc.gc.ca/eng/ibp/cisti/index.html**

- Transport Research Laboratory in UK
  Web site: **http://www.trl.co.uk/library/reports_publications/**

- Pacific Northwest Snow Fighters (PNS)
  Web site: **http://www.nwsrg.org/publications**

A total of 12 combinations of various key words were used during the search of the four databases. These 12 searches resulted in identifying 1,358 potential references. The number of references identified in each search ranged from zero to 400, depending on the combination of key words used. The titles of the 1,358 potential references were reviewed for relevancy to the project. This review resulted in a large number of citations being dropped because of non-applicable subject matter identified in Appendix A. The next step was to reduce the number of potential references

by first reviewing the abstracts and then quickly review the articles themselves. This approach identified 12 potentially useful documents. These are given in Appendix A. The search revealed studies in Canada that have tested the usefulness of using beet molasses mixed with salt brine. Also, studies have been conducted by Colorado DOT using blends of $MgCl_2$ with agricultural-based material. Nebraska DOT also has conducted a study using salt brine and liquid corn salt. Finally a study was identified that determined the effects of mixing three liquid chloride base chemicals together.

Other references potentially important to the project continue to be found external to the computerized searches by the team members from individual sources and from returned questionnaires from the surveyed highway agencies. The team expects to find additional documents pertinent to the project as we proceed with Tasks 2 and 3 of the project.

II. Contact Manufactures

A total of 35 potential North American manufactures/suppliers of snow and ice control chemicals and related blends were identified by the team members. The names and addresses of these vendors were obtained from the Pacific Northwest Snow Fighters (PNS) Qualified Product List, APWA North American Snow Conference Exhibitors, and various listing of manufacturers. Seven of the 35 potential vendors are located in Canada. A list of the vendors was developed and contact assignments were made among the four primary team members by time zone. The names and locations of the vendors contacted are given in Appendix B.

A detailed survey questionnaire was developed for e-mailing/interviewing technical representatives of each identified manufacturer and/or supplier of the snow and ice control chemicals. The survey was designed to determine the chemical composition of the products, laboratory performance data, specifications, and any field performance data they were willing to share with the study team.

A draft version of the questionnaire was submitted to the Clear Roads Subcommittee for review and comments. The draft questionnaire was revised in response to the review comments. The final version of the questionnaire contained 21 questions and covered such areas as:

- General information, including highway agencies using each producer's products along with the annual amounts sold;
- Laboratory performance data;
- Field performance data; and
- Quality assurance.

The procedures used for contacting vendors of snow and ice control chemicals are as follows:

First, a preliminary telephone call was made to the chemical manufacturer/vendor to introduce the project and to solicit help in identifying a technical contact person(s) in the company that we could talk with concerning questions we had about the product(s) produced/marketed. The team member making the call could use the text prepared in the telephone call form to insure uniformity of approach.

Second, an introductory e-mail was sent, if necessary, to an identified individual in the company that we could interview to obtain technical information concerning the products manufactured/marketed. The e-mail identified the topics we would like to discuss and asked for a

convenient date and time to call for the interview. This e-mail was to be followed-up with a reminder in a given amount of time if no response was forthcoming.

Third, and most frequently followed, a call was made to the product contact person for interviewing using the questions in the interview form. The contact person was given the option of receiving the questionnaire by e-mail in place of being interviewed by phone. Most, if not all the contact persons, chose to receive the questionnaire by e-mail.

The team sent questionnaires to manufacturers of snow and ice control chemicals that initially agreed to participate in the survey. Some of the vendors responded soon after receiving the questionnaire, but most required a follow-up reminder. We followed-up 4 – 6 times with e-mails and telephone contacts with a number of the companies over a three-month period that initially agreed to participate in the survey, but did not respond when we sent the questionnaire.

As we waited for the survey responses to be returned, we looked more closely at the nature of the chemical companies business and products. This approach allowed us to concentrate our interviewing efforts on a few, but important vendors.

At the end of a three-month interviewing period we received completed questionnaires from 14 companies. Of the remaining companies, we know the following:

- 7 were dropped from consideration because of the nature of their business i.e, hauler of chemicals; not a supplier to a highway agency; partnered with another chemical vendor; only a supplier of organic compound to a chemical manufacturer; and no longer in business.
- 7 are producers of non-corrosion inhibited NaCl (PNS Category 8 chemical).
- 4 are producers of chemicals that we were able to identify sufficiently through company websites and other internet sources.
- 3 companies refused outright to participate in the study for a variety of reasons.

The 14 companies that returned the survey questionnaire plus the results of the other 21 companies being contacted are given in Appendix B.

A summary of the chemical products produced by 18 manufacturers/vendors is given in the table that follows. This table is a partial summary of findings obtained from the manufacturers/vendors questionnaire and/or information taken from the internet. Nearly all the responders provide laboratory data e.g. MSDS and sometimes friction testing results. Phase diagrams were obtained on seven of the chemicals identified. Limited controlled field test data were obtained, but most of the field data consisted of testimonials from users.

The first column on the left is the listing, by alphabet order, of identified chemical product names. This listing exceeds the number of products that were identified by the highway agencies in their questionnaire. The second column contains a manufacturer code for each product. A number was assigned to each manufacturer/vendor to provide confidentially that was promised by the study team at the start of interviewing. Columns three and four identify the form for the product, e.g. liquid or solid. Columns five, six, and seven provide information on the additive base of the products. Columns eight through thirteen provide information on the basic snow and ice control chemical that the organic additive is pre-mixed with by the vendor. Column fourteen lists the mixing ratios, if given. Column fifteen identifies if a phase diagram was made available to the team for the product.

Tabulation of Chemical Products Identified Along with Any Organic Inhibitor Added to the Base Chemical

Product	Manufacturer	Liquid form	Solid form	Additive			Base Chemical						Mixture	Phase Diagram Available
				Sugar Beet	Corn based	Other	NaCl	$MgCl_2$	$CaCl_2$	CMA	KAc	NaAc		
Apogee	6	X		Is not chloride or acetate based									Use as is	Yes
Alpine Ice Melt	9	X				X					X		Use as is	Yes
AMP	6		X			X							100	Yes
Anti-Corrosion Super Salt	17		X				X		X				82.5/9.5	No
BEET 55	15	X		X									To be mix	Yes
BEET HEET	8	X		X				X	X					No
BOOST 55	1	X		X									To be mix	No
$CaCl_2$ BOOST	1	X		X					X					No
Caliber M1000	7	X			X			X						No
Caliber M2000	7	X			X									No
Clear Guard	17	X					X	X	X				1.9/3.55/27.9	No
ClearLane enhanced	2		X			X	X	X						No
Cryotech NAAC	3		X									X		No
Cryotech CF7	3	X									X			Yes
Cryotech CMA	3		X							X				No
Cryotech CMA40	3		X				X			X				No
Freeze Fighter HiCal 50	4	X		X			X	X	X					No
Freezgard	13	X			X			X						No
Freezgard MgCl	10	X			X			X						No
Fusion 55	5	X		X									To be mix	No
GeoMelt 55	16	X		X									To be mix	Yes
Ice Ban 305	13	X			X			X					79/21	Yes
Ice B'Grone Magic	14	X		X				X					20/80	No
Ice Slicer	12		X			X	X							No
Liquid Corn Salt	6	X			X		X						90/10	No
Master Melt 50	11	X		X			X	X	X					No
Meltdown AP	6	X						X					5/30	Yes
Meltdown APEX	6	X			X	X		X					5/5/30	Yes
North Pro	10		X				X							No
Road Guard Plus	17	X		X				X	X				3.5/26.5/10	Yes
Salt	10		X				X							Yes
Salt Blend-$CaCl_2$ Enhanced	17		X				X		X				87.2/9.5	No
Salt brine (23%) +AMP (5%)	6	X				X	X						5/23	Yes
SOS	6	X						X					5/26	Yes
TC Econo	17	X		X			X		X					Yes
Thawrox	10		X		X		X	X					.06/97/2.4	NO
Thawrox MG	10	X		X				X						Yes
Tiger Salt	17		X				X		X				20/20/	No

III. Expert Interviews

A total of 37 North American winter maintenance experts were identified by the team members. These individuals were identified for purposes of interviewing them regarding the anti-icing and deicing materials they have used and their experiences with those products. Twenty-three experts were identified from a 2013 listing of the 26 Clear Roads member states. Seven experts from Canadian Providences were identified from a list of attendees at the Transportation Association of Canada's Summer and Winter Maintenance Subcommittee meeting. Seven experts from both U.S. and Canadian local highway agencies including one Toll Road Authority were identified because of their active interest in winter maintenance operations and innovative use of a variety of snow and ice control chemicals. Two of the seven local highway agency experts are representatives from Canadian cities and were identified from the list of attendees of the Transportation Association of Canada's Summer and Winter Maintenance Subcommittee meeting. The remaining five representatives from local highway agencies were identified with the assistance of a member of the American Public Works Association (APWA) Subcommittee on Winter Maintenance. The 37 experts selected for interviewing come from areas of mountainous, high plain, plains, lake effect, and maritime jurisdictions that represent an array of climatic and geographic regions across North America.

A list of names and titles of the winter maintenance experts contacted/interviewed is given in Appendix C

Two forms were prepared for contacting the highway agencies regarding their usage of snow and ice control chemicals during winter maintenance operations. The first form was used during a preliminary contact with the agency. It described the project and asked for name(s) of a knowledgeable person who could be called for a short (10-15 minute) interview. The interview would cover specific questions that relate to his/her agency's experience concerning the use and performance of the various ice control chemicals for anti-icing and deicing operations. The initial contact form also provided a list of specific topics that would be addressed during the telephone interview and sought a date and time that the interview could be accomplished using a prepared list of questions. The preliminary contact form also asked for some information that could be obtained from the agency before the interview to help streamline the interview process.

The second form contained a set of questions that would be used during the telephone interview process.

A draft version of the preliminary contact form and questionnaire was submitted to the Clear Roads Subcommittee for review and comments. Both forms were revised slightly in response to the review comments. The final version of the questionnaire contained 39 questions and covered the following categories: liquid snow and ice control chemicals; solid snow and ice control chemicals; and levels of service considerations. Specific question categories include: general information, mixing and storage considerations (for liquids), operational considerations, application rates, factors influencing application rates, and evaluation results.

The team contacted and sent questionnaires to all 37 identified North American winter maintenance experts. In every instance, the identified expert asked that the questionnaire be e-mailed to him/her for completion.

Some of the experts responded soon after receiving the questionnaire, but most required follow-up reminders. The interviewing of experts from highway agencies was terminated three months after the process began. At that time, we obtained completed questionnaires from 31 highway agencies that included 19 state DOTs, six Canadian Provinces and six local highway agencies. Those highway agencies that returned the completed questionnaires are identified in Appendix C.

As stated earlier, the questionnaire sent to the highway agencies contained 37 questions divided between three major areas. The questionnaire contained 25 questions in the liquid chemical area, nine questions in the solid chemical area, and five questions in the LOS area. It would be too involved to summarize the responses to all 37 questions at this stage of the project. Instead, it was decided to summarize the responses to15 questions in the liquid chemical area; to summarize the responses to seven questions in the solid chemical area; and to summarize the responses to only two questions in the LOS area. This approach provides a summary of responses to 24 out the 39 questions asked. The 24 questions being addressed are divided among four categories of inquiry as follows:

- Eight questions from the General Information category;
- Five questions from the Operational Considerations category;
- Six questions from the Application Rates category; and
- Five questions from the Evaluation Results category.

For convenience, the summary response to each of the 24 questions is preceded by the area the question is taken from, an alpha-numeric code that corresponds to the question number in the survey, and a restatement of the question.

A. General Information Category

1. LIQUID CHEMICALS G1 – PLEASE LIST THE LIQUID SNOW AND ICE CONTROL CHEMICALS YOU ARE CURRENTLY USING.

The various liquid snow and ice control chemicals used during winter maintenance operations by the surveyed highway agencies is given in Appendix D. All of the state DOTs responding use salt brine either in direct application to the pavement and/or during prewetting operations. Nine states also use $MgCl_2$ and 10 states use $CaCl_2$ which are usually mixed with an organic corrosion inhibitor. Six states use KAc either on very expensive bridge structures or on roads in very environmentally sensitive areas. Seven states utilize various proprietary forms of beet sugar juice or corn based additives as a corrosion inhibitor and as a temperature depression for chloride chemicals.

Four of the six reporting Canadian Providences use organic corrosion inhibitors with their snow and ice control chemicals. One local highway agency in Canada reported using a proprietary pre-mixture of a corrosion inhibitor with their snow and ice control chemicals.

2. LIQUID CHEMICALS G2 – WHICH LIQUID CHEMICALS ARE BLENDS OF COMMON SNOW AND ICE CONTROL CHEMICALS?

Two state DOTs mix NaCl brine with $CaCl_2$ brine. One Canadian Providence uses a mixture of all three common chloride base chemicals; and two local highway agencies use a mixture of either two or three chloride base chemicals.

3. LIQUID CHEMICALS G3 & G4 – WHICH LIQUID CHEMICAL USED IS A BLEND OF COMMON SNOW AND ICE CONTROL CHEMICALS AND A CORROSION (ORGANIC) INHIBITOR?

Nearly all the reporting state DOTs use a corrosion inhibitor with their liquid snow and ice control chemicals. These states either purchase the corrosion inhibitor and mix it with their common snow and ice control chemicals or they purchase a proprietary pre-mixture of an inhibitor and a common snow and ice control chemical. The corrosion inhibitors are either a beet sugar juice or corn based product and are marketed under the following trade names: BEET 55®, BOOST 55®, GeoMelt 55®, and Fusion55®. The stand alone proprietary corrosion (organic) inhibitors usually have a concentration of 55% solids with the balance being water.

4. LIQUID CHEMCIALS G5 - WHAT ARE THE ANNUAL AMOUNT OF EACH LIQUID ICE CONTROL CHEMICAL USED BY YOUR ADGENCY?

The annual amounts of liquid chemicals used varied considerably among the highway agencies because of the size of the agency's jurisdiction and the severity of winter. However, most all highway agencies reported using salt brine as their liquid chemical of choice. The only exceptions are the use of pre-mixed $MgCl_2$ with an organic corrosion inhibitor in environmentally sensitive areas. There appears to be increasing interest among state DOTs in using liquid $MgCl_2$ mixed with a corrosion inhibitor. One state DOT reported using a mixture of three liquid based chloride chemicals in their snow and ice control program.

5. LIQUID CHEMICALS G6 – WHAT IS THE AVERAGE AGENCY COST FOR EACH OF THE LIQUID CHEMICALS YOU ARE USING? THE COST NEEDS TO EXCLUDE TRANSPORTATION RELATED COSTS, IF POSSIBLE.

- The cost for salt brine ranges from $0.05 to $0.53 per gallon. The average cost is $0.17 per gallon or a median of $0.15 per gallon.
- The cost for $MgCl_2$ brine ranges from $0.44 to $1.35 per gallon with the average cost at $0.88 per gallon.
- The cost for $CaCl_2$ brine ranges from $0.56 to $1.35 per gallon with the average cost at $0.88 per gallon.
- The two states that use KAc pay $6.45 and $6.85 per gallon, respectively.
- Only five highway agencies reported their costs for organic corrosion inhibitors. Those cost ranged from $1.03 to $2.67 per gallon for the straight inhibitor.
- The cost for a proprietary pre-mixture of an inhibitor with snow and ice control chemicals ranged from $1.00 to $2.56 per gallon of mixture.

6. SOLID CHEMICALS G1 – WHAT SOLID ICE CONTROL CHEMICALS ARE USED BY YOUR AGENCY?

The various solid snow and ice control chemicals used during winter maintenance operations by the surveyed highway agencies is given in Appendix D. All of the reporting highway agencies, except two, are using untreated rock salt as their primary solid snow and ice control chemical. The two exceptions are local highway agencies. One uses treated salt and other uses only Ice Slicer. Four state DOTs reported using Ice Slicer in addition to rock salt. Three state DOTs reported using solar salt in addition to rock salt. Five state DOTs use solid $CaCl_2$ in addition to rock salt. Three highway agencies use premixed treated salt in addition to rock salt.

7. SOLID CHEMICALS G2 – WHAT ARE THE ANNUAL AMOUNS OF EACH OF THE SOLID SNOW AND ICE CONTROL CHEMCIALS USED BY YOUR AGENCY?

Rock salt is the predominant solid roadway chemical used by the various highway agencies. The quantities used are dependent on the amount of lane-miles, winter weather climate, and level of service conditions found in each highway jurisdiction.

8. SOLID CHEMICALS G3 – WHAT IS THE AVERAGE AGENCY COST FOR EACH OF THE SOLID CHEMICALS YOU ARE USING? THE COST SHOULD EXCLUDE TRANSPORTATION RELATED COSTS, IF POSSIBLE.

- The cost for rock salt ranges from $29.25 to $150.00 per ton. The large variance in cost could be due to the inclusion of transportation cost in the figures.
- The cost for treated salt range from $55.00 to $100.00 per ton.
- The cost for $CaCl_2$ ranges from $278.00 to $450.00 per ton.
- Only two agencies reported on their cost for Ice Slicer. One agency reported paying $87.00 per ton and the other agency reported paying $96.85 per ton.

B. Operational Considerations Category

1. LIQUID CHEMICALS O5 – WHAT IS THE MINIMUM PAVEMENT TEMPERATURE YOU USE LIQUID ICE CONTROL CHEMICALS APPLIED DIRECTLY TO THE PAVEMENT?

Thirteen agencies reported a minimum pavement temperature of 15 °F. An additional 10 agencies reported minimum temperatures ranging from -18° to a plus 25° F with the coldest temperatures generally in the northern states and provinces and highest temperature in Rhode Island in the east. Nine states reported "no information", one (City of Lake St. Louis) reported no minimum and two - Manitoba and Michigan reported "no direct application to pavement".

2. **LIQUID CHEMICALS O6 – WHAT IS THE MINIMUM PAVEMENT TEMPERTURE YOU USE A SOLID ICE CONTROL CHEMICAL THAT IS PRE-WET OR PRE-TREATED WITH A LIQUID ICE CONTROL CHEMICAL?**

   Eleven agencies reported "no information or no experience". Five agencies reported no established minimum pavement temperature. Nineteen agencies reported minimum pavement temperatures ranging from -18°C (Toronto) to plus 18°F (Utah) with six agencies reporting a minimum pavement temperature of 15°F

3. **LIQUID CHEMICALS O7 – WHEN USING PRE-WET OR PRE-TREATED SOLID ICE CONTROL CHEMICALS, HAVE YOU OBSERVED THAT FEWER TREATMENT CYCLES ARE NEEDED? DO YOU HAVE ANY REPORTS THAT DOCUMENT THIS EXPERIENCE?**

   Twenty agencies reported “yes” that fewer treatment cycles were needed, but most did not provide and reports or other supporting documentation. Six agencies reported no fewer cycles. Five agencies provided no information while four others did not know if fewer cycles were realized.

4. **SOLID CHEMICALS O2 – WHAT IS THE LOWEST PAVEMENT TEMPERATURE YOU USE TREATED AND UNTREATED SOLID CHEMICALS?**

   Seven agencies reported no lowest temperature. Seven others reported no information or no experience. Seven reported a low temperature of 15°F while four noted a low temperature of 10° F. For the remaining seven agencies, each reported a low temperature ranging from 0° F to plus 23° F.

5. **LEVEL OF SERVICE O2 – HOW ARE SNOW AND ICE CONTROL MATERIAL CHOICES INFLUENCED BY YOUR LEVELS OF SERVICE CATEGORIES?**

   Twenty agencies reported their choice of ice control chemicals was influenced by LOS considerations. Six agencies noted that LOS considerations did not influence their choice of chemicals. Four did not know or had no opinion as to LOS influence on chemical choice. Five provided no information on this question.

C. Application Rates Category

1. **LIQUID CHEMICALS A1 – WHAT ARE THE LIQUID CHEMICAL APPLICATION RATES GAL/LANE-MILE USED WHEN DIRECTLY APPLIED TO THE PAVEMENT FOR VARIOUS ROAD AND WEATHER CONDITIONS?**

   The range of rates was 15 to 100 gal /lane-mile, with the average in the range of 50 gal /lane-mile. Most agencies varied the rate according to pre-storm or within storm status and weather, road and operational conditions.

2. **LIQUID CHEMICALS A2 – WHAT ARE THE LIQUID CHEMICAL APPLICATION RATES IN GAL/LANE-MILE USED TO PRE-TREAT BRIDGE DECKS?**

   The range of rates was 15 to 100 gal /lane-mile and the average was 49 gal /lane-mile. The distribution of values was more closely centered than in Question A-1. This is probably a result of most of the treatments being pre-storm in nature.

3. **LIQUID CHEMICALS A3 - WHAT ARE THE APPLICATION RATES IN GAL/TON FOR LIQUID ICE CONTROL CHEMICALS WHEN USED TO PRE-WET OR PRE-TREAT SALTOR OTHER SOLID ICE CONTROL CHEMICALS?**

   The range in rates was from 3 to 30 gal/ton, and the average was 10 gal/ton.

4. **SOLID CHEMICALS A1 - WHAT ARE THE SOLID CHEMICAL APPLICATION RATES IN LBS/LANE-MILE YOU USE FOR VARIOUS ROAD AND WEATRHER CONDITIONS?**

   The range in rates was from 50-600 lbs/lane-mile, and the average was 252 lbs /lane-mile.

5. **SOLID CHEMICALS A2 - IF YOU PRE-WET OR STOCKPILE TREAT WITH LIQUID CHEMICALS, WHAT APPLICATION RATES IN LBS/LANE-MILE DO YOU USE FOR VARIOUS ROAD AND WEATHER CONDITIONS?**

   The range in rates was from 50 to 600 lbs/lane-mile and the average was in generally in the range of untreated solid chemicals. However, several agencies reported they use a percent reduction in solid chemical application rates when pre-wetting.

6. **LEVEL OF SERVICE CONSIDERATIONS A1 - HOW ARE LIQUID AND SOLID CHEMICAL APPLICATION RATES INFLUENCED BY YOUR LEVELS OF SERVICES CATEGORIES?**

   Level of service classification was the most common driver of chemical application rates reported. This was followed by treatment cycle time, and road and weather conditions, respectively.

D. Evaluation Results Category

1. **LIQUID CHEMICALS E1 – HAS YOUR AGENCY CONDUCED ANY FIELD TESTS OR MADE PERFORMANCE EVALUATION OF LIQUID CHEMICAL USAGE? IS THIS DOCUMENTED IN ANY REPORTS?**

   A total of 10 state DOTs claim to have conducted field tests or made performance evaluations of liquid chemical usage but only three of these agencies had documented their findings. Only one Canadian Providence and one local highway agency has conducted any field tests or made performance evaluations of liquid chemical usage. Neither of these last two agencies have any reports that document their experiences.

2. **LIQUID CHEMICALS E2 – DO YOU HAVE ANY EVIDENCE OF ICE/PAVEMENT BOND PREVENTION FROM USING LIQUID CHEMICALS THAT ARE ORGANICALLY ENHANCED? IF SO, CAN YOU IDENTIFY THE LIQUID CHEMCIALS THAT DO AND DO NOT PROVIDE THIS PROTECTION ALONG WITH THEIR RESPECTIVE APPLICATION RATES AND OPERATING CONDITIONS?**

   Only three state DOTs claim to have evidence of ice/pavement bond prevention from using liquid chemicals that are organically enhanced. Two of the three state DOTs provided some documentation on the specifics of the protection achieved and the chemical used. Two local highway agencies claim to have evidence of ice/pavement bond prevention from using liquid chemicals that are organically enhanced. Only one of two local highway agencies gave any particulars of their experience.

3. **LIQUID CHEMICALS E3 – DO YOU HAVE ANY EVIDENCE OF USING CERTAIN ORGANICALLY ENHANCED LIQUID CHEMICALS THAT HAVE A RESIDUAL CARRY-OVER EFFECT FROM PREVIOUS TREATMENTS THAT REQUIRE SMALLER SUBSEQUENT LIQUID APPLIACATION RATES? IF SO, CAN YOU SHARE THESE EXPERIENCES WITH DOCUMENTATION?**

   Six state DOTs, one Canadian Providence, and two local highway agencies have evidence of a residual carry-over effect from previous treatments that allow for smaller subsequent liquid application rates. Five of the state DOTs, one Canadian Providence, and two local highway agencies have photographic and other evidence to document their experiences.

4. **LIQUID CHEMICALS E4 – HAVE YOU EXPERIENCED PAVEMENT SLICKNESS ISSUES WITH THE USE OF LIQUID ICE CONTROL CHEMICALS? IF SO, WHAT ARE YOUR EXPERIENCES AND DO YOU HAVE ANY DOCUMENTATION OF YOUR EXPERIENCES?**

   This question stimulated a large positive answer from the various highway agencies. A total of 16 state SOTs, one Canadian Providence, and four local highway agencies indicated they have experience slickness issues with the use of liquid ice control chemicals. Twelve state DOTs and two local highway agencies reported they have documentation of the issues. The primary reasons given for the pavement slickness issues deal with improper application rates and types of liquid chemical used for the conditions.

5. **SOLID CHEMICALS E1 – DO YOU HAVE REPORTS OF STUDIES YOU HAVE CONDUCTED THAT SUPPORT YOUR SOLID CHEMICAL APPLICATION RATES? IF SO, PLEASE PROVIDE A COPY OF THE STUDY FINDINGS.**

   Two state DOTs and one local highway agency have reports of studies they have conducted that support their solid chemical application rates used. The one local highway agency claims to have documented the appropriateness of the Salt Institute's Application Rate recommendations.

IV. Conclusions

The activities associated with Task 1 are now complete. The team has identified and assembled important information from our search of the literature, our contacts with the manufacturer/vendors of snow and ice control chemicals, and our interviews of experts in the field of winter maintenance. These contacts and interviews have resulted in receiving published and unpublished information related to anti-icing and deicing operations. We are now prepared to proceed with the Task 2 activities associated with updating the chemical application rate guidelines for a wide range of chemicals currently being used in winter maintenance operations.

APPENDIX A

Search of Databases

Computerized literature searches were made to determine what field and laboratory studies of the effectiveness of common and new blends of ice control chemicals have been performed since the NCHRP Project 6-13 was conducted. That project resulted in the issuance of NCHRP Report 526 in 2004 that dealt with "Guidelines for Snow and Ice Control Materials and Methods." The search of the literature covered the 15–year period of 1999 to the present. The search included the 4–5 year period before the issuance of the NCHRP Report 526 to uncover any studies that might not have been identified during the final years of Project 6–13.

The four databases used during the searches included:

- Joint Transport Research Center's International Transport Research Documentation
  Web site: **http://trid.trb.org/**

- Canada Institute for Scientific and Technical Information (NRC-CISTI)
  Web site: **http://cisti-icist.nrc-cnrc.gc.ca/eng/ibp/cisti/index.html**

- Transport Research Laboratory in UK
  Web site: **http://www.trl.co.uk/library/reports_publications/**

- Pacific Northwest Snow Fighters (PNS)
  Web site: **http://www.nwsrg.org/publications**

A total of 12 combinations of various key words were used during the search of the four databases. These 12 searches resulted in identifying 1,358 potential references. The number of references identified in each search ranged from zero to 400, depending on the combination of key words used.

The titles of the 1,358 potential references were reviewed for relevancy to the project. This review resulted in a large number of citations being dropped because of subjects related to bridges, traffic, transportation studies, environmental issues, and agricultural/biofuel studies. Also a number of duplicate citations were removed. This reduction resulted in 75 potentially useful documents. The abstracts of the 75 were printed and reviewed for relevancy to the project using the same screening technique used for the titles. This final step resulted in the identification of 12 references which were quickly reviewed. The 12 documents found from the computerized literature search as being potentially most useful to the project are given below.

1. Balgowan, R, "Reducing the Use of Chlorides for Snow and Ice Control," PowerPoint Presentation given at APWA North American Snow Conference , April 2010
2. Cuelho, Eli, J. Harwood, M. Akin, and E. Adams, "Establishing Best Practices for Removing Snow and Ice from California Highways," Western Transportation Institute, College of Engineering, December 2010
3. "Deicing Performance Measures," PowerPoint Presentation given by EnviroTech Services at the APWA & PNS North American Snow Conference, April 2011

4. Fay, L., Kevin Volkening, et.al, "Performance and Impacts of Current Deicing and Anti-icing Products: User Perspective versus Experimental Data," paper presented at TRB 2008 Annual Meeting, Washington D.C.
5. Fischel, M., "Evaluation of Selected Deicers Based on a Review of the Literature," The Sea Crest Group, Final Report No. CDOT-DTD-R-2001-15, October 2001
6. Fu, Liping, R. Omer, and C. Jiang, "Field Test of Organic Deicers as Prewetting and Anti-Icing Agents for Winter Road Maintenance," paper presented at TRB 2012 Annual Meeting, Washington, D.C.
7. Fu, Liping, "Effectiveness of Alternative Chemicals for Snow Removal on Highways," Transportation Research Record: Journal of the Transportation Research Board, No. 1948, Transportation Research Board of the National Academies, Washington, D.C., 2006, pp. 125–134.
8. Kahl, Steve, "Agricultural By-Products for Anti-icing and Deicing Use in Michigan," MDOT Research Report R 1418, December 2002
9. MnDOT publication "Application Rate Guidelines," 2012
10. Shi, Xianming, et.al., "Evaluation of Alternative Anti-icing and Deicing Compounds Using Sodium Chloride and Magnesium Chloride as Baseline Deicers – Phase I," Colorado Department of Transportation, Final Report No CDOT-2009-1, February 2009
11. Sooklan, R., Liping Fu, Max Perchanak, "Effectiveness of Pre-wetting Strategy for Snow and Ice Control on Highways," Presentation at the Success in Road Salt Management Session of the 2006 Annual Conference of the Transportation Association of Canada
12. Wright, R. and Monty Mills, 'Inhibitor Longevity and Deicer Performance Study," PowerPoint Presentation, PNS Pooled Fund Research

Other references potentially important to the project continue to be found by the team members from individual sources and from returned survey questionnaires. Three such documents are:

1. "Code of Practice for Highway Maintenance Management," UK Roads Liaison Group, July 2005
2. "Anti-icing in Winter Maintenance Operations: Examination of Research and Survey of State Practice," MnDOT Transportation Research Synthesis , May 2009
3. "Winter Chemical Catalog," MnDOT Office of Maintenance, October 2010

The team expects to find additional document pertinent to the project as we proceed with Tasks 2 and 3 of the project.

APPENDIX B

North American Manufacturers/Vendors of Snow and Ice Control Chemicals Selected for Interviewing

A total of 35 potential North American manufacturers/vendors of snow and ice control chemicals and related blends were identified by the team members. These companies were identified for purposes to interview a technical representative regarding the chemical compositions of the snow and ice control products they supply to highway agencies. We were also looking for any laboratory performance data, specifications, and any field performance data they were willing to share with the research team.

The manufacturers/vendors contacted/surveyed are listed alphabetically in Table B. Also given are the location of the manufacturer/vendor and the results of being contacted/surveyed. The results of the contacts are given by the following code:

1- Questionnaire received
2- Company dropped from consideration because of the nature of their business
3- Company producer of non-corrosion inhibited NaCl (PNS Category 8 chemical)
4- Company products identified through websites and other internet sources
5- Company refused to participated in study

Table B – North American Manufacturers/Vendors of Snow and Ice Control Chemicals That Were Contacted/Surveyed

Chemical Manufacturer/Vendor Contacted/Surveyed	Location of Manufacturer/Vendor	Results of Being Contacted/Surveyed
America West Environmental	Pasce, WA	**1**
Broken Arrow Salt	Lake Point, UT	**3**
Cargill Deicing Technology	North Olmsted, OH	**1**
Cryotech Deicing Technology	Fort Madison, IA	**1**
Den-Mar Brines	Bothwell, Ontario	**4**
Earth Friendly Chemicals, Inc	Virginia Beach, VA	**2**
Eco-Solutions	Winnipeg, Manitoba	**4**
EnviroTech Service Inc.	Greeley, CO	**1**
Dow Chemical	Midland, MI	**2**
Glacial Technologies	Decatur, IL	**5**
Intrepid Potash	Denver, CO	**2**
International Salt	Clarks Summit, PA	**3**
Kayway Industries	Esterhazy, Saskatchewan	**3**
K-Tech Specialty Coatings	Ashley, IN	**1**
Mainroad Canada	Surrey, British Columbia	**3**
Melt Snow	Mesa, AZ	**5**
Morton Salt	Chicago, IL	**3**
Nachurs Alphine Solution Industrial	Marion, OH	**1**
NaturaLawn of America	Frederick, MD	**1**
North America Salt Co.	Overland Park, KS	**1**

Chemical Manufacturer/Vendor Contacted/Surveyed	Location of Manufacturer/Vendor	Results of Being Contacted/Surveyed
Northern Salt Minerals Ltd	New Brighton, MN	**1**
NSC Minerals Ltd	Saskatoon, Saskatchewan	**3**
Pollard Highway Products	Harrow, Ontario	**4**
Redmond Minerals Inc.	Redmond, UT	**1**
Rivertop Renewables	Missoula, MT	**1**
Road Solutions Inc.	Indianapolis, IN	**2**
Scotwood Industries, Inc.	Overland Park, KS	**4**
Sears Ecological Application Co. LLC	Rome, NY	**1**
SFG Road Maintenance Office (Smith Fertilizer & Grain)	Knoxville, IA	**1**
Shelton Salt	Wendover, UT	**3**
SNI Solutions	Geneseo, IL	**5**
SureCrop Farm Services	Junction City, OR	**2**
Syn-Tech Products Corp	Toledo,OH	**2**
TETRA Technologies Inc.	The Woodlands, TX	**2**
Tiger Calcium Services	Sherwood Park, Alberta	**1**

In summary, the following results were obtained from contacting the 35 potential manufacturers/vendors of snow and ice control chemicals:

- 14 companies completed and returned the survey questionnaire
- 7 companies were dropped from consideration because of the nature of their business i.e., hauler of chemicals; not a supplier to a highway agency; partnered with another chemical vendor; only a supplier of organic compound to a chemical manufacturer; or no longer in business
- 7 companies are producers of non-corrosion inhibited NaCl (PNS Category 8 chemical)
- 4 companies' products were identified through websites and other internet sources when they did not return the questionnaire
- 3 companies refused outright to participate in the study for a variety of reasons

APPENDIX C

North American Winter Maintenance Experts Selected for Interviewing

A total of 37 North American winter maintenance experts were identified by the team members. These individuals were identified for purposes of interviewing them regarding the anti-icing and deicing materials their agencies have used and their experiences with these products. Twenty-three experts were identified from a 2013 listing of the 26 Clear Roads member states. Seven other experts from Canadian Providences were identified along with seven experts from both U. S. and Canadian local highway agencies.

The primary expert contacted for interviewing in each agency is given in Table C along with his/her title. In some instances, the primary expert was assisted by an associate in addressing the response to the survey questionnaire. The name and title of the assisting individual is also given. Finally, the highway agency individual that completed the survey is identified in the table by an asterisk (*) following his/her name. If no asterisk is given following any individual's name, that indicates the survey questionnaire was not received from that agency.

The state highway agencies are listed alphabetically first in Table C. These are followed by an alphabetical listing of the Canadian Provincial agencies which, in turn, are followed by an alphabetical listing of local highway agencies.

Table C – North American Winter Maintenance Experts Contacted/Interviewed

Highway Agency		Expert Contacted/Interviewed	Expert's Title
State DOTs			
	Colorado	David Wieder (*)	Maintenance and Operations Branch Manager
	Idaho	Ron Wright (*)	Chemical Lab Supervisor
		Steve Spoor (*)	Maintenance Services Manager
	Illinois	Tim Peters (*)	Winter Operations Engineer
	Iowa	Robert Younie	Office of Maintenance
		Tina Greenfield(*)	RWIS Coordinator
	Kansas	Troy Whitworth (*)	Area Maintenance Superintendent
	Maine	Brian T. Burne (*)	Highway Maintenance Engineer
	Massachusetts	Scott Wilson	Director Roadway Operations
		Paul Brown	Snow and Ice Engineer
	Michigan	Justin Droste (*)	Roadway Operations Engineer
	Minnesota	Tom Peters (*)	Research & Training Engineer
	Missouri	Tim Chojnacki (*)	Maintenance Liaison Engineer
	Montana	Justun Juelfs (*)	Winter Maintenance Specialist
	Nebraska	Michael T. Mattison (*)	Maintenance Engineer
	New York	Michael Lashmet (*)	Snow & Ice Program Engineer
	North Dakota	Larry J. Gangl (*)	District Engineer
	Ohio	Samuel M. Grier (*)	Program Administrator
	Rhode Island	Joseph D. Baker (*)	Adm. Division of Highways
	Utah	Lynn Bernhard (*)	Maintenance Methods Engineer
	Vermont	Wayne Gammell	Maintenance Transportation Administrator

Highway Agency		Expert Contacted/Interviewed	Expert's Title
	Virginia	Allen Williams	Salem District Maintenance Engineer
	Washington State	Monty Mills (*)	Maintenance & Operations Branch Manager
	West Virginia	Jeff Pifer (*)	Maintenance Engineer
	Wisconsin	Mike Sproul	Winter Maintenance Engineer
	Wyoming	Cliff Spoonemore (*)	Field Operations Maintenance Staff Engineer
Canadian Providences			
	Alberta DOT	Steve Otto (*)	Director of Highway Operations
	Manitoba DOT	Larry Halayko	Director of Engineering & Operations Div
		Mike Knight (*)	Director of Operations Services
	New Brunswick DOT	David Cogswell	Executive Director
		Jeffrey McDonnell (*)	Highway Maintenance Engineer
	Nova Scotia	Olga J. Kidson (*)	Program Administration Officer
	Ontario MTO	Max Perchanok	Main Research Coordinator –Maintenance Standards Section
		Heather McClintock	Head-Maintenance Standards Section
		Steve Birmingham (*)	Maintenance Officer
	Quebec DOT	Anne Baril	Direction du soutien aux opérations
	Saskatchewan DOT	Andrew Liu	Director
Local Agencies			
	City of Calgary	Bill Biensch	
	City of Denver	William Kennedy (*)	Denver Public Works
	City of Lake St. Louis	Derek B. Koestel (*)	Director of Public Works
	City of Toronto	Dominic Guthrie (*)	Winter Operations
	McHenry Co., IL	Mark DeVries (*)	Maintenance Superintendent
	NY Throughway Auth	Michael Osborne (*)	Sr. Thruway Maintenance Specialist
	West Des Moines	Bret Hodne (*)	Public Works Director

APPPENDIX D

Liquid and Solid Snow and Ice Control Chemicals Used by Surveyed Highways Agencies During Winter Maintenance Operations

Table D - 1 Liquid Snow and Ice Control Chemicals Used by Surveyed Highway Agencies During Winter Maintenance Operations

Highway Agency	Common Snow and Ice Control Chemicals				Organic Corrosion Inhibitor					Premixed Snow and Ice Control Chemical with Addotove/Corrosion Inhibitor										
	Salt Brine	$MgCl_2$	$CaCl_2$	KAc	BEET 55	BOOST 55	GeoMelt 55	Fusion 55	Caliber M2000	Apogee	Liquid Corn	Ice B'Gone	Caliber M1000	Meltdown APEX	Freezgard	Ice Ban	GeoMelt 80/20	Master melt 50	Freezefighter-HiCal 50	$CaCl_2$ w/ BOOST
Colorado DOT	1	1							1	1			1	1		1				
Idaho DOT	1	1		1																
Illinois DOT	1		1																	
Iowa DOT	1		1																	
Kansas DOT	1	1																		
Maine DOT	1											1								
Massachusetts DOT																				
Michigan DOT	1	1		1		1									1					
Minnesota DOT	1	1	1	1							1									
Missouri DOT	1		1		1															
Montana DOT	1	1																		
Nebraska DOT	1			1	1		1							1						
New York DOT	1	1	1																	
North Dakota DOT	1																1			
Ohio DOT	1		1		1												1			
Rhode Island DOT	1	1	1																	
Utah DOT	1	1	1	1																
Vermont DOT																				
Virginia DOT																				
Washington State DOT	1		1	1											1					1
West Virginia DOT	1		1																	
Wisconsin DOT																				
Wyoming DOT	1																1			
Subtotal	19	9	10	6	3	1	1	0	1	1	1	1	1	2	2	1	3	0	0	1
Alberta, DOT	1	1	1										1				1			
Manitoba, MIT	1							1								1				
New Brunswick, DOT	1																			
Nova Scotia	1																			
Ontario, MTO	1	1	1	1														1	1	
Quebec. DOT																				
Saskatchewan, DOT	1												1			1				
Subtotal	6	2	2	1	0	0	0	1	0	0	0	0	2	0	0	2	1	1	1	0
City of Calgary																				
City of Denver		1																		
City of Toronto	1												1				1			
Lake St. Louis	1				1															
McHenry Co, IL	1	1	1		1															
NY Throughway Auth.	1	1			1															
West Des Moines	1		1														1			
Subtotal	5	3	2	0	3	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0

Table D - 2 Solid Snow and Ice Control Chemicals Used by Surveyed Highway Agencies During Winter Maintenance Operations

Highway Agency	Rock Salt	Treated Salt	Solar Salt	$CaCl_2$	Rapid Thaw	Ice Slicer
Colorado DOT	1		1		1	1
Idaho DOT	1					1
Illinois DOT	1			1		
Iowa DOT	1			1		
Kansas DOT	1					
Maine DOT	1					
Massachusetts DOT						
Michigan DOT	1			1		
Minnesota DOT	1	1				
Missouri DOT	1			1		
Montana DOT	1					
Nebraska DOT	1					1
New York DOT	1	1				
North Dakota DOT	1					
Ohio DOT	1					
Rhode Island DOT	1					
Utah DOT	1		1			1
Vermont DOT						
Virginia DOT						
Washington State DOT	1		1			
West Virginia DOT	1			1		
Wisconsin DOT						
Wyoming DOT	1					
Subtotal	19	2	3	5	1	4
Alberta, DOT	1					
Manitoba, MIT	1					
New Brunswick, DoT	1					
Nova Scotia	1					
Ontario, MTO	1					
Quebec. DOT						
Saskatchewan, DOT	1					
Subtotal	6	0	0	0	0	0
City of Calgary						
City of Denver						1
City of Toronto	1					
Lake St. Louis	1					
McHenry Co, IL		1				
NY Throughway Auth.	1	1				
West Des Moines	1					
Subtotal	4	2	0	0	0	1