TETRA TECH

TECHNICAL MEMO

ISSUED FOR USE

To:	Wanda Goulden, FEC, FGC, M.Sc., P.Eng., P.Geo.	**Date:**	May 14, 2019
c:		**Memo No.:**	2019-01
From:	Arma Dhaliwal, M.Eng., P.Eng. Bryan Palsat, P.Eng. Art Johnston, C.E.T.	**File:**	704-ENG.EMAT03571-02
Subject:	Industry Survey of the State of the Practice for Winter Maintenance on Bridge Decks		

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) is pleased to provide the City of Edmonton (the City) with the following Technical Memo summarizing the findings of an industry survey reviewing the state of the practice for bridge deck winter maintenance. The premise for this industry survey was provided in Tetra Tech Proposal "Literature Review of Winter Maintenance on Bridge Decks" (Tetra Tech File: 704-PENG.EMAT03571-01) dated February 1, 2019.

Authorization to proceed was provided by Ms. Wanda Goulden via email on February 8, 2019.

2.0 BACKGROUND INFORMATION

2.1 Objective

The primary objective of this industry survey was to capture the current state of the practice for bridge deck winter maintenance. Through discussions with the City, it was determined that the most practical method for completing this survey was to review the current practices of municipal agency, provincial agency and private roadway and bridge operators for winter bridge maintenance, particularly with respect to the application of anti-icing and de-icing chemicals and solutions. The extent of this survey would be limited to geographies where winter maintenance includes the management of bridge infrastructure in freezing conditions.

With input from the City, the following "guiding principles" were established and set the overall framework for the survey:

- What is the standard industry practice for winter bridge deck maintenance for traffic safety specific to the use of salt, sand, and brine use for both de-icing and anti-icing practices?
- What rationale and/or criteria have been established and/or are currently in use for determining both anti-icing and de-icing practices?
- The survey shall include consideration to: temperature related reasons, environmental reasons, protection of infrastructure, and other information determined during the review.

The objective of this survey was to assemble a summary of current anti-icing and de-icing practices used throughout Canada and in the northern United States of America.

Tetra Tech Canada Inc.
14940 - 123 Avenue
Edmonton, AB T5V 1B4 CANADA
Tel 780.451.2121 Fax 780.454.5688

2.2 Methodology and Approach

Tetra Tech compiled a list of nine survey questions to canvass various municipal agencies, provincial agencies and private roadway and bridge operators. These questions were developed with the intent to gain a reasonably detailed summary of the current anti-icing and de-icing practices used by each entity contacted.

The nine survey questions included:

1. What is your current practice for the use of anti/de-icing chemicals and/or traction aids (i.e., sand) on bridge decks?
2. Is this practice the same, or different than that used on your roadway network?
3. What products do your presently use for concrete wearing surfaces? What concentrations/application rates are typically used?
4. What products do your presently use for asphalt wearing surfaces? What concentrations/application rates are typically used?
5. What temperature considerations are employed in the selection of anti/de-icing chemicals and/or traction aids?
6. What environmental protection or environmental considerations are in place for the selection of anti/de-icing chemicals and/or traction aids?
7. Have you completed any investigation into the potential anti/de-icing chemicals might have on your bridge infrastructure?
8. Are you aware of any research that has been completed on the use of anti/de-icing chemicals and/or traction aids on bridge infrastructure?
9. What is your experience with automated de-icing systems?

2.3 Summary of Respondents

In total twenty-one entities were identified as potential respondents. These entities included: municipalities, provincial agencies, US Departments of Transportations (US DoTs), private roadway and bridge operators, contractors, consultants, and academia.

Responses were received from 14 entities, including:

- Four municipalities (Calgary, Saskatoon, Regina, and Winnipeg),
- Four provincial agencies (Saskatchewan Ministry of Highways and Infrastructure, Manitoba Infrastructure and Transportation, the Ontario Ministry of Transportation, and one that requested to remain anonymous),
- One US DoT (Minnesota),
- Two Private Roadway and Bridge Operators (Lafarge – Operations for Southeast and Southwest Anthony Henday Drive, and Confederation Bridge Group – Operations of the Confederation Bridge),
- One Academic Institution (University of Waterloo),
- One International Consultant (Sweco Sweden), and
- One Contractor (Miller Group Inc.).

3.0 PRESENTATION OF RESULTS FROM SURVEY

Responses from each respondent were compiled and summarized in tabular format. Some respondents provided their answers to the nine questions in writing. Others provided their answers via telephone through a pseudo interview process.

The summary of responses is provided in Table A-1, in Appendix A of this Technical Memo.

Some commonalities and trends were noted from the 14 respondents for the nine survey answers. The following provides a brief description of this information:

1. What is your current practice for the use of anti/de-icing chemicals and/or traction aids (i.e., sand) on bridge decks?

   - Rock salt, salt brine and sodium chloride brine, are typically used for anti-icing / de-icing materials. Sand with low additions of salt and/or sodium chloride appear to be the preference for traction aids.
   - The shift from anti-icing and de-icing materials to sand is typically at about -10°C and below.
   - Two respondents reported use of rock salt (sodium chloride) when temperatures are greater -5°C to -6°C. Twelve respondents indicated that rock salt is used when temperatures are greater than about -10°C to -12°C.
   - In cold weather when temperatures are below the previously noted range, a blend of sand and salt or salt blended/pre-wetted with various chloride brines are used. The use of magnesium chloride was noted by four respondents and the use of calcium chloride was mentioned by six respondents. These products were generally reported to being used to about -15°C to -20°C; however, one responded indicated that magnesium chloride can be used to about -65°C. Two respondents indicated that sand with 5% to 6% salt is used, and one respondent indicated that 2/3 sand/salt mixture with brine is used in cool temperatures.
   - One of the 14 respondents do not use anti-icing, instead only dry salt or dry sand (with 5% to 6% rock salt) are used by this agency.
   - It was specifically noted by five respondents that the use of brine helps material stick to the surface and improves efficiency.
   - Three respondents indicated the use of Beet juice (including two pilot projects), and one respondent reported the use of corn syrup and molasses.

2. Three respondents reported using Fixed Automated Spray Technology (FAST) systems on their bridge decks. The FAST systems use potassium acetate or corrosion inhibited magnesium chloride. Is this practice the same, or different than that used on your roadway network?

   - One agency attempts to not apply de-icing materials to bridge decks; however, all other agencies indicated that the same practice is used for bridge decks and the road network, with the exception being that higher priority is placed on bridge decks and key intersections. Bridge decks may get more anti-icing treatments than the road network.
   - One agency indicated that they carry out spot treatments by applying sand and salt on sections of roads that are icy and at intersections, bridge decks, ramps and merging lanes, curves and school frontages rather than continuously sanding the entire road network.

- Several respondents indicated that the strategy is depended on the level of service, the storm event, weather conditions, location and environment. Specific attention is given to slippery sections, particularly at intersections, on hills, curves and bridges.

- Three respondents specifically pointed out that bridge decks could be a different temperature than the adjacent roadway and/or tend ice up more than adjacent pavements. As a result, bridge decks may require a different or more treatment than the adjacent roadway.

3. What products do your presently use for concrete wearing surfaces? What concentrations/application rates are typically used?

   - Sodium chloride (salt), and/or magnesium chloride and calcium chloride are used by various agencies at various dosages.

   - Rarely do products differ between concrete surfaced bridges and asphalt surfaced bridges.

4. What products do your presently use for asphalt wearing surfaces? What concentrations/application rates are typically used?

   - It was confirmed that entities do not have differing products for asphalt or concrete surfaces. The only exception to this is that one agency only uses calcium chloride on asphalt wearing surfaces under exceptional conditions (i.e., calcium chloride is not used on concrete wearing surfaces).

   - Although the products are the same for both concrete and asphalt wearing surfaces, four agencies specifically indicated that product and concentration selection is dependent on the surface type, road type, traffic, temperatures (air and bridge deck temperatures at surface and at depth), temperature trend, site specific forecasts and wind. Both chemical properties and melting properties need to be considered when selecting the treatment type. Exposed concrete bridge deck surfaces (i.e., without some type of overlying surfacing such as an asphalt concrete layer, a micro-surfacing layer or some kind of seal layer) are rare. Two agencies indicated that they do not have exposed concrete wearing surfaces on their bridge decks.

5. What temperature considerations are employed in the selection of anti/de-icing chemicals and/or traction aids?

   - The common practise appears to be the use of salt at temperatures between 0°C and -10°C. Below -10°C calcium chloride or magnesium chloride are typically used. Below -10°C sand, with a small dosage of de-icing chemical to prevent “clumping” is typically used.

   - Five respondents indicated the pre-wetting of salt is used to provide better adhesion of the material to the bridge deck.

6. What environmental protection or environmental considerations are in place for the selection of anti/de-icing chemicals and/or traction aids?

   - Most jurisdictions attempt to balance the effectiveness of a product with its environmental impact.

   - Two agencies reported that environmental impacts are considered during product selection. Both agencies try to select the most effective products with the least known environmental effects. Another agency indicated that only products listed on the Pacific Northwest Snowfighters – Qualified Products List are selected.

   - Two respondents cited Environment Canada. One respondent noted that operations are planned and executed to be consistent with the federal Code of Practice for the Environmental Management of Road Salts. Another respondent indicated that all materials have to meet contaminant specifications set by the

Ministry of Environment, and that rock salt is used according to the best practices set out in the Ministry's Rock Salt Management Plan and is reported to Environment and Climate Change Canada.

- Six entities specifically mentioned “Salt Management Plans” but more attention is provided to aspects such as salt storage.
- In some cases, more emphasis is being placed on the use of “environmentally friendly products such as Beet Juice, corn syrup and molasses.

7. Have you completed any investigation into the potential anti/de-icing chemicals might have on your bridge infrastructure?
   - Although there has been limited research undertaken, entities are very aware of the negative effect chlorides have on bridge deck concrete and rebar.
   - Although a few entities cited references regarding chloride damage to bridge deck, only one entity had undertaken specific research related to their bridge infrastructure. Additionally, one entity reported to have completed a literature review within the department on the effects of de-icing chemicals on the bridge infrastructure.
   - Chlorides are generally considered the largest contribution to bridge deck deterioration.
   - Most entities are very diligent in washing bridge decks (at least annually) and monitoring bridge deck deterioration. Three respondents provided details of their bridge cleaning process and four respondents described their bridge monitoring program. Three entities also specifically noted applying a sealer to bridge decks as a preventative measure. One respondent indicated that supplementary cementing materials are incorporated into the design mix to slow down the chloride ingress into decks.
   - Three agencies reported pilot studies: including one on the use of magnesium chloride on the road network, and two on the use of Beet juice for anti-icing.
8. Are you aware of any research that has been completed on the use of anti/de-icing chemicals and/or traction aids on bridge infrastructure?
   - Several entities cited the Transportation Association of Canada (TAC) “Salt Management Guide”. One respondent indicated that they actively participate with other organizations and Environment Canada in the Transportation Association of Canada committees and Road Salt Working Group
   - Two respondents mentioned Clear Roads – a research organization in the US.
   - One entity provided references to seven publications.
9. What is your experience with automated de-icing systems?
   - Fixed Automated Spray Technologies (FAST) is the most common automated system used by some agencies. These systems typically use potassium acetate. One respondent indicated that corrosion inhibited magnesium chloride is also used.
   - Mixed reviews were seen in the use of FAST with some entities expressing good performance and others decommissioning the systems due to operational or safety concerns. Three agencies reported good performance; three agencies had tried FAST but decommissioned them; and the remaining eight agencies have not installed them. There appears to be a trend that FAST systems work better is less harsh climate conditions.
   - Heated bridge decks are becoming more common in Europe.

4.0 LIMITATIONS OF REPORT

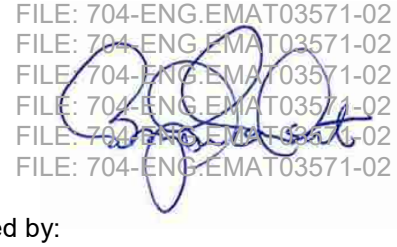
This report and its contents are intended for the sole use of the City of Edmonton and their agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than the City of Edmonton, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on the Use of this Document attached in Appendix B or Contractual Terms and Conditions executed by both parties.

5.0 CLOSURE

We trust this technical memo meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully Submitted,
Tetra Tech Canada Inc.

Prepared by:
Arma Dhaliwal, P.Eng.
Pavements and Geotechnical Engineer
Transportation Practice
Direct Line: 778.945.5745
arma.dhaliwal@tetratech.com



Prepared by:
Bryan Palsat, P.Eng.
Team Lead – Transportation Asset Management
Transportation Practice
Direct Line: 587.460.3558
bryan.palsat@tetratech.com

Reviewed by:
Art Johnston, C.E.T.
Principal Consultant
Transportation Practice
Direct Line: 403.723.6855
art.johnston@tetratech.com

/wgn

APPENDIX A

TABLE A-1 SUMMARY MATRIX OF SURVEY QUESTIONNAIRE

TABLE A-1: SUMMARY MATRIX OF SURVEY QUESTIONNAIRE

Agency / Entity	City of Saskatoon	City of Regina	City of Calgary	City of Winnipeg
Agency / Entity Type	Municipality	Municipality	Municipality	Municipality
1. What is your current practice for the use of anti/de-icing chemicals and/or traction aids (i.e. sand) on bridge decks?	The City road network is divided into different categories based on classification (i.e. expressway, arterial, collector, local, etc.). Most bridges are classified as “high priority/high service level” class because they have high volumes of traffic. The level of service is tied to storm events (i.e. treatments are not applied day to day, rather treatments are applied before, during and after weather events). The City's anti-icing / de-icing practices are dependent on the type of storm event and the level of service (to determine treatment frequency). For “high priority/high service level” roadways, anti-icing / de-icing applications range from once every 4 hours to once every 2 hours. Depending on the weather and temperature, the City either places straight salt mix or sand with 5% salt mix. Straight salt is used when the forecasted temperature ranges between about -5°C and -10°C. Magnesium chloride (about 30%) mixed with sand is used for temperature ranges between -10°C and -65°C. Usually bridges are cleared and salted at the same time as roadways.	The City primarily only uses dry material to control ice (dry sand or dry salt); anti-icing is not used. Dry materials used include dry salt (rock salt - sodium chloride) when the temperature is above -10°C, and below -10°C move to dry gravel or sand (with up to 5-6% rock salt in the sand piles so that they don't freeze). The City started a prewetting pilot project a couple of years ago on a very small selection of short sections of roads to test liquid salt as an alternative to the traditional dry salt/sand mix on local residential streets and some high speed roads (not on any bridge decks). Liquid magnesium chloride was added to sand and salt as a prewetting agent at proportions of up to 20% (i.e. on the controller maximum 20% of liquid was mixed at the spinner point) before it was applied to the roads. This has helped the material stick to the pavement, thereby reducing the overall quantity of dry salt and sand. Primary focus is on how to achieve bare pavement. Overall goal is to keep the salt concentration and application rates as low as possible; however some salt is required otherwise the sand piles would freeze and clumps would form. Tell operators not to apply any products directly on to the bridge decks, and to stop application about 1 truck length (about 25 m) from the start of the bridge decks. Sand and mechanical devices (ploughs, grader, blades) are used on bridge decks. Unless if a spot requires specific attention because it is very icy, then it is treated differently. Depending on the weather and pavement conditions, decide on the most appropriate product for the specific spot - usually try sand first, and if more traction is required then try chips and lastly apply salt. However with colder temperatures adding salt usually doesn't help. If one were to come to Regina they would find the roads covered in sand.	Nothing specific for bridge decks. Sometimes bridge decks are a different temperature than the surrounding roadway so that can lead to slightly different treatments. For example, if there are slushy conditions that are slowly freezing, then maintenance would monitor the bridge decks first because they tend to develop icy conditions before the roadway does. Otherwise, both bridge decks and roadways tend to receive the same treatments/practices.	Anti-icing chemicals (sodium chloride brine) are used on bridge decks in the City of Winnipeg during times of frost and during freezing rain events. The frequency of application is dependent on the weather event. Where snow accumulations greater than 1 cm and temperatures are greater than -10°C, the City of Winnipeg uses rock salt. Where snow accumulations are greater than 3 cm and temperatures are less than -10°C, the City of Winnipeg uses sand.
2. Is this practice the same, or different than that used on your roadway network?	The level of service (frequency/timeline of treatment application and type of product used) varies for the entire network depending on the road class. There is typically a higher priority placed on anti-icing /de-icing bridge decks and some key intersections. In addition, there is typically more snow clearing and less salting on the road network compared to bridge decks. Local roads generally don’t receive the magnesium chloride sand mix.	On the road network the City does not continuously sand. Apply sand and salt selectively on sections of roads that are icy and at intersections, bridge decks, ramps and merging lanes, curves and school frontages (i.e. do spot sanding) and the material is carried by the vehicles. Also sand for a few car lengths before entering an intersection depending on the road type (for example for a large intersection on a high speed road would start sanding at least 9-10 car lengths before entering the intersection and continue sanding up to the point where the intersection starts). The ploughs and sanders work closely. Plough first then sand. Plough policy description below. The sanders cycle the roads every 4 hours, and wherever the operators observe that the pavement is icy they apply product. Typically use separate equipment/vehicles for ploughing and sanding/salting; however the City does have some sander vehicles with the plough attached. These are generally used on high speed roads, not on the residential/smaller streets. Only use plough where it is required. Plow snow according to the priority categories as follows (from City website): - Major Arterial Roads are plowed within 24 hours with a minimum 5 cm of snow. - Minor Arterial Roads are plowed within 36 hours with a minimum 5 cm of snow. - Major Collector Roads, Industrial/Commercial Roads, and Transit Routes not yet completed are plowed within 48 hours with a minimum 10 cm of snow. - Minor Collector Roads and streets near School Zones are plowed within 60 hours with a minimum 10 cm of snow. - Residential Roads are plowed after 25 cm of snow from single event when weather and time permit.	Same treatment as bridge decks, unless the temperature is cooler on the bridge decks than the adjacent roadway.	Anti-icing is different but sanding and/or salting is the same. Anti-icing is done on P1 network.

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Agency / Entity	City of Saskatoon	City of Regina	City of Calgary	City of Winnipeg
Agency / Entity Type	Municipality	Municipality	Municipality	Municipality
3. What products do your presently use for concrete wearing surfaces? What concentrations/application rates are typically used?	Straight salt is used when the forecasted temperature ranges between about -5°C and -10°C. Magnesium chloride (about 30%) mixed with sand is used between -10°C and -65°C. The same materials/products are used before, during and after storm events.	Normally use sand and rock salt. For "sand and rock salt" the maximum concentration of the salt is typically 5-6%. Also see response to Question 1.	Don't differentiate between concrete and asphalt wearing surfaces. The following products are used: - 6.5 mm sanding chip blended with 2% road salt. - Granular road salt. - Hot mix, which is a blend of sanding chips, road salt and ¼" minus, which is a sand and sodium chloride blend. - Calcium chloride with 8% rust inhibitor. - Salt brine (23.3% sodium chloride). - Beet 55 (a proprietary substance, the City does not know exactly what it is comprised of). Beet 55 was used during the 2018/2019 season on downtown cycle tracks and as a pre-treatment on downtown priority 1 roads – just experimenting with it.	Sodium Chloride brine at 27% concentration applied at 80 liters per lane-km.
4. What products do your presently use for asphalt wearing surfaces? What concentrations/application rates are typically used?	Same treatments/products as concrete wearing surfaces. No differences between the two wearing surfaces.	Same as response to Question 3.	Same as response to Question 3.	Same as response to Question 3.
5. What temperature considerations are employed in the selection of anti/de-icing chemicals and/or traction aids?	See response to question number 3 for temperatures. Each product is limited in suitability for a certain temperature range, so the City just follows the advised temperature range.	Addressed in response to Question 1.	The concentration/application rate depends on the road conditions. The City has developed a chart with guidelines for concentration/application rates dependent on the road conditions. In general, pre-wet sodium chloride salt is used to control icy roads for forecasted temperatures of -5°C or higher. A combination of pickle & salt mix (Hotmix) or sand & salt mix are applied to slippery sections of roadways when temperatures reach -15°C (1/4 minus can be used as an alternative for black ice). Calcium chloride or salt brines are sprayed on to salt and pickle to reduce the amount of back-splay or bounce. Anti-icing (calcium chloride or salt liquid brine) is sprayed directly on the road in advance of a storm to prevent the bonding of ice on the road surface. Liquid brines are applied to designated routes prior to the dew point and the pavement surface temperatures coming within 3°C of each other. Anti-icing continues if pavement surface temperatures	Whether the is temperature dropping below -10°C or staying above -10°C.

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6. What environmental protection or environmental considerations are in place for the selection of anti/de-icing chemicals and/or traction aids?	Environmental impacts are considered during product selection. The City tries to select the most effective products with the least known environmental effects. However once the products have been selected there aren't many environmental considerations. Annual bridge sweeping and bridge washing is completed to clean up the debris. In addition the City completes a pre-sweep as soon as the weather changes to pick up debris. The annual bridge washing program and detailed cleaning is completed in the summer to remove salt off of the bridges and manage the impact salt has on the service life of the structures. In addition, a sealer is applied to concrete bridges with rebar to prevent water from penetrating into the concrete and corroding bridge structure rebar.	Educate operators: too much chloride is not good for the environment. Recently procured profile sanders with advanced controllers. With these the material is applied directionally and because of the advanced controllers the application rates can be controlled. The application rates are condition dependent (temperature, wind, weather). The minimum and maximum application rates for dry salt are set at 100 g/cm^3 and 300 g/cm^3. For sand the maximum application rate is 600 g/cm^3. The application rates can be varied in increments of 50 g/cm^3. Also the City collects runoff samples from several different sections of the creek that runs from one end of the City to the other at the start and end of the season to see how salt is impacting the water quality of their storm channels. It provides a quick indication on whether they are polluting it; however since the City does not use much salt, the water quality has generally been good.	Calgary Roads' snow and ice control (SNIC) program is guided by a Road Salt Management Plan, the objective of which is to promote environmental protection while maintaining road safety. There are many environmental considerations addressed in the plan including best management practices for SNIC material selection, storage and handling, application on roadways, identification of salt vulnerable areas, and spring cleanup of SNIC materials. The City's operations are planned and executed to be consistent with the federal Code of Practice for the Environmental Management of Road Salts. They actively participate with other organizations and Environment Canada in the Transportation Association of Canada committees and Road Salt Working Group to share information on best practice applications and emerging technologies. The City also conducts their own trials of alternative pre-wetting and de-icing materials, for example their pilot use of the Beet 55 brine product in the past two SNIC seasons. Two key environmental considerations for that pilot were the potential for environmental impact of the product (i.e. toxicity to human health, plants, and aquatic organisms) relative to chlorides, and to what degree the alternative product enables a reduction of salt use. (Other key considerations were the relative cost, effectiveness, and corrosiveness of the product relative to chlorides).	None.
7. Have you completed any investigation into the potential anti/de-icing chemicals might have on your bridge infrastructure?	No known studies have been completed. The City is aware of the impacts and how the anti-icing chemicals with chlorides react with the concrete and rebar, so understand the risks, and have a program for bridge maintenance in place to try to help mitigate the risks. The bridge program includes washing yearly, and seal bridges on a 5 year cycle. Bridge structures are also inspected yearly by the City, and on a three year cycle by an external consultant. For bridges that are over 10 years old (or its been 10 years since the last rehabilitation) a testing program is carried out every 6 years. The testing program involves measuring the chloride in the concrete and tests on the structure to estimate the service life and how current conditions could affect life cycle costs of the structure (i.e. the maintenance, monitor and preservation plans of each structure). After 10 years a detailed deck testing program is carried out, and repeated on a 6 year cycle. The testing involves extracting samples to determine amount of chloride in the concrete, to see how the rebar is actually corroding, and delamination testing. The objective of these inspections and tests is to investigate service life changes (i.e. deteriorating faster than anticipated), they are not specifically being carried out only because of / to determine the effects of the anti/de-icing chemicals. In general, City bridges are deteriorating at the anticipated/projected deterioration rate, and sometimes the impact is not as bad as anticipated (i.e. slower deterioration than projected). The City completed research with other municipalities on anti-icing chemicals – different levels/percentage of salt largely impacted the amount of chloride that could get into the bridge deck and it depends on the protection system each bridge has. For example exposed concrete is the worst, whereas a membrane and an asphalt surface is expected to perform better as long as the integrity of the membrane is performing adequately.	The City has an understanding that any chloride is bad for bridge infrastructure, so they don't apply directly to bridge decks. Not aware of any studies completed specifically to determine how the City's salt application is impacting bridge decks. However, the pilot study noted in Question 1 is underway.	Chlorides are one of the biggest contributors to bridge deterioration. The City regularly has consultants complete bridge deck surveys, which consists of a series of testing including: - Measurements of the rebar cover. - Level and depth of chloride penetration into the concrete. - CSC testing of the rebar to determine the potential level at which the rebar is actively corroding at. The deck surveys provide a good indication of the level of chloride penetration (i.e. whether the chlorides have reached a level at the rebar that is starting to cause problems). The surveys also allow the City to gauge the effectiveness of their mitigation efforts, which range from washing and sealing (i.e. applying polymer asphalt to seal things off), and enables the City to strategize their rehabilitation works and provide practical feedback to the City's Bridge Design Group. The City has an inventory of about 200 traffic bridges, about 10% of the bridges are surveyed every year. Chloride induced corrosion is probably the number one deterioration observed on bridge decks. Maintenance includes sealing chlorides out of the bridge, but once the chlorides have reached the rebar in sufficient levels the bridge needs to be rehabilitated because there's not a whole lot of other things that can be done. Rehabilitation essentially comprises removing chloride contaminated concrete and replacing it with non-contaminated concrete.	No.

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Agency / Entity Type	Municipality	Municipality	Municipality	Municipality
8. Are you aware of any research that has been completed on the use of anti/de-icing chemicals and/or traction aids on bridge infrastructure?	The City is aware of other studies/investigations that have been completed by other agencies *(but no specific references were provided)* .	Yes - City generally follows reports by TAC and Environment Canada. Periodically review studies completed by DoT's, and collaborations between Canadian/American universities and DoT's/MoT's, and many Michigan DoT studies/reports.	Not aware of any recent specific research projects; however, some studies may have possibly been completed in the past and would be in the archives. The City is quite familiar with the effects of chlorides on bridge infrastructure, so a battle the City is fighting in their area all the time is– how to combat the negative effects of chloride.	No.
9. What is your experience with automated de-icing systems?	The City has researched and considered the use of automated de-icing systems (permanent installations on a bridge where there's a pump, fill up a reservoir and there's an automated spray system) in the past / during the design phase of a couple of projects. It was determined that it would not be a good fit for the City due to potential maintenance issues. The City has also looked into the truck mounted sprayer system, but determined that they were not interested as they are specific to only bridges (can't use them elsewhere in the City), as well as high initial capital costs, ongoing maintenance costs, and operations costs of the system.	The City does not have any FAST systems and does not have any first hand experience with FAST systems (however are aware of them and of other agencies using them through conferences/meetings). Such systems would likely be tricky as someone needs to monitor them since weather patterns have been changing significantly (i.e. recently experiencing much more freezing rain compared to the past), so controls would need to be in place with the automated systems.	No automated systems on bridge decks in the City; however, embedded heating elements were installed on a new concrete stairway leading to downtown about 5 years ago. Have heard second hand that the heating elements work fine when they work; however, there have been some issues with the heating elements and they require regular maintenance (there may be some technical issues with the heating element). There have been some talks about heating up bridge decks to try to control the ice, however, there is some concern as sometimes the biggest challenge with ice control is dealing with the differences in temperatures, which the heating elements could introduce. There is some concern/speculation that the heating elements could introduce variable temperatures across the bridge deck where there could be an area that is melting and water tracks onto another area that is potentially freezing.	None

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Agency / Entity	Anonymous Entity	Saskatchewan Ministry of Highways and Infrastructure	Manitoba Infrastructure and Transportation	Ontario Ministry of Transportation	University of Waterloo	Lafarge - SEAHD/SWAHD
Agency / Entity Type	Provincial Agency	Provincial Agency	Provincial Agency	Provincial Agency	Academic	Private Operator
1. What is your current practice for the use of anti/de-icing chemicals and/or traction aids (i.e. sand) on bridge decks?	The department's practice is to plow any snow and, if required, apply sand or salt, the decision regarding the appropriate practice of sand/salt application is determined by the highway contractor. Sand is used for slippery sections, particularly at intersections, hills, curves and bridges. Salt is used based on a number of factors, including temperature, traffic volume, the time of day, road geometry, and expected weather conditions. As a preventative measure, bridge decks are also sealed every 3 to 4 years to slow de-icing ingress into the decks. Supplementary cementing materials are also incorporated into the design mix to slow down the chloride ingress into decks.	Typically use sand on the bridge decks. It typically includes some magnesium chloride. The Bridge Preservation group is concerned about the use of magnesium chloride on the bridge decks in terms of the corrosive effects of the magnesium on the bridge, so they produced specifications to reduce/limit the amount of magnesium chloride in the de-icer material. The maximum amount of magnesium chloride that the Province allows in the de-icer material is 4%.	Our Department uses salt brine and Fusion(Beet Juice) for anti-icing, and straight pre-wet road salt for de-icing. Treated winter sand is used for traction control at the colder temperatures. The salt brine mixture consists of 60% Salt Brine and 40% Beet Juice as per the supplier.	Use anti-icing liquids in advance of snow accumulation on high traffic highways (the choice of the specific liquid is left up to the contractor). Also use dry or pre-wet rock salt during storms at temperatures as low at -18C, and sand is used at cooler temperatures. Also have FAST systems (automated spray technologies) that use potassium acetate. The FAST system is used on seven bridge decks. A screening system exists for selecting bridges to install the Fast system on. The bridges need to meet a combination of criteria (risk, traffic volume, prone to icing or in a higher risk kind of environment, collision information) because the FAST systems are not cheap to install or operate, so there's some benefit cost that needs to be considered.	No response provided.	We use sand/salt pre-wetted with calcium chloride if required.
2. Is this practice the same, or different than that used on your roadway network?	Bridges are treated as part of the road network and receive the same treatment, with that said bridges often ice up more than the surrounding road so they may receive more treatment.	The same products applied to the bridge deck would also be applied to the sections of the road adjacent to the bridge deck. As the operators are spraying the anti-icing or traction aids along the bridge decks, they would just continuously spray on the adjacent sections of highway as well. The entire network receives the same products.	We don't do much anti-icing on the road network in our region, more pre-wetting.	Same practice for both, except that FAST system is only used on several bridge decks.	No response provided.	Bridge decks are treated in the same way as adjacent roadways.

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3. What products do your presently use for concrete wearing surfaces? What concentrations/application rates are typically used?	Typically sand (treated or untreated) is used for traction and salt (sodium chloride) is the primary de-icing agent. Calcium chloride and magnesium chloride are also used in some areas for de-icing. All materials (sand and salt) are pre-wetted as they leave the truck with either a salt (sodium chloride) brine or calcium chloride or magnesium chloride solution and at times the salt brine is mixed with either the calcium or magnesium chloride solutions. Application rates are determined between the District and the Contractor.	Magnesium chloride is primarily used at maximum 4%. Also use calcium chloride liquid de-icer and sodium chloride salt. The calcium chloride liquid de-icer is typically used as a pre-wetting agent. It is applied to the sand in order to pre-wet it to enable the sand to stick better to the pavement surface or the bridge deck when it is applied. The calcium chloride liquid de-icer is applied at about 63-158 kg/lane-km. The sodium chloride granular salt is applied at rates ranging from 70 to 175 kg/lane-km. The magnesium chloride is not a separate product - it is a component of calcium chloride de-icer. When magnesium chloride is present in the liquid de-icer, it's concentration is limited to maximum 4%.	The products and concentrations are the same that is being applied on the adjacent roadway surfaces (i.e. don't add any additional products). The products include salt brine, Fusion (Beet Juice) for anti-icing, pre-wet road salt for de-icing, and treated winter sand for traction control.	Rock-salt is primary, but also use anti-icing liquids or pre-wet liquids, including sodium chloride, magnesium chloride and calcium chloride.	The current de-icing practice in Ontario is to use rock salt at an application rate of 130 kg/2Ln-km (with a 5% by mass pre-wet). Sand is applied at a rate of 570 Kg/2Ln-km when temperature are too cold for salt to be effective.	We don't have any concrete wearing surfaces on bridges decks.
4. What products do your presently use for asphalt wearing surfaces? What concentrations/application rates are typically used?	Same as response to Question 3.	Same as response to Question 3. It is noted that in Saskatchewan the majority of bridge decks do not have exposed concrete decks. Most bridge decks the concrete is covered by either an asphalt concrete layer, a microsurfacing layer or some kind of seal layer. There are very few bridge decks in the Province where the concrete is exposed.	Same as response to Question 3.	Same as response to Question 3.	Same as response to Question 3.	We use sand/salt pre-wetted with calcium chloride if required.
5. What temperature considerations are employed in the selection of anti/de-icing chemicals and/or traction aids?	Sand will be used at any time when roads are slippery. Salt (sodium chloride) will typically be used for de-icing at temperatures between 0° and -10°C. Calcium or magnesium chloride is used at temperatures between -10 and -20°C. The use of these materials will also depend on time of day, temperature trends, and amount of traffic.	When the pavement temperature is below -11°C, granular salt loses its effectiveness and does not stick or stay on the bridge deck surface. Therefore at temperatures below -11°C, a pre-wet salt is preferred because the pre-wet material enables the salt to stick to the bridge deck surface. This method seems to be effective up to -35°C.	Temperatures up to -5°C are treated with anti-icing/pre-wetting. Temperatures between -5°C and -15°C are treated with de-icing. Below -15°C we use treated sand for traction control.	Higher rates are normally used at colder temperatures. Anti-icing is only used when the surface temperatures are forecasted to remain higher than a set level above the chemical's freeze point. MTO has a chart for this. Chemicals (salt brine, magnesium chloride and calcium chloride) are selected based on expected temperatures at the location of use across the Province.	At -12°C and below. This will also depend on the forecasted temperature (going up or down).	Have a winter maintenance decision support system. Decision to sand and salt, or just sand is based on road type, mainline or ramp/loop, wind condition, now condition, and roadway surface temperature.

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6. What environmental protection or environmental considerations are in place for the selection of anti/de-icing chemicals and/or traction aids?	The department has an Environmental Management Plan for salt handling which primarily deals with handling and storage at the highway maintenance yards.	Two parts to response: a. Through the use of pre-wet materials over the years the Province has been able to use less material because the material sticks to the surface and there is less material loss into the ditches from traffic and wind. There tends to be a high chance of losing materials at curves, hills and intersections. b. Salt storage strategies such as a salt management guide, and setting up salt storage facilities to meet certain standards to prevent leachate of salt into the groundwater.	We have a trial in progress using Fusion as a pre-wet for our road salt and some anti-icing on some bridge decks. Our Department has its own salt Management plan which is mainly housekeeping and we now have all of our storage in covered buildings. Application rates vary from 250 kg to 400 kg per km for our road salt.	All materials have to meet contaminant specifications set by the Ministry of Environment. Rock salt is used according to the best practices set out in the Ministry's Rock Salt Management Plan, and is reported to Environment and Climate Change Canada. Potassium acetate is used with the automated anti-icing spray systems on bridge decks equipped with the FAST system. Have specifications for impurities - both the rock salt and liquid specifications list the maximum amounts. In terms of environmental protection salt is stored in covered facilities, there are systems at the yards to contain run-off, and have oil-water separators, and have secondary containment for some of the anti-icing liquids in the tanker trucks that go down the highway. Good house keeping practices that including pushing salt back into the dome so that salt is not sitting out in the yard or in the mouth of the dome. These housekeeping techniques are described in the Rock Salt Management Plan.	No response provided.	We choose products from the Pacific Northwest Snowfighters – Qualified Products List.
7. Have you completed any investigation into the potential anti/de-icing chemicals might have on your bridge infrastructure?	We have reviewed various research papers and conducted literature review within the department on the effects on de-icing chemicals on the bridge infrastructure.	Haven't completed any targeted research to identify the long term effects. However, there have been concerns from the bridge preservation group about the negative effects of salt on the bridge infrastructure. The group has looked into reducing the amount of magnesium chloride allowed in liquid de-icer products as they want to reduce the concentration as much as possible but still have an effective de-icer. As noted in the responses to questions 1 and 3 the group currently allows a max concentration of 4%.	We conduct detailed condition surveys on bridges to help us determine the amount of damage/deterioration over time on an as needed basis but have not conducted any studies that might look at the differences between different de-icing products or the application rates. We do annual Level one visual bridge inspections.	The MTO in collaboration with the Engineering Research Office, completed a field study on corrosion rates associated with different winter liquids for the effects on vehicles. Bridge office has completed some corrosion studies on chloride ingress rates.	We did a study for MTO related to jurisdictional review of anti-icing as well as a number of studies on de-icing materials (e.g. performance evaluation of different materials, rates and pre wet ratios etc.). None focused on bridge decks only.	We have not.

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8. Are you aware of any research that has been completed on the use of anti/de-icing chemicals and/or traction aids on bridge infrastructure?	We are aware of the following research reports: - The Deleterious Chemical Effects of Concentrated De-icing Solutions on Portland Cement Concrete, Lawrence L. Sutter, Ph.D. Michigan Tech. April 2008. - NCHRP report 577 – Chapter 4. 2007. - Effects of De-icers on Concrete Deterioration – The University of Kansas Center for Research, Inc. December 2007. - Report in Progress: Inhibitor Longevity and De-icer Performance Study: Western Transportation Institute College of Engineering Montana State University – Bozeman for the Research Office Washington State Department of Transportation, initiated October 2007. Draft Report due by end of 2008. - Magnesium Chloride as a Road De-icer: A Critical Review. Peter G. Snow, FACI. - Effects of Various De-icing Chemicals on Pavement Concrete Deterioration. Hyomin Lee, Robert D. Cody, Anita M. Cody, and Paul G. Spry 2002. - The Economic Impact of Magnesium Chloride De-icer on Concrete Bridge Decks: A Study for the Montana Department of Transportation, Reid Crowther and Partners, 2000.	Aware of TAC publications.	No.	Research was completed some time ago on calcium magnesium acetate (CMA), urea, porous coating that were indented to store and release chlorides when needed. As least one company has developed a coating material that was an epoxy/sealer with volcanic rock/gravel, which was quite porous. The idea was that the pores would hold the salt and release it as it is needed, so the intention was that less salt would need to be used. However, Ontario has never tried it and is not aware if it has had a lot of take up. An American company had proposed to use this aggregate on a bridge deck, however it wasn't on Ontario's approved designated sources of material list and the other concern was that the aggregate was pointy, and snowblades would take the tips off quickly during winter maintenance. There was also concern that the aggregate would be prone to polishing, which overtime could lead to a more slippery bridge deck. Also, concerned the brine could be subjected to dilution and refreeze if it doesn't drain off. So the material might have more application in an area that has frost, but not snow. Clear Roads (a research organization in the US)	No response provided.	We have not looked into the literature at all.
9. What is your experience with automated de-icing systems?	We installed FAST systems on some of our bridges in the past. However, we found out the FAST system had detrimental effects on our bridge wearing surfaces and in some instances, the system was not fully operational leading to various safety and durability concerns. The FAST system has now been decommissioned from our bridges.	No automated systems have been installed because generally the locations are not dangerous for the operators. However there could be some opportunities to try them out in the future.	None.	There are seven operational FAST systems . The first FAST was installed in 2000. Adjustment of the spraying protocol, so that the chemical is released only when required/needed is challenging, so Ontario is currently reviewing with respect to the effective use of automated spraying. The department has seen the benefit of the system. The first one was installed on a ramp, and within one year they saw accidents drop from several collisions a year to 0. However there's a cost to operating the systems, so there's a benefit cost consideration that needs to be considered. It's good technology, but it needs to be treated as an asset as there is capital cost to acquire and then costs to operate and maintain. The nozzles are cleaned and maintained about once or twice a year. Potassium acetate costs about three times other liquids. Intended to have long service life, generally in line with the service life of the deck.	No response provided.	A Fixed Asset Spray Technology system is in place on one of our bridge decks. It sprayed Potassium Acetate based upon readings from an active sensor. The system was removed as a part of a bridge deck rehab 3-4 years after it was installed and it was not re-established.

TABLE A-1: SUMMARY MATRIX OF SURVEY QUESTIONNAIRE

Agency / Entity	Confederation Bridge Group	Sweco	Miller Group	MnDOT
Agency / Entity Type	Private Operator	International Consultant (Sweden)	Private Operator	State Agency
1. What is your current practice for the use of anti/de-icing chemicals and/or traction aids (i.e. sand) on bridge decks?	Normally apply 2/3 sand/salt mixture with brine wetting for activation and for material to stick. In cold weather sand only is used (very rare) and in freezing rain/icing conditions, salt only is applied. The brine wetting solution consists of 23% salt concentration and water.	Typically salt (sodium chloride). Sand on low volume network.	It's important to understand the (relatively simple) science of de-icers/anti-icing. Need to understand the chemical action and the melt action and the difference between the two. In principle a de-icer, such as salt, needs heat, moisture and time to work. Salt alone won't melt anything; brine does the melting, so salt has to dissolve into brine first. Standard practice should involve brining the bridge deck before it gets slippery, instead of applying salt or sand. Some agencies, such as York region (North of Toronto) do a good job of anti-icing by spraying brine. They don't sand because it doesn't get cold enough. Agencies should include brining in the bridge deck winter maintenance go-no-go strategy decision tree. The strategy is dependent on the level of service strategy (plus, location, environment). For example if the level of service required after a storm is bare pavement, then have to have an interface / chemical layer at the surface of the pavement that prevents snow and ice from bonding to the surface, because without an interface snow and ice will bond to the surface and will be nearly impossible to scrape off or hard scraping would be required, which could destroy the pavement. For example magnesium chloride is used as an interface on an ice road located North of North Bay in Ontario (rather than salt brine) because salt brine stops melting at about -10°C to -12°C. Use corn syrup, beet juice or molasses. The synergistic reaction between a carbohydrate and a chloride lowers the freeze point (5°C colder before it freezes) and reduces the corrosion factor. 10 million L of corn syrup and 20 million L of liquid salt brine are distributed each year.	Combination of Fixed Spray Systems Using either corrosion inhibited magnesium chloride or potassium acetate or same as roadway using trucks and rock salt that may be blended with various chloride brines. Bridge Decks may get anti-icing treatments depending on the conditions.
2. Is this practice the same, or different than that used on your roadway network?	This is part of the Trans Canada Highway Network. Normal DOT practice is to use salt only. Occasional pre-application of brine to bare roads is performed if forecast suggests beneficial. Brine is used on the bridge deck to hold material to the deck. Brine application is not completed prior to storms.	No	There's a best practice for treating bridge decks differently from the adjacent roadways. May need to pre-treat/anti-ice a bridge deck with different chemicals depending on the level of service strategy, pavement surface and weather. Both chemical properties and melting properties need to be considered when selecting the treatment type. For example, with concrete that’s grey to whitish there’s less heat from radiation, and if there’s low traffic volumes then there’s no heat from traffic so salt will completely stop working at about -12°C, so an agency might use a different chemical than the adjacent section of road for these reasons.	For locations without fixed spray systems the practice is the same except bridges may get more anti-icing treatments.

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Agency / Entity	Confederation Bridge Group	Sweco	Miller Group	MnDOT
Agency / Entity Type	Private Operator	International Consultant (Sweden)	Private Operator	State Agency
3. What products do your presently use for concrete wearing surfaces? What concentrations/application rates are typically used?	Not Applicable - because there are no concrete wearing surfaces	- Roads: Sodium Chloride In solution up to 15%, or 9 grams per m^2. Application rate based on precipitation and road category. - Airports: Sodium Formate	Need a certain amount of chemical to melt a certain amount of ice. In the past it was 450 lbs/lane-mile, and in Ontario it was converted to 130 kg/2 lane-km, because 450 lbs/lane-mile would melt 0.5 inch of snow to water without ever ploughing, so 130 kg/2 lane-km will melt 1 cm of snow to water without ever ploughing. Saltable events and ploughable events are based on this application rate. Different chemicals are used on concrete wearing surfaces and asphalt wearing surfaces depending on the surface type, traffic and weather conditions and temperatures - see discussion in question 2.	Not specific to surface type. Concentrations and application rates are variable.
4. What products do your presently use for asphalt wearing surfaces? What concentrations/application rates are typically used?	Sand derived from crusher operations and screened to 5mm and less. Salt is obtained from Sussex NB. This 2/3 sand/salt mixture is normally applied at 150kg/lane km, but may vary from 60-220kg/lane km depending upon conditions. When straight salt is used it is usually applied at 75kg/lane km.	- Roads: same as concrete, but open texture may require a higher concentration. Calcium Chloride may be used under exceptional conditions. - Airports: Sodium Formate for asphalt concrete and Portland cement concrete.	Same as response to Question 3.	Not specific to surface type. Concentrations and application rates are variable.
5. What temperature considerations are employed in the selection of anti/de-icing chemicals and/or traction aids?	Air temperature, bridge deck temperature (surface temperature and temperature at depth), temperature trend (such as sun in morning causing heating), site specific forecast, winds. Salt is used at temperatures down to -10°C. The sand/salt mixture is used between -10°C and -20°C. Only pure sand is used at temperatures below -20°C.	Sodium Chloride is applied at temperatures down to -6°C. Sodium formate and calcium chloride between -10°C and -18°C. Traction Aids: Winter Tires are mandatory for cars and trucks 1 Dec – 31 March. Studded tires are allowed and commonly used, except for the Southern part of the country.	There's a long standing chart used for over 30 years in Ontario on what to do at different temperatures and weather events as the treatment is dependent on service level and weather conditions. A weather event can be quite dynamic. Two examples of different weather events with the same level of service (bare pavement as soon as possible after a storm) are as follows: #1: Storm starts as a mild flurry that develops into snow fall intensity, and when the storm is over temperatures plunge (as they typically do in Edmonton after a storm due to westerlys / Alberta-clippers). In this case if you don't have bare pavement within 1-2 hours you'll never get bare pavement because the temperature will drop 10°C to 15°C and whatever brine is left on the surface will freeze. As the storm front moves through and the air dries up, the pavement then dries up and becomes bare and dry. With this weather event it would not be good to apply a chemical that will get the road bare and wet, and eventually bare and dry due to the cold air, because then a traction aid would be required. #2: Storm starts in a very cold condition. Apply a traction aid (i.e. sand) in the first place. In northern Ontario they sand a lot - sand is layered on to snow over months (want to distribute the material evenly so that sand pockets don't develop and pothole the snowpack) and the salt is distributed on the centerline so that it melts/dissolves and creates a brine that flows across the crossfall (salt shouldn't be distributed across the lane because it won't turn into a concentrated brine).	Fixed spray systems use the same product regardless of temp. Truck systems use sodium chloride solid/brine at 15 degrees and above and lower temp blends below.

Agency / Entity	Confederation Bridge Group	Sweco	Miller Group	MnDOT
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6. What environmental protection or environmental considerations are in place for the selection of anti/de-icing chemicals and/or traction aids?	All materials (sand and salt) are stored indoors. Salt is used as the waterway below the bridge is salt water as well – so minimal issues. Materials, mainly sand, are swept up and recovered between storms. Materials have also been tested for toxicity to ensure not harmful to environment.	Local Governments decide what can be used, which is usually sodium chloride. In some cases all chemicals are banned, especially in the north with cold winters.	Beet juice, corn syrup and molasses are environmental friendly, and all three are used. 10-12 million L of corn syrup is distributed every year. Beet juice is hauled from Milton, Ontario (outside Toronto) to Lavale, Quebec for a bridge which Miller is the asset manager for. The bridge is over open water at -35°C, so the bridge deck frosts every day all winter. Beet juice is used because don't want to corrode the bridge. With beet juice get lower eutectic and less corrosion. There's environmental protection by using beat juice because it's a natural product (but it lowers the BOD in the water, which might harm the sturgeon in the river). Miller has a 30+ year contract term on the A-25 (Autoroute 25) between Lavelle and Montreal. The current salt rate is about 150 kg/2 lane-km (could double to about 300 kg/2 lane-km for consistency with MTQ). It was noted that if a sufficient gap doesn't exist between the time the salt is applied and ploughing to allow the salt to dissolve and become a brine, then more than half of the salt would just get ploughed into the ditches. 140,000 tonnes of salt in Ontario this winter on the highways at 22% to 26% concentration means tens of millions of liters of brine is made every year. All of the salt will turn into brine somewhere, just want all of the salt to turn into brine on the road surface to justify applying it. Salting and its application rate doesn't mean anything if the plougher cycle follows immediately or shortly after applying salt because most of the salt would just get ploughed into the ditches as salt (it doesn't get the opportunity to turn into brine). Salt within half an hour of the start of a storm, let it dissolve (for half an hour to 2 hours depending on the temperature) before start ploughing the slush off. In the last 10-20 years many authorities across Canada have started using combination salter and plougher units. These result in less power units, less drivers and less cost, but they travel/operate at a compromise of the ideal speeds for both salting and ploughing because ploughing efficiency starts at about 42 km/hour, but if salt is applied at speeds greater than 32 km/hour the bounce and scatter aspect will take the salt off the road. Salting at the same time behind the plough with the same unit isn't necessarily a bad thing, but about half the salt doesn't stay on the road (because of bounce and scatter, or gets ploughed off too early). Salt efficiency would increase if agencies salt and plough separately (which was the case 20 years). Now, even with the same application rates, the efficiency of the salt melting on the road is less because the ploughing equipment is more efficient so the trucks get around quicker now, and as a result tend to plough the salt before it turns into brine. Need patience when salting.	Minnesota has an Approved/ Qualified Products process which incorporates a Hazard Evaluation Process for environmental screening. Both have policies to address them. http://www.dot.state.mn.us/policy/operations/op005.html http://www.dot.state.mn.us/policy/operations/op010.html
7. Have you completed any investigation into the potential anti/de-icing chemicals might have on your bridge infrastructure?	Yes, chloride concerns are carefully considered. Surface build-up of chlorides is measured; as is penetration. Bridge deck including shoulders is swept even in winter conditions and barrier walls are washed in springtime. Every application is reviewed by technical personnel to ensure procedure is followed and the application was necessary. Alternative de-icers have been considered, but issues with effects on structure and environment (potassium on rubber membrane for instance, or products that may alter pH of concrete, or contaminate waters beneath bridge, and cost) have all resulted in continuing use of de-icing salt.	Not known if any effort was done on concrete bridges only. There were quite a few investigations on all sorts of materials earlier.	No actual research because purpose isn't to do research and produce papers. Instead using best practices and available technology. However, they do mark and distribute many products and provide information back to clients to convince them they're on the correct path, especially when mixing food grade corn syrup (or beet juice or molasses) with sodium chloride brine.	There was some evaluation prior to implementing Fixed Spray Systems. Not aware of any formal evaluation or investigation, but there is evidence that salt concentrations from de-icing can accelerate the deterioration of structural steel and steel reinforcement. Once steel reinforcement corrodes, it expands, causing more cracking and spalling of the surrounding concrete.

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8. Are you aware of any research that has been completed on the use of anti/de-icing chemicals and/or traction aids on bridge infrastructure?	Aware of the TAC guide for best practices.	Same response as for Question 7.	TAC Salt Management Guide - 1998 and 2012.	There have been some related to High Friction Surface Treatments.
9. What is your experience with automated de-icing systems?	We have no experience.	The Swiss “Verglimit” has tried these before, but was too expensive and/or the pavement did not last long. Heated pavements are quite common in cities and some airports.	Miller has 3 fixed automated FAST systems (Fixed Anti-Icing Spray Technology)– responsible for flushing them in the spring, re-charging the system with potassium acetate or potassium formate in the fall. There’s a road weather system that automatically fires them. Have put in 6 integrated Road Weather Information System (RWIS) sites in Ontario at own expense (spent about $300,000 on systems and saved about $0.5 M in five years; payback was less than 5 years). Three of the seven FAST systems mentioned by MTO are Miller's to maintain. The 6 RWIS sites were put in 100% at Miller's expense and use, and then negotiated with the Province to take them over and put them in their network….so they still exist.	Several are in place and have had success with them. High volume Metropolitan locations over water or that have icing issues are the primary locations implemented.

APPENDIX B

TETRA TECH'S LIMITATIONS ON THE USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

DESIGN REPORT

1.1 USE OF DOCUMENT AND OWNERSHIP

This document pertains to a specific site, a specific development, and a specific scope of work. The document may include plans, drawings, profiles and other supporting documents that collectively constitute the document (the "Professional Document").

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1.3 STANDARD OF CARE

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If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

1.4 DISCLOSURE OF INFORMATION BY CLIENT

The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by third parties other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this report, at or on the development proposed as of the date of the Professional Document requires a supplementary exploration, investigation, and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

Unless so stipulated in the Design Report, TETRA TECH was not retained to explore, address or consider, and has not explored, addressed or considered any environmental or regulatory issues associated with the project specific design.

1.8 CALCULATIONS AND DESIGNS

TETRA TECH may have undertaken design calculations and prepared project specific designs in accordance with terms of reference that were previously set out in consultation with, and agreement of, TETRA TECH's client. These designs have been prepared to a standard that is consistent with current industry practice. Notwithstanding, if any error or omission is detected by TETRA TECH's Client or any party that is authorized to use the Design Report, the error or omission should be immediately drawn to the attention of TETRA TECH.

1.9 GEOTECHNICAL CONDITIONS

A Geotechnical Report is commonly the basis upon which the specific project design has been completed. It is incumbent upon TETRA TECH's Client, and any other authorized party, to be knowledgeable of the level of risk that has been incorporated into the project design, in consideration of the level of the geotechnical information that was reasonably acquired to facilitate completion of the design.

If a Geotechnical Report was prepared for the project by TETRA TECH, it may be included in the Design Report as appropriate. The Geotechnical Report contains Limitations that should be read in conjunction with these Limitations for the Design Report.

1.10 APPLICABLE CODES, STANDARDS, GUIDELINES & BEST PRACTICE

This report has been prepared based on the applicable codes, standards, guidelines or best practice as identified in the report. Some mandated codes, standards and guidelines (such as ASTM, AASHTO Bridge Design/Construction Codes, Canadian Highway Bridge Design Code, National/Provincial Building Codes) are routinely updated and corrections made. TETRA TECH cannot predict nor be held liable for any such future changes, amendments, errors or omissions in these documents that may have a bearing on the assessment, design or analyses included in this report.