Summary of SNIC Pilot Research and Monitoring Studies

Administration undertook a wide range of research and monitoring studies in 2018-2019 to evaluate the benefits and trade-offs of different winter maintenance tools. These studies comprise of literature reviews, laboratory testing as well as field testing.

Results from the literature reviews were shared with Committee in the June report, CR_6851 (Snow and Ice Control - Pilot Update).

Results from the laboratory and field testing on the effects of salt and brine on safety, infrastructure and the environment have been summarized below. The comprehensive reports are available at edmonton.ca/snowandicepilot. These include:

- Effects of Achieving Bare Pavement on Collisions - University of Alberta (pages 2-3)
- Effects of Salt and Brine on Roadway Concrete - Tetra Tech (pages 4-5)
- Effects of Salt and Brine on Roadway Concrete - Tetra Tech (page 6)
- Effects of Salt and Brine on Asphalt - Tetra Tech (pages 7-8)
- Effects of Salt and Brine on Metal Corrosion - Corrpro (pages 9-11)
- Effects of Salt and Brine on Soil Salinity - Nichols (pages 12-15)

EXECUTIVE SUMMARY

Worldwide, reports on traffic collision statistics and research studies show a dramatic increase in collisions during winter months in regions with adverse winter weather conditions. In Canada, the yearly cost associated with injury and property-damage collisions caused by adverse weather conditions is estimated at $1 billion annually. Not only does adverse weather impact road safety at a considerable cost to the economy, it also significantly reduces traffic mobility. As such, Winter Road Maintenance (WRM) operations are performed to improve traffic safety and mobility. WRM is a costly snow and ice control operation that involves extensive use of both material and manpower as it targets restoring pavement to a safe condition, thereby reducing traffic collisions.

Canadian municipalities are increasingly choosing to implement achieving bare pavement (BP) for snow and ice control during fall/winter seasons. One strategy, when a snowstorm event is forecasted, is to apply anti-icing chemicals to the pavement surface to prevent the snow and ice from forming a bond with the road surface prior to snow fall. Such an approach facilitates a more efficient plowing operation and reduces the amount of deicing chemicals needed to achieve BP compared to traditional reactive WRM. As such, it reduces the cost of WRM operations. In 2017, the City of Edmonton (CoE), with the intention of improving its WRM operations and after a review of current practices in major Canadian cities, expanded a pilot project to test the benefits of achieving bare pavement using anti-icing.

The use of anti-icing has its own limitations. Anti-icing chemicals are applied directly to the road surface compared to reactive deicing where the chemicals are applied to the snow and ice layer, which it penetrates as it melts. While in both approaches, the chemical comes in contact with the infrastructure surface, its direct application in anti-icing may have a stronger impact on the pavement's long-term performance. Another limitation is vehicle wear and tear due to the corrosive nature of the chemicals. However, the CoE has been combining their anti-icing agent with corrosion inhibitor to overcome this limitation.

Since there is limited research regarding the benefits of achieving bare pavement using anti-icing agents, there is debate as to whether or not adopting such a policy would be beneficial from a safety standpoint while also being economically feasible. This report investigates the safety performance of the CoE anti-icing pilot compared to the traditional reactive WRM approach on urban roads using a before-and-after Empirical Bayes (EB) approach, as outlined in the AASHTO Highway Safety Manual. Further, the corresponding changes in collisions were converted to monetary values, based on three different collision cost methods, to determine its economic feasibility.

The safety effectiveness and statistical significance of anti-icing, on 1,293 linear-km of urban roads, for different collision types, severities, and priority levels were determined. Results suggest that reaching BP significantly reduces all collision types and severities on midblocks

with a reduction value in the range of 13.7% to 19.7%. Reaching BP on intersections was found to be very effective in reducing injury collisions with an estimated reduction of 12.50%. When sites were grouped based on a WRM priority-basis, it is found that anti-icing is effective for reducing the majority of collision types and severities on the different priority levels with reductions ranging from 8.70% to 49.83% on midblocks and between 5.37% and 13.00% at intersections. All reductions were statistically significant. Table E1 shows a summary of the evaluation results. The monetary benefits of the reductions in PDO and nonfatal injury collisions were estimated at $20.4 million to $59.4 million using a 1.92% interest rate and a 2-year service life. These findings provide unequivocal evidence that achieving BP using anti-icing can lead to significant societal safety benefits that economically translate in huge collision cost savings.

Further research is required to evaluate the effects of achieving BP using anti-icing at a more disaggregate level, i.e., snowstorm event level. This could provide further insight into the relationship between safety improvements and several WRM variables. In addition, comparing the impact of different anti-icing technologies is recommended.

TABLE E1 Overall Before-and-After Evaluation Results

Collision Location/Type		**Severity**	**SE (%)**	***t*-ratio**
Midblocks Collisions	*All*	*TOT*	16.20	10.20*
		PDO	15.80	9.40*
		INJ	17.84	3.60*
	ILC	*TOT*	19.70	6.04*
	RE	*TOT*	13.73	4.80*
	SPEED	*TOT*	16.63	7.88*
		PDO	16.45	7.38*
		INJ	17.93	2.76*
Intersections Collisions	*All*	*TOT*	1.77	1.57
		PDO	-0.06	-0.05
		INJ	12.48	4.34*
	LTXP	*TOT*	12.38	4.38*
	FOTC	*TOT*	7.72	2.94*

*Statistically significant at the 99% confidence level; *SE* = safety effectiveness, positive implies reduction and negative implies increase; *TOT* = Total; *ILC* = Lane change improperly; *RE* = Rear-end; *LTXP* = Left turn cross path; *FOTC* = Failed to observe traffic control; *PDO* = Property-damage only; *INJ* = Non-fatal Injury.

EXECUTIVE SUMMARY

Introduction

Tetra Tech Canada Inc. (Tetra Tech) was retained by the City of Edmonton (CoE) to conduct an investigation into the effects of sodium chloride (salt) and calcium chloride (brine) on concrete infrastructure (i.e. concrete curbs, medians, bus pads and crossings) adjacent to main arterial roadways and freeways.

The Design and Control of Concrete Mixtures, eighth Canadian edition states: "*The most destructive weathering factor is freezing and thawing while the concrete is wet, particularly in the presence of de-icing materials*". Tetra Tech undertook this research to determine if concrete deterioration was accelerated due to the use of salt and brine.

Literature Review

Tetra Tech completed an overview of research into the effects of de-icing and anti-icing agents on Portland cement concrete (concrete). This includes how sodium chloride (NaCl) salt and/or calcium chloride ($CaCl_2$) brine solutions effect concrete properties. The key findings are as follows:

- Chloride based de-icing chemicals (NaCl or $CaCl_2$) can be safely applied to concrete that is well made, well finished, well cured, of adequate strength and has an effective air void system provided that it is allowed "mature" by undergoing a short period of air drying.
- Use less chemical. Reducing solution concentrations reduces the potential for concrete distress and rate of distress. Apply de-icing/anti-icing brines with an initial concentration less than the pessimum (worst case) amount.
- Use NaCl Brines for anti-icing. The addition of small amounts of $CaCl_2$ may be a good approach provided that the amount of this salt is kept low (and below the pessimum value).
- The detrimental effects of de-icers/anti-icers on concrete exist through three main pathways: 1) physical deterioration such as "salt scaling"; 2) chemical reactions between de-icers and cement paste (especially in the presence of $CaCl_2$ and $MgCl_2$); and 3) de-icers aggravating aggregate-cement reactions.

Studies indicate to combat potential anti-icing and de-icing damage, concrete should meet all design strength, maximum water/cementing materials ratio, air void, finishing and curing specifications. Supplementary cementitious materials can be utilized in concrete mix designs to decrease chloride permeability. This can include the use of fly ash which is commonly used in City of Edmonton concrete applications. The effective use of surface sealants (siloxane and silane sealants) can also be an effective way to reduce chloride ingress into the concrete

Laboratory Testing

To determine the scaling resistance of concrete surfaces exposed to de-icing and anti-icing chemicals using mass loss, concrete panels were cast and tested in accordance with CSA A23.2-22C. The testing was completed on CoE Class 'C' concrete.

The concrete panels were exposed to different concentrations comprising of the following:

- 3% NaCl (as per CSA A23.2-22C);
- 4% $CaCl_2$ (based on total brine solids);
- 8% $CaCl_2$ (based on total brine solids); and
- Distilled water (control sample).

No significant scaling was observed (Category 0) for the control samples and the two samples exposed to brine. The concrete exposed to 3% NaCl was classified as Category 2A, which exhibits the characteristics of slight to moderate scaling of surface mortar (possibly a few popouts).

The test results indicate that, as was expected from the literature review, typical CoE Class C concrete is slightly more prone to freeze thaw damage exacerbated by salt than brine.

Roadway Survey

Tetra Tech was tasked to determine if there were differences in concrete field performance after the 2018/2019 winter season that could be related to the use of salt with sand and/or brine.

In order to document the field performance of sidewalks and curbs, photographic images of five (5) selected sites were obtained in fall of 2018 and again after street cleaning in spring of 2019.

Concrete infrastructure was surveyed along the following de-icing routes, where only salt was placed on the adjacent roadway:

- 122 Street between Whitemud Drive and Fox Drive northbound; and
- Groat Road (87 Ave to Groat Bridge), northbound and southbound.

Concrete infrastructure was also surveyed along the following anti-icing routes where a combination of brine and salt was placed on the adjacent roadway:

- 178 Street between 87 Avenue and 95 Avenue;
- 111 Avenue between 124 Street and 132 Street (Groat Road); and
- 50 Street, 82 Avenue to 101 Avenue and 106 Avenue to 109 Avenue,

Current Condition of Infrastructure

Based on the survey of five roadways where concrete was recently placed, there is little to no sign of actual or potential damage caused by freeze/thaw distress exacerbated by anti-icing and de-icing solutions. This exposure would include any salt and/or brine solutions that may have come into contact with the concrete.

The primary issue observed on the concrete infrastructure was damage from the snow removal equipment on 122 Street, 111 Avenue and 50 Street. The areas of moderate to significant damage due to snow removal are now somewhat more susceptible to freeze-thaw attack exacerbated by anti-icing and de-icing chemicals and deterioration in general.

Future Observations

Further investigation into the few distresses observed could be completed in the future. It is suggested that follow-up surveys later this year (late September/early October) and next spring might better identify locations where a detailed investigation, possibly including core sampling and laboratory analysis should be concentrated.

TETRA TECH

TECHNICAL MEMO

ISSUED FOR USE

To:	Wanda Goulden, FEC, FGC, M.Sc., P.Eng., P.Geo	**Date:**	July 25, 2019
c:		**Memo No.:**	001
From:	Richard Rogoza, P.L.(Eng.), P.Tech.(Eng.), PMP J.D. (Dave) Robson, P.Eng.	**File:**	ENG.EMAT03618-01
Subject:	Residential Concrete Brine Impact Study – Current Condition of Concrete Infrastructure Edmonton, AB		

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) was retained by the City of Edmonton (CoE) to conduct an investigation into the impacts of sodium chloride (salt) and calcium chloride (brine) when placed adjacent to newly constructed Portland cement concrete (concrete) infrastructure (i.e. concrete sidewalks, curbs and driveways) mainly in residential areas. This included comparing the concrete from the fall of 2018 to the spring of 2019. The formal report is presented under separate cover while the following details the current condition of the concrete observed.

2.0 CURRENT CONDITIONS OF CONCRETE INFRASTRUCTURE

Based on the survey of five neighborhoods where concrete was placed in 2018, there is little to no sign of actual or potential damage caused by freeze/thaw distress exacerbated by anti-icing and de-icing solutions. This exposure would include salt and/or brine solutions that may have come into contact with the concrete.

Damage to concrete caused by anti-icing and de-icing solutions would include spalling of the surface which includes removal of surface paste exposing coarse aggregate. Some mortar flaking, and minor scaling (similar to freeze/thaw distress) was observed in two locations (on the north side of 111 Street and limited areas at Laurel) but this may be attributed to construction defects, exposure to more frequent freeze/thaw cycles or ice chipping respectively.

The primary issue observed on the concrete infrastructure was damage from the snow removal equipment on 111 Avenue and the Uplands. The areas of significant damage at 111 Avenue due to snow removal are now somewhat more susceptible to freeze-thaw attack exacerbated by anti-icing and de-icing chemicals and deterioration in general. Some snow removal scraping was observed at the Uplands; however, the damage is not expected to reduce the service life.

3.0 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 the Appendix A or Contractual Terms and Conditions executed by both parties.

Tetra Tech Canada Inc.
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Tel 780.451.2121 Fax 780.454.5688

EXECUTIVE SUMMARY

Introduction

Agencies responsible for constructing and maintaining roadway infrastructure are tasked with balancing public safety and the potential for the harmful effects of anti-icing and de-icing chemical applications. Historically, the effects of anti-icing and de-icing materials have been primarily from an environmental perspective. More recently, attention has shifted to the potential impacts these anti-icing and de-icing materials have on the physical roadway infrastructure, specifically asphalt and concrete materials.

In support of the City of Edmonton's (the City) ongoing investigations into the evaluation of anti-icing and de-icing chemicals on roadway infrastructure, Tetra Tech Canada Inc. (Tetra Tech) was retained to investigate the potential impacts of sodium chloride (NaCl) (salt) and calcium chloride ($CaCl_2$) (brine) on asphalt concrete pavement (ACP). The overall premise of the study was to gain an understanding of the effects that salt and brine may have on asphalt pavements under local Edmonton conditions.

The scope of this investigation focused on three key areas: 1) A literature review of the current "state-of-the-industry practices" for the use of salt and brine, as well as an academic study review of evaluations previously completed by others; 2) A laboratory investigation evaluating the potential impacts salt and brine have on ACP; and 3) A supplemental field review, where a comparison of pavement surface condition pre and post 2018/2019 winter maintenance activities was completed.

Literature Review

The current state-of-the-industry practice review included forty agencies – thirty-two Provincial Agencies/US State DoTs and eight municipalities. This review is based primarily on the works published in the Clear Road Survey (Blackburn and Associates, 2013 and 2014) and the C-SHRP 1999/2000 Lead State Survey (C-SHRP 2000).

Sodium Chloride is the most common chemical used in winter maintenance operations as a de-icing agent as the material is inexpensive and easy to obtain. Some agencies also use solid rock salt as an anti-icing agent, however the dry salt is typically pre-wetted before the spreading operation. Salt solution is used in thirty-two states/provinces as an anti-icing agent and $CaCl_2$ brine is used as an anti-icing agent in fourteen states/provinces. Some agencies mix the $CaCl_2$ brine with an organic corrosion inhibitor in solution. Nine agencies use magnesium chloride solution and six states use potassium acetate solution as anti-icing agents in their winter maintenance operations.

In summary, current City winter maintenance practices are generally consistent with industry practice.

Review of recent academic studies into the impacts of anti-icing and de-icing chemicals on asphalt concrete pavements is limited. Of the eleven academic publications reviewed, consensus indicated that exposure to salt and $CaCl_2$ solutions can have a negative influence on some mix properties which could result in a reduced pavement service life. These observations should be qualified because the research reviewed was based on laboratory testing and not field studies.

Laboratory Investigation

The laboratory program was broken into two distinct phases:

- Phase 1: Exposure of the asphalt concrete samples to a selection of anti-icing and de-icing chemicals at different concentrations, and
- Phase 2: Assessment of five key asphalt concrete properties following the chemical exposure.

Phase 1 of the laboratory testing program was developed to mimic actual field conditions as closely as possible. Specimens were prepared with a ±7.0% air void content to reflect typical field conditions. Specimens were then exposed to each anti-icing and/or de-icing material for several cycles, where each cycle was intended to represent one season of exposure in the field. Each exposure cycle would consist of three days submerged in one of the anti-icing and/or de-icing solutions, plus one control sample in distilled water. At the end of each cycle, each specimen was air-dried for one day before the next cycle was started.

Following completion of the chemical exposure completed under Phase 1, Phase 2 of the laboratory program focused on evaluating the potential impact on five key asphalt concrete mix properties:

1. Durability: Assessed with the Cantabro Abrasion Test
2. Moisture Susceptibility: Assessed with the Tensile Strength Ratio (TSR) Test
3. Cohesion (Strength): Assessed with the Dry Tensile Strength
4. Rutting Performance: Assessed with the Hamburg Wheel-Track Test
5. Asphalt Binder Properties: Assessed with Asphalt Binder Characterization Testing

Discussion on the results obtained from the laboratory testing program are as follows:

- Mix durability: There is no indication that the anti-icing or de-icing chemicals investigated have any negative impact on asphalt concrete durability and performance.
- Mix strength (cohesion): It appears that long term exposure to anti-icing and de-icing chemicals may result in some decrease in mix strength, but it is not likely significant enough to have a negative impact on asphalt concrete performance.
- Moisture susceptibility: Although there was a noted decrease in moisture susceptibility for the anti-icing and de-icing chemicals, it is not likely to have an impact on asphalt concrete performance.
- Rutting potential: Anti-icing and de-icing chemical exposure had no influence on rutting potential.
- Asphalt Binder Characteristics: Although it was clear that exposure to liquid (any anti-icing/de-icing chemical solutions or distilled water) significantly increased binder stiffness, there was no difference between anti-icing/de-icing chemical exposure and water exposure.

Supplemental Field Review

Supplemental to the laboratory investigation, Tetra Tech completed a field review of select City roadways pre and post the 2018/2019 winter maintenance season. The purpose of this field review was to evaluate the potential in-situ impact anti-icing and de-icing chemicals have under Edmonton winter conditions.

Five roadway sections were surveyed with Tetra Tech's Pavement Surface Profiler (PSP-7000) pre-winter season in October 2018, and post-winter season in May 2019. The PSP surveys provided high resolution right-of-way (ROW) images, as well as Laser Crack Mapping System (LCMS) pavement surface images along each travel lane, for each roadway. Both the ROW and LCMS photologs collected pre and post the 2018/2019 winter maintenance season were included as part of this field review.

In general, no discernible differences in roadway surface condition or performance were observed for roadway sections related to the application of anti-icing and/or de-icing chemicals through the 2018/2019 winter maintenance season. This observation is expected and is reasonably consistent with laboratory observations, given the field review captured only a single season of anti-icing and/or de-icing chemical application and the laboratory program attempted to simulate several seasons of winter maintenance operations.

EXECUTIVE SUMMARY

The City of Edmonton (the "City") commissioned Corrpro Canada, Inc. (Corrpro) to conduct a targeted corrosion research project related to their newly implemented anti-icing pilot project.

The City began their anti-icing pilot project in 2017 to improve the overall efficiency and effectiveness of their winter road maintenance program. The City's existing winter road maintenance program (the "existing program") involves the use of sodium chloride (NaCl) for de-icing purposes. The anti-icing pilot involves the added use of corrosion-inhibited calcium chloride ($CaCl_2$) brine as an anti-icing agent (in addition to NaCl). The inhibited $CaCl_2$ brine is sprayed on the road as a thin layer prior to snowfall to improve the efficiency of snow plowing. This research project involves an investigation into the corrosion impacts of NaCl and $CaCl_2$ on a selection of metals expected to be most exposed to municipal anti-icing and de-icing solutions. The metals tested and reasons for inclusion are detailed below:

- Carbon steel (heavily utilized in vehicle, bicycle and municipal infrastructure construction)
- Galvanized steel (light poles, sign poles, etc.)
- Aluminum (bicycle frames and some vehicles)
- Stainless steel (some vehicle/bicycle components)

The scope of work for this research project included a literature review followed by field and laboratory testing.

The field testing program included the installation and monitoring of corrosion coupons on buses and municipal infrastructure. The coupons were placed in areas where the application of the anti-icing and de-icing products is well known. Half of the coupons were placed in areas that were exposed to NaCl salt only (existing program), whereas the remaining coupons were placed in areas exposed to both NaCl salt and $CaCl_2$ brine (anti-icing pilot). After exposure to Edmonton winter conditions (winter 2018/2019) and retrieval from the field, the corrosion effects of the anti-icing and de-icing products were evaluated.

The laboratory portion of this research study was based on an industry standard corrosion test method (NACE TM0169). The corrosion effects of NaCl and $CaCl_2$ solutions on carbon steel, stainless steel, aluminum, and galvanized steel were evaluated.

The major findings from the literature review, field program, and laboratory programs in this research study are summarized below:

- Anti-icing and de-icing products, including $CaCl_2$, NaCl and other chloride salts, are used globally for winter road maintenance in areas that experience icy conditions.
- Research studies and pilot programs have been introduced worldwide to determine the impact of anti-icing and de-icing products on metal infrastructure and vehicles. However,

the results of research programs found in literature review have been inconsistent. Both laboratory and field programs are highly dependent on several factors, such as metal type, temperature, humidity, amount of exposure, and many more. Literature review has shown significant variations between the corrosion effects of NaCl and $CaCl_2$.

- Literature review of various case studies has proven that laboratory and field testing results do not always correlate with each other. Unknown factors in real world results cannot be easily replicated in laboratory testing.
- Aqueous solutions containing chloride salts, such as NaCl, $CaCl_2$ and $MgCl_2$, are known to cause corrosion to metal infrastructure and vehicles. Regular cleaning and maintenance of protective coatings (i.e. paint) is recommended to minimize corrosion.
- The amount/length of exposure to corrosive environments was a major contributing factor to amount of corrosion observed on laboratory and field coupons. In general, more exposure to corrosive environments leads to more corrosion.
- The amount of corrosion observed varied with coupon material type. Carbon steel was the most easily corroded material, while stainless steel was the most resistant to corrosion.
- With regards to the comparison of anti-icing/de-icing programs, the field testing produced inconclusive results due to insufficient time in the field, varied/atypical application of inhibited $CaCl_2$ brine in winter 2018/2019, and due to the high correlation between exposure amount and amount of corrosion observed. Additional testing time in the field is recommended to further investigate the corrosion effects of the anti-icing pilot.
- In the lab program, the corrosivity of various liquids was tested. The liquids tested included distilled water, tap water, concentrated NaCl and $CaCl_2$ brines, inhibited $CaCl_2$ brine plus multiple brine mixtures and dilutions. The corrosion observed on the coupons varied with liquid type:
  - Tap water was one of the most corrosive liquids, while distilled water was one of the least corrosive liquids. These results display the large effect that impurities have on the corrosivity of water.
  - Salt concentrations had a large effect on corrosivity of the liquids:
    - The addition of NaCl or $CaCl_2$ brines to distilled water significantly increased corrosivity. It is anticipated the effect would be the same on environmental moisture (rain and snow/ice melt).
    - The results indicate that very concentrated aqueous salt solutions (brines) become more corrosive as they are diluted (in the absence of a corrosion inhibitor).
    - Further research is required to better compare the corrosivity of different aqueous salt solution types.
  - The addition of inhibitor had a varied effect on the corrosion observed:
    - The addition of inhibitor appeared to greatly reduce the corrosivity of *diluted* $CaCl_2$ brine, but slightly increased the corrosivity of *concentrated* $CaCl_2$ brine. However, a diluted state of the inhibited $CaCl_2$ brine may be

more typical of exposure conditions in Edmonton (as part of the anti-icing pilot project).

  - When reviewing the corrosivity of all liquids tested, it appears that the inhibitor may only be effective over a range of inhibitor and salt concentrations. Further research is recommended to better understand the range of effectiveness.
  - Biological products formed in solutions that contained diluted inhibited $CaCl_2$ brine. While further research is recommended to understand the impact of these biological products on corrosion, this result does indicate that the corrosion inhibitor would biodegrade over time once released into the environment.
- The results indicate that carbon steel, zinc and aluminum can corrode when exposed to typical environmental conditions found in Edmonton. It is recommended that additional corrosion prevention methods be applied to metal surfaces exposed to corrosive environments. Examples methods include limitation of actual exposure to moisture (keeping surfaces dry), the application and maintenance of high-performance corrosion protection coatings (e.g. paint on a car) or lubrication (e.g. for bicycle chains/cassettes).
- There are many factors that can influence the corrosive effects of anti-icing/de-icing programs. Many of these factors could be investigated further for additional clarification.

August 20, 2019
Project No. 19-424-CAI

Via E-mail: paul.fuellbrandt@edmonton.ca
Original Will Remain on File

The City of Edmonton
11004 - 190th Street NW
Edmonton, Alberta
T5S 0G9

ATTN: Paul Fuellbrandt

RE: Anti-Icing Salinity Data Review
Edmonton, Alberta

Dear Mr. Fuellbrandt:

Nichols Environmental (Canada) Ltd. was retained by The City of Edmonton to conduct an Anti-Icing Salinity Data Review for a number of sites located across Edmonton, Alberta.

BACKGROUND

A planning and monitoring program was initiated to assess the effects of calcium chloride ($CaCl_2$), an anti-icing agent, on the soils and vegetation adjacent to treated roadways. In total, 18 sites across Edmonton, Alberta were selected and sampled in 2018 and 2019 as part of the assessment program. Twelve sites (S1 through S12) were selected by The City of Edmonton and six sites (SA through SF) were selected by the Urban Development Institute (UDI). Of the 18 sites, nine used only road salt (sand mixed with sodium chloride), while the other nine were in areas where $CaCl_2$ was also used. A total of 292 soil samples were collected from the sites at several distances from the road shoulder (1.5 m, 3.0 m, and 7.0 m) and depths (10 cm, 20 cm, and 30 cm). All samples were collected by City of Edmonton personnel and all laboratory analyses were completed by Element Materials Technology.

RESULTS

As part of the review, the road salt and $CaCl_2$ sites were separated for each sampling season, depth interval, and distance interval for both The City of Edmonton and UDI site groups.

City of Edmonton Sites (S1 through S12)

A summary of the City of Edmonton sites is provided in Table 1 (attached).

The average electrical conductivity (EC) and sodium absorption ratio (SAR) on road salt sites were 2.6 deciSiemens per metre (dS/m) and 13.8 (respectively), while the average EC and SAR on $CaCl_2$ sites were 3.6 ds/m and 11.6 (respectively). Overall, the road salt site group average would be classified as having an "Unsuitable" soil condition rating, while the $CaCl_2$ site group average would be classified as "Poor". However, soil conditions were found to have higher percentages of "Good" and "Fair"

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ratings across most intervals for the road salt sites, while $CaCl_2$ sites generally had higher percentages of "Poor" and "Unsuitable" ratings. Sites that used $CaCl_2$ also reported overall higher concentrations for each parameter of concern at most depth and distance intervals. It should also be noted that elevated concentrations and "Poor/Unsuitable" soil condition ratings were found to be increased as both depth from surface and distance from the shoulder increased at those sites that used $CaCl_2$, suggesting potential increased mobility and/or migration.

Urban Development Institute Sites (SA through SF)

A summary of the UDI sites is provided in Table 2.

The average EC and SAR on road salt sites were 1.8 dS/m and 2.4 (respectively), while the average EC and SAR on $CaCl_2$ sites were 1.5 ds/m and 2.8 (respectively). Overall, both site group averages would be classified as having a "Good" soil condition rating. Sites that used just road salt reported overall higher concentrations for each parameter of concern at most depth and distance intervals. However, soil conditions and concentrations were generally found to be similar to those of the same sampling interval within the opposite site group.

CLOSURE

We trust this meets your current requirements. If you have any questions, please contact our office at 780-484-3377 at your convenience.

Yours truly,
NICHOLS ENVIRONMENTAL (CANADA) LTD.
APEGA PERMIT TO PRACTICE NO. P6730

Kyle Jackson, C.E.T.
Senior Project Manager

Reviewed by:

ALBERTA SOCIETY of Professional Biologists
Ryan J. Taylor
1552
PROFESSIONAL BIOLOGIST

PROFESSIONAL GEOLOGIST ALBERTA
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20Aug19

Ryan Taylor, P.Biol., EP
Northern Region Manager

R.W. (Rob) Dickie, P.Geol., R.E.T., EP
President

KJ/RT/RWD/sam

Attachments

Nichols Environmental (Canada) Ltd.

TABLE: 1

TITLE: COE SITE SUMMARY

PROJECT#: 19-424-CAI
CLIENT: The City of Edmonton
PROJECT: Anti-Icing Salinity Data Review
LOCATION: Edmonton, Alberta

All Data - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	1.1	6	25	35	44%	27%	Good
MAX	7.8	50.0	513	1690	1120		18%	Fair
GEOMEAN	1.9	8.3	55	236	220	56%	15%	Poor
AVERAGE	2.6	13.8	89	464	344		41%	Unsuitable

2018 - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	1.1	6	28	36	50%	26%	Good
MAX	7.5	50.0	513	1690	1120		24%	Fair
GEOMEAN	1.9	8.4	56	242	229	50%	11%	Poor
AVERAGE	2.6	14.5	98	472	359		39%	Unsuitable

2019 - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	1.2	14	25	35	39%	28%	Good
MAX	7.8	50.0	497	1510	1030		11%	Fair
GEOMEAN	1.9	8.3	53	231	212	61%	19%	Poor
AVERAGE	2.7	13.2	80	455	329		43%	Unsuitable

10 cm - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	1.1	6	30	35	53%	36%	Good
MAX	7.5	41.0	314	1690	818		17%	Fair
GEOMEAN	1.5	7.1	39	163	154	47%	8%	Poor
AVERAGE	2.0	12.0	59	304	221		39%	Unsuitable

20 cm - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	1.6	19	25	40	42%	25%	Good
MAX	6.0	50.0	325	1330	915		17%	Fair
GEOMEAN	1.9	8.9	50	230	229	58%	17%	Poor
AVERAGE	2.5	14.9	67	469	357		42%	Unsuitable

30 cm - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.6	1.6	21	35	64	39%	19%	Good
MAX	7.8	49.0	513	1630	1120		19%	Fair
GEOMEAN	2.6	9.1	83	350	302	61%	19%	Poor
AVERAGE	3.4	14.6	140	617	453		42%	Unsuitable

1.5 m - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.8	6.7	11	32	104	6%	0%	Good
MAX	7.8	50.0	513	1690	1120		6%	Fair
GEOMEAN	3.2	19.2	48	574	474	94%	19%	Poor
AVERAGE	3.9	23.2	95	797	565		75%	Unsuitable

3.0 m - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.6	3.3	6	44	70	28%	6%	Good
MAX	6.9	50.0	391	1630	1090		22%	Fair
GEOMEAN	2.2	12.1	48	303	292	72%	25%	Poor
AVERAGE	2.8	15.6	76	499	381		47%	Unsuitable

7.0 m - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	1.1	21	25	35	100%	75%	Good
MAX	3.0	5.2	325	320	168		25%	Fair
GEOMEAN	1.0	2.5	70	76	77	0%	0%	Poor
AVERAGE	1.2	2.7	95	94	86		0%	Unsuitable

All Data - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	0.6	8	12	18	33%	10%	Good
MAX	9.3	38.0	1290	2310	2050		23%	Fair
GEOMEAN	2.9	7.7	117	326	308	67%	29%	Poor
AVERAGE	3.6	11.6	221	572	464		38%	Unsuitable

2018 - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.7	0.6	8	19	23	31%	13%	Good
MAX	9.1	38.0	1290	2310	2050		19%	Fair
GEOMEAN	2.8	7.5	121	303	310	69%	31%	Poor
AVERAGE	3.5	11.5	232	573	493		37%	Unsuitable

2019 - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	0.9	10	12	18	35%	7%	Good
MAX	9.3	36.0	866	1840	1550		28%	Fair
GEOMEAN	3.1	8.0	113	351	305	65%	26%	Poor
AVERAGE	3.7	11.7	211	570	436		39%	Unsuitable

10 cm - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	0.6	8	16	18	44%	22%	Good
MAX	7.3	37.0	362	2040	1620		22%	Fair
GEOMEAN	2.0	6.6	67	200	190	56%	22%	Poor
AVERAGE	2.5	10.7	104	378	298		33%	Unsuitable

20 cm - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.9	1.5	11	12	58	33%	8%	Good
MAX	6.6	38.0	760	1970	1610		25%	Fair
GEOMEAN	2.9	8.5	104	327	314	67%	25%	Poor
AVERAGE	3.4	12.7	184	514	419		42%	Unsuitable

30 cm - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	1.1	1.6	17	19	112	22%	0%	Good
MAX	9.3	31.0	1290	2310	2050		22%	Fair
GEOMEAN	4.2	8.3	229	531	487	78%	39%	Poor
AVERAGE	4.9	11.4	376	822	676		39%	Unsuitable

1.5 m - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	1.1	3.4	8	47	117	6%	3%	Good
MAX	9.3	37.0	509	2310	2050		3%	Fair
GEOMEAN	3.7	14.0	92	573	470	94%	36%	Poor
AVERAGE	4.5	17.1	158	848	642		58%	Unsuitable

3.0 m - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.7	1.6	10	38	62	36%	6%	Good
MAX	9.3	38.0	1180	1640	1550		31%	Fair
GEOMEAN	2.7	8.9	91	358	300	64%	28%	Poor
AVERAGE	3.5	11.6	213	532	418		36%	Unsuitable

7.0 m - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	0.6	31	12	18	58%	22%	Good
MAX	6.9	21.0	1290	1410	994		36%	Fair
GEOMEAN	2.5	3.7	192	169	207	42%	22%	Poor
AVERAGE	2.8	6.1	292	335	334		19%	Unsuitable

= Favorable Condition/Concentration
Condition = Percentage of samples that are Good, Fair, Poor, Unsuitable

Nichols Environmental (Canada) Ltd.

TABLE: 2

TITLE: UDI SITE SUMMARY

PROJECT#: 19-424-CAI
CLIENT: The City of Edmonton
PROJECT: Anti-Icing Salinity Data Review
LOCATION: Edmonton, Alberta

All Data - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	0.4	66	3	18	92%	60%	Good
MAX	4.6	11.0	595	948	440		31%	Fair
GEOMEAN	1.6	1.6	166	103	84	8%	8%	Poor
AVERAGE	1.8	2.4	189	207	125		0%	Unsuitable

2018 - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	0.4	66	3	18	96%	67%	Good
MAX	4.6	6.3	506	948	256		29%	Fair
GEOMEAN	1.5	1.5	165	90	80	4%	4%	Poor
AVERAGE	1.7	2.1	188	197	113		0%	Unsuitable

2019 - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.7	0.5	91	16	20	88%	54%	Good
MAX	4.0	11.0	595	670	440		33%	Fair
GEOMEAN	1.7	1.8	166	117	88	13%	13%	Poor
AVERAGE	1.9	2.8	190	217	137		0%	Unsuitable

10 cm - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	1.0	0.4	91	3	23	94%	75%	Good
MAX	3.0	11.0	289	670	440		19%	Fair
GEOMEAN	1.5	1.8	145	96	87	6%	6%	Poor
AVERAGE	1.5	2.8	151	178	128		0%	Unsuitable

20 cm - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.6	0.5	84	14	20	94%	69%	Good
MAX	3.3	9.9	388	818	415		25%	Fair
GEOMEAN	1.5	1.7	139	100	81	6%	6%	Poor
AVERAGE	1.7	2.6	156	202	123		0%	Unsuitable

30 cm - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	0.5	66	11	18	88%	38%	Good
MAX	4.6	6.1	595	948	430		50%	Fair
GEOMEAN	2.0	1.4	226	113	83	13%	13%	Poor
AVERAGE	2.2	1.9	261	242	124		0%	Unsuitable

1.5 m - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	1.2	0.8	100	3	46	78%	33%	Good
MAX	4.6	11.0	397	948	440		44%	Fair
GEOMEAN	2.1	2.8	179	172	148	22%	22%	Poor
AVERAGE	2.3	3.8	197	342	192		0%	Unsuitable

3.0 m - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	0.4	66	11	18	100%	67%	Good
MAX	3.3	6.3	595	450	269		33%	Fair
GEOMEAN	1.4	1.5	158	98	78	0%	0%	Poor
AVERAGE	1.7	2.1	194	167	113		0%	Unsuitable

7.0 m - Road Salt

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.7	0.4	91	15	21	100%	92%	Good
MAX	2.1	1.4	289	132	78		8%	Fair
GEOMEAN	1.2	0.8	159	51	40	0%	0%	Poor
AVERAGE	1.3	0.8	171	65	44		0%	Unsuitable

All Data - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.4	0.2	42	7	8	86%	61%	Good
MAX	3.1	13.0	523	716	503		25%	Fair
GEOMEAN	1.2	1.6	105	55	63	14%	11%	Poor
AVERAGE	1.5	2.8	143	141	109		4%	Unsuitable

2018 - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.4	0.2	42	9	8	93%	64%	Good
MAX	3.1	9.4	523	290	255		29%	Fair
GEOMEAN	1.0	1.3	101	49	54	7%	7%	Poor
AVERAGE	1.2	2.2	146	77	81		0%	Unsuitable

2019 - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.5	0.3	45	7	11	79%	57%	Good
MAX	3.1	13.0	439	716	503		21%	Fair
GEOMEAN	1.4	1.8	109	61	74	21%	14%	Poor
AVERAGE	1.7	3.3	140	204	138		7%	Unsuitable

10 cm - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.6	0.2	49	11	8	90%	70%	Good
MAX	2.8	9.2	292	688	382		20%	Fair
GEOMEAN	1.1	1.1	114	60	49	10%	10%	Poor
AVERAGE	1.3	2.2	132	134	91		0%	Unsuitable

20 cm - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.4	0.6	45	7	18	90%	60%	Good
MAX	3.0	8.0	431	709	337		30%	Fair
GEOMEAN	1.1	1.6	102	51	64	10%	10%	Poor
AVERAGE	1.4	2.5	137	141	99		0%	Unsuitable

30 cm - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.6	1.1	42	14	24	75%	50%	Good
MAX	3.1	13.0	523	716	503		25%	Fair
GEOMEAN	1.4	2.3	98	54	85	25%	13%	Poor
AVERAGE	1.7	3.8	165	148	145		13%	Unsuitable

1.5 m - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.6	0.5	42	15	24	78%	39%	Good
MAX	3.1	13.0	523	716	503		39%	Fair
GEOMEAN	1.5	1.9	128	77	84	22%	17%	Poor
AVERAGE	1.8	3.4	180	179	139		6%	Unsuitable

3.0 m - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.7	1.7	83	60	67	100%	100%	Good
MAX	1.6	3.8	109	279	143		0%	Fair
GEOMEAN	1.1	2.5	94	128	100	0%	0%	Poor
AVERAGE	1.2	2.7	95	163	106		0%	Unsuitable

7.0 m - $CaCl_2$

	EC	SAR	Ca	Cl-	Na		Condition	
MIN	0.4	0.2	45	7	8	100%	100%	Good
MAX	0.8	1.7	85	17	44		0%	Fair
GEOMEAN	0.6	0.7	61	11	20	0%	0%	Poor
AVERAGE	0.6	0.9	63	12	24		0%	Unsuitable

(green) = Favorable Condition/Concentration
Condition = Percentage of samples that are Good, Fair, Poor, Unsuitable