Edmonton

Integrated Infrastructure Services

Business Planning and Support

Engineering Services

Anti-icing Brine Pilot Project

Environmental Monitoring and Metrics Report

2017-2018

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EXECUTIVE SUMMARY

In the winter of 2017/2018, the City of Edmonton Parks and Roads Services Branch undertook an anti-icing pilot program on selected routes. Calcium chloride brine was applied to test routes in a thin layer before or during a snowfall in an effort to reduce the amount of snow that sticks to the road, making snow removal easier and more efficient.

An evaluation was conducted using historic winter road maintenance materials usage, water sampling data at four major outfalls to the North Saskatchewan River, and environmental monitoring at City snow storage sites. Consideration was given to historic data with similar snowfall years and an evaluation of chloride, phosphorus, ammonia and biological oxygen demand which are environmental constituents of concern. The current and historical data provides the necessary information to clearly understand the environmental implications of changes to the City's winter road safety program. EPCOR collects monthly water samples from the four largest storm sewer outfalls, each of which collects stormwater from the City of Edmonton's major drainage basins. This data was provided to the City of Edmonton.

The materials inventory records clearly show that, of the total chloride applied to Edmonton roads for road safety in 2017/2018, 4.5% was due to the application of calcium chloride brine for anti-icing. The incremental contribution of anti-icing brine to environmental chloride loadings during this pilot year was minimal.

A separate program undertaken to reduce road sand was accompanied by increased sodium chloride salt application. The reduction of winter sand application by half to three quarters of the amount applied during previous similar snowfall years was accompanied by an increase in sodium chloride salt application by a factor of 1.7 X to 3.0 X.

The 2017/2018 anti-icing pilot produced no discernable impact on the quality of the City's stormwater that discharges to the North Saskatchewan River. The increased sodium chloride salt application in 2017/2018 was not obvious in the environmental data, potentially due to overland flow, discharge to other outfalls and/or contributions of deicers to the historic loadings data from other sources such as private business and citizens.

Laboratory test results show that brine with organic inhibitors have lower corrosion rates than sodium chloride salt or calcium chloride brine with inorganic inhibitors such as phosphate or magnesium hydroxide. Brine samples with organic corrosion inhibitor additives consistently met the *Pacific Northwest Snowfighters Snow and Ice Control Chemical Products Specifications and Test Protocols* requirement for corrosion value: 30% of the corrosion rate of sodium chloride salt or lower. However, research under road conditions conducted by the Washington State Department of Transportation found that the use of organic corrosion inhibited salt and brine did not reduce corrosion in the field to the rates measured under laboratory conditions. A research program in the City of Edmonton will be conducted to evaluate corrosion rates due to winter maintenance under Edmonton winter road conditions.

A compilation and analysis of monitoring data showed that there were no discernible impacts on BOD, phosphorus or ammonia loadings to the North Saskatchewan River related to the 2017/2018 anti-icing pilot project.

Continued monitoring is necessary to ensure that stormwater quality is not unacceptably impacted due to any future expansion of the anti-icing pilot program. Sodium chloride salt application procedures by the City for winter road safety would benefit from a review and optimization, with a focus on source reduction and the lowest reasonably achievable application rates.

1.0 Introduction

This report documents the environmental monitoring and metrics for the anti-icing brine pilot project undertaken by Infrastructure Operations, Parks and Roads Services, City Operations in the winter of 2017/2018. This evaluation was conducted by Engineering Services, Business Planning & Support, Integrated Infrastructure Services. The analysis includes historical winter road maintenance materials usage, water sampling data at four major outfalls to the North Saskatchewan River and environmental monitoring at City of Edmonton snow storage sites. Consideration was given to historic data with similar snowfall years and an evaluation of chloride, phosphorus, ammonia and biological oxygen demand which are environmental constituents of concern. Laboratory data on brine corrosion rates with corrosion inhibitor additives is also included in this report.

1.1 Background

Each year the City of Edmonton Parks and Roads Services Branch applies a combination of sand and salt to winter roads to improve road safety. Two types of salt are applied:

- Granular sodium chloride salt: "sodium chloride salt"
- Liquid calcium chloride brine: "calcium chloride brine"

"Salt" is the common name for dry sodium chloride (table salt). However, the chemical definition for "salt" is any substance composed of positively and negatively charged ions. There are many kinds of salt including sodium chloride and calcium chloride.

Brine is water with high concentrations of dissolved salt. We commonly refer to a saturated solution of calcium chloride salt as "brine" but technically, brine is a high concentration solution of any type of salt.

For clarity, this report uses the following terms: 'sodium chloride salt' and 'calcium chloride brine'.

Sodium chloride salt is blended with road sand to keep the stockpiles from freezing and additional sodium chloride salt may be added to maintenance trucks depending on the ambient temperature. Historically, calcium chloride brine was used to pre-wet road sand as it was spread, to help the sand stick to the road and improve longevity of the application in trafficked areas.

In the winter of 2017/2018, the City of Edmonton Parks and Roads Services Branch undertook an anti-icing pilot program on selected routes using calcium chloride brine, a naturally occurring liquid pumped from saline geologic formations, with various additives for corrosion inhibition. Calcium chloride brine for anti-icing was applied to roads in a thin layer before or during a snowfall in an effort to reduce the amount of snow that sticks to the road, making snow removal easier and more efficient.

1.2 Objective and Scope

The objective of this monitoring and metrics project is to establish whether there were environmental implications associated with the 2017/2018 calcium chloride brine anti-icing pilot program. The scope of this report includes:

- Winter road maintenance material usage:
    - historic annual sodium chloride salt, calcium chloride brine and sand quantities applied to City streets,
    - 2017/2018 quantities of sodium chloride salt, calcium chloride brine and sand applied.
- Water sampling data from EPCOR outfalls to North Saskatchewan River
    - EPCOR collects monthly water samples at four major outfalls to the North Saskatchewan River, and shared the current and historic monitoring data at these outfalls for use in this evaluation.
    - The City provided funding for increased water sampling frequency at the outfalls for the duration of the 2017/2018 anti-icing pilot program.
    - EPCOR's data of the total kilograms of chloride, BOD, phosphorus and ammonia-N over the last decade were compared to the 2017/2018 winter season.
- City of Edmonton Snow Storage Sites
    - Historic snow meltwater monitoring data and loadings from City of Edmonton snow storage sites were evaluated from October one year to October the next to capture full winter seasons of snow meltwater quality. The chloride loadings in 2017/2018 were compared to chloride loadings during similar snowfall years.
- Laboratory analysis of calcium chloride brine samples containing various corrosion inhibitors.

Chloride a primary constituent of concern related to the anti-icing program and is mobile in the environment. Biological oxygen demand, phosphorus and ammonia were evaluated to establish any measurable impacts related to organic corrosion inhibitors added to the calcium chloride brine. Current and historical data provides the necessary information to clearly understand the environmental implications for the winter 2017/2018 anti-icing pilot project and other changes related to the winter road program.

Limitations

There are 225[1] major and minor storm sewer outfalls that discharge to the North Saskatchewan River and its tributaries. EPCOR collects monthly water samples at the four largest storm sewer outfalls, each of which collects stormwater from the City of Edmonton's major drainage basins. This data was provided to the City of Edmonton. The loadings from the four major outfalls do not represent total loadings from the storm sewer system in Edmonton. However, the monitored outfalls are critical indicators of City stormwater quality and are used herein to compare the anti-icing pilot year to prior years.

Each year, private business and residents apply snow melt products to sidewalks, driveways and parking lots. Most commercially available snow melt products are chloride-based and often a blend of calcium chloride and sodium chloride, but may contain other chloride salts. The amount of chloride applied by citizens and private business is not known, but could potentially be significant to overall river loadings. Transport by overland flow or infiltration of salt or brine from streets, parking lots, sidewalks and driveways are also unaccounted for.

Due to reporting deadlines, snowmelt data up to the end of July 2018 was used in the chloride loadings evaluation for 2017/2018. At that time, minor amounts of snow were left at some of the snow sites; however, the chloride concentrations in the last amounts of meltwater is low and deemed not significant enough to influence the data interpretation.

2.0 Methodology

Inventory records and environmental compliance monitoring data were used to establish whether the anti-icing program produced any measurable environmental impacts to the North Saskatchewan River:

1. City of Edmonton Parks and Roads Services winter road maintenance material usage inventories.
2. EPCOR outfall sampling data.
3. City of Edmonton Snow Storage Site environmental compliance data.

The data between October one year to October the next year were used to compare one winter season to the next. The loading calculations to evaluate phosphorus, ammonia and biological oxygen demand related to organic corrosion inhibitors excluded the summer months, in order to capture anti-icing contributions and eliminate summer loadings due to summer runoff. All data and calculations were verified by the Engineering Services Environmental Compliance Team and the report was peer reviewed.

[1] EPCOR Storm Sewers (downloaded August 7, 2018)
https://www.epcor.com/learn/about-our-drainage-system/Pages/storm-sewers.aspx

2.1 Material Inventories

Infrastructure Operations' historic seasonal roadway maintenance materials usage inventories from 2001 to 2018 were compiled. The sodium chloride salt and calcium chloride brine inventories were used to calculate the total amount of chloride applied by the City to winter roads in each winter season.

Calcium chloride and sodium chloride dissociates into calcium or sodium ions and chloride ions when dissolved in water. Chloride is readily soluble and mobile in the environment, therefore it is a key indicator of potential environmental impacts to water due to the use of road safety products.

2.2 Snow Storage Sites

A portion of the calcium chloride brine, sodium chloride salt, and sand used for road safety is removed with snow during plowing and transported to snow storage sites where meltwater is directed to settling ponds before discharge to the stormwater system. Engineering Services collects regular water samples from City snow storage sites. EPCOR collects water flow volume data from the snow site discharge point, which Engineering Services uses to calculate environmental loadings from snow storage sites and to advise Infrastructure Operations of emerging issues. Analytical results for the environmental compliance samples taken at the snow storage sites were used to compare chloride loadings from the 2017/2018 anti-icing pilot year to historical years.

2.3 Four Major EPCOR Outfalls

EPCOR collects semi-monthly stormwater baseflow samples, flow event samples and regular monthly water samples from four major outfalls: 30th Avenue, Groat Road, Kennedale and Quesnell. For the 2017/2018 season, the City funded an increased frequency of outfall sample collection for the duration of the anti-icing pilot project, and EPCOR agreed to provide current and historical data for the City's use in this evaluation.

The historic chloride, BOD, phosphorus and ammonia-N loadings at the four major outfalls were evaluated to establish any observable changes to loadings potentially associated with the 2017/2018 anti-icing pilot program. Loadings are reported in kilograms. Historic outfall chloride loadings from October to October each year were used for an overall assessment of salt and calcium chloride brine impacts due to the 2017/2018 anti-icing pilot project. Winter and spring loadings were used to evaluate potential impacts due to the use of organic corrosion inhibitors.

3.0 Historic Cumulative Snowfall

Historic cumulative snowfall at the Edmonton International Airport was retrieved from the Environment Canada's Monthly Climate Summaries web page. The snowfall from October to October each year was analyzed to capture and compare annual winter maintenance practices.

Missing snowfall data between 2006 and 2008 was estimated by averaging snowfall data from Edmonton weather stations. Historical cumulative snowfall is presented in Table 1. Previous years with similar snowfall to 2017/2018[2] were used for comparison purposes.

Table 1: Historical Cumulative Snowfall

Year (Oct - Oct)	Cumulative Snowfall (cm)	Year with Similar Snowfall to 2017/2018
2001/2002	123	✓
2002/2003	140	
2003/2004	111	✓
2004/2005	64	
2005/2006	61	
2006/2007	140	
2007/2008	96	
2008/2009	106	✓
2009/2010	82	
2010/2011	160	
2011/2012	101	
2012/2013	138	
2013/2014	151	
2014/2015	106	✓
2015/2016	53	
2016/2017	138	
2017/2018	117	✓

[2] Years with similar snowfall was defined as +/-15 cm compared to 2017/2018 snowfall measured at the Edmonton International Airport. There is considerable variability in the snowfall measured at different monitoring stations. Within this report, all of the available historical material use, loadings and snow data is presented to facilitate additional interpretation.

4.0 Historic Roadway Materials Usage

The Infrastructure Operations section of the Parks and Roads Services in City Operations uses calcium chloride brine, sodium chloride salt, and sand for traffic safety during the winter. Table 2 presents the material inventory records back to the 2001/2002 winter season. The mass of chloride associated with the salt and brine inventory records were calculated and included in Table 2.

Table 2
Historic Roadway Materials Usage

Year (Oct - Oct)	Sand (tonnes)	Sodium Chloride Salt (tonnes)	**Chloride from Salt (tonnes)**	Calcium Chloride Brine (litres)	Calcium Chloride Brine (m^3)	**Chloride from Brine (tonnes)**	**Total Chloride* (tonnes)**	Similar Snowfall Year (✓)
2001/2002	115,269	17,280	**10,482**	606	1	**0**	**10,483**	✓
2002/2003	149,148	30,252	**18,352**	73,821	74	**17**	**18,368**	
2003/2004	135,357	17,400	**10,555**	245,445	245	**55**	**10,610**	✓
2004/2005	157,108	13,041	**7,911**	200,680	201	**45**	**7,956**	
2005/2006	74,709	9,719	**5,896**	229,645	230	**52**	**5,947**	
2006/2007	160,619	16,599	**10,069**	406,070	406	**91**	**10,161**	
2007/2008	146,270	13,688	**8,303**	393,937	394	**89**	**8,392**	
2008/2009	161,470	20,300	**7,548**	235,400	235	**53**	**7,601**	✓
2009/2010	91,829	13,200	**9,724**	144,500	145	**32**	**9,757**	
2010/2011	120,465	22,800	**13,796**	141,300	141	**32**	**13,828**	
2011/2012	68,857	19,900	**12,063**	139,400	139	**31**	**12,095**	
2012/2013	127,357	25,300	**15,332**	285,500	286	**64**	**15,397**	
2013/2014	100,380	18,500	**11,408**	172,200	172	**39**	**11,447**	
2014/2015	95,388	21,200	**12,857**	185,500	186	**42**	**12,899**	✓
2015/2016	75,195	10,800	**4,840**	80,800	81	**18**	**4,858**	
2016/2017	110,099	17,700	**11,713**	178,800	179	**40**	**11,754**	
2017/2018	40,362	36,800	**22,317**	4,673,100	4,673	**1,050**	**23,367**	✓

* Total chloride is the sum of chloride from sodium chloride salt and chloride from calcium chloride brine.

4.1 Applied Chloride due to Calcium Chloride Brine in 2017/2018

Historically, calcium chloride brine was used to pre-wet sand as it was applied to improve longevity on the roads by making it "stick" to the road surface. The historic volumes of calcium chloride brine are presented in Table 2. In 2017/2018 the use of calcium chloride brine was increased for anti-icing purposes. The chloride contribution from calcium chloride brine is a key environmental performance indicator for the 2017/2018 anti-icing pilot.

According to the roadway maintenance inventory records, sodium chloride salt is the primary source of chloride applied to roads by the City of Edmonton (Table 3). The anti-icing pilot project material usage records show that the application of thin layers of calcium chloride brine did not contribute significant amounts of chloride compared to sodium chloride salt.

Table 3 shows the contribution of calcium chloride brine compared to the total chloride applied by the City for road safety during the 2017/2018 winter season.

Table 3
Chloride Sources from Road Maintenance Materials 2017/2018

Source of chloride	Chloride applied 2017/2018 (tonnes)
Total chloride applied (sodium chloride salt + calcium chloride brine)	23,367
Chloride from calcium chloride brine	1,050
% of total chloride from calcium chloride brine	4.5%

Of the total chloride applied to Edmonton roads by the City in 2017/2018, only 4.5 % was due to the application of calcium chloride brine. 95% of the chloride applied during the winter was due to the application of sodium chloride salt. The incremental contribution of calcium chloride brine to environmental chloride loadings during this pilot was minimal.

4.2 Sodium Chloride Salt

The amount of sodium chloride salt applied in 2017/2018 compared to sodium chloride salt application during past similar snowfall years is presented in Table 4. Similar snow years were previously identified in Table 1.

Table 4
Historic Sodium Chloride Salt Applied for Winter Road Safety Purposes During Years with Similar Snowfall as 2017/2018

Year (Oct - Oct)	NaCl Salt (tonnes)	Snowfall (cm)	Salt Applied 2017/2018 ÷ similar snowfall year
2001/2002	17,280	123	2.1 X
2003/2004	17,400	111	2.1 X
2008/2009	12,443	106	3.0 X
2014/2015	21,194	106	1.7 X
2017/2018	36,789	117	

In 2017/2018, sodium chloride salt application to winter roads was greater by a factor of 1.7 X to 3.0 X the applications in previous winters that experienced similar snowfall.

Sodium chloride salt is blended into sand piles to prevent freezing while stockpiled at City maintenance yards. Depending on climatic conditions such as temperature and amount of snowfall (“spiking”), additional salt is applied directly or added to the sand/salt mix during loading.

Table 5
Sodium Chloride Salt applied to Edmonton Streets During 2017/2018

Sodium Chloride Salt	Sodium Chloride (tonnes)	% of Total Sodium Chloride Usage
Salt blended with sand to prevent stockpiles from freezing	1,180	3%
Salt added to trucks (“spiking”)	35,685	97%
Total salt applied in 2017/2018	36,789	100%

4.3 Sand for Winter Traction

The amount of sand applied in 2017/2018 compared to sand applications during similar snowfall years is presented in Table 6. Similar snow years were previously identified in Table 2.

Table 6
Historic Sand Tonnages Applied for Roadway Maintenance Purposes During Years with Similar Snowfall as 2017/2018

Year (Oct - Oct)	Sand (tonnes)	Snowfall (cm)	Sand Applied 2017/2018 ÷ similar snowfall year
2001/2002	115,269	123	0.4X
2003/2004	135,357	111	0.3X
2008/2009	161,470	106	0.3X
2014/2015	95,388	106	0.4X
2017/2018	40,362	117	

In 2017/2018, the quantity of sand applied to winter roads for traction purposes was approximately a third of the amount of sand applied during four previous winters that experienced similar snowfall.

5.0 Chloride Loadings to the North Saskatchewan River

5.1 Chloride Loadings at Four Major EPCOR Outfalls to the NSR

EPCOR drainage services collects water samples related to key environmental parameters and flow volumes at four major outfalls to the North Saskatchewan River. Chloride loadings (total kilograms of chloride discharged each year) are calculated from the flow volume and chloride concentrations measured in the water samples. The monitored outfalls are: 30th Avenue, Kennedale, Groat Road, and Quesnell. The historic chloride loading data from these major drainage basins are presented in Table 7. Figure 1 shows the City's major drainage basins.

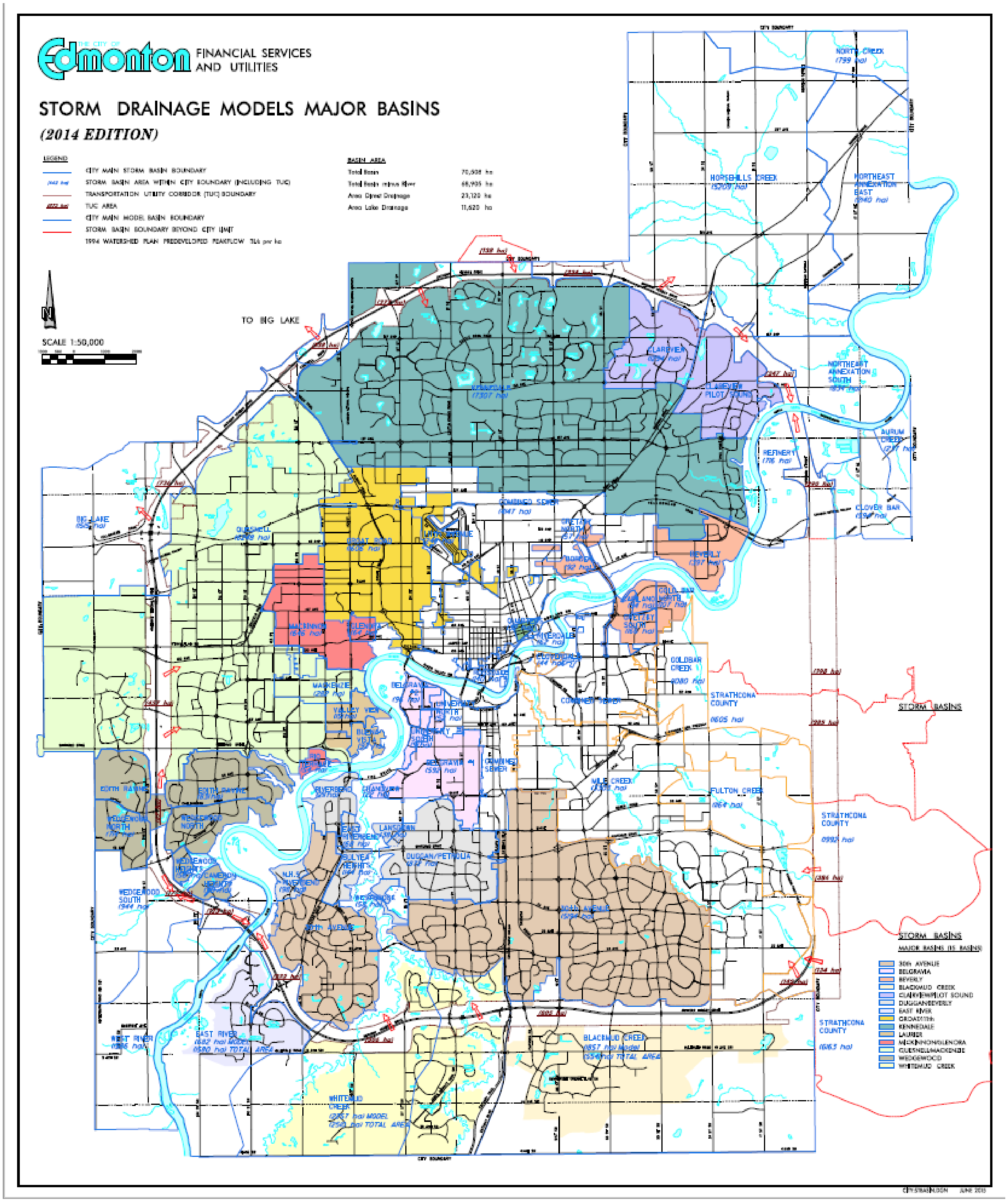

Figure 1: The [City's major stormwater drainage basins](#).

Table 7
Historic Chloride Loadings from Major Outfalls to North Saskatchewan River (kg)

Year Oct - Oct	30th Ave (kg of Cl^-)	Groat (kg of Cl^-)	Kennedale (kg of Cl^-)	Quesnell (kg of Cl^-)	Sum of Loadings (kg of Cl^-)	Annual Snowfall (mm)	Similar Snowfall Years as 2017/2018
2001/2002	-	-	-	-	-	123	✓
2002/2003	885,261	-	-	-	-	140	
2003/2004	825,657	-	-	-	-	111	✓
2004/2005	812,835	-	-	-	-	64	
2005/2006	677,843	-	-	-	-	61	
2006/2007	809,424	-	-	-	-	140	
2007/2008	583,971	384,840	1,327,591	2,430,951	4,727,353	96	
2008/2009	994,510	2,024,843	1,007,498	2,684,582	6,711,433	106	✓
2009/2010	964,868	1,082,519	609,459	2,259,479	4,916,325	82	
2010/2011	1,270,519	2,242,934	1,405,376	2,410,289	7,329,118	160	
2011/2012	1,572,224	901,347	649,712	1,735,728	4,859,011	101	
2012/2013	1,492,915	1,035,358	714,539	2,584,155	5,826,967	138	
2013/2014	1,460,165	735,453	596,414	2,605,668	5,397,700	151	
2014/2015	1,163,590	910,287	471,408	1,943,328	4,488,613	106	✓
2015/2016	892,578	384,713	306,384	1,463,779	3,047,454	53	
2016/2017	1,167,917	1,053,059	646,513	1,785,688	4,653,177	138	
2017/2018*	1,392,641	774,618	531,652	1,742,580	4,441,491	117	✓

*Data from October 1 to July 30

5.2 Influence of Snowfall on Chloride Loadings at Outfalls

The outfall chloride data was evaluated with and without the snowfall outlier years. When all of the snowfall years over the last decade are used to compare chloride loadings, the data trend shows an increase in chloride loadings at monitored outfalls with increasing annual snowfall (Figure 2). However, when the snowfall outliers are removed from the data set (the highest and the lowest snowfall amounts), there is no apparent relationship between the amount of snow and the chloride loadings that discharge to the outfalls (Figure 3).

When high and low snow years are included in the average snowfall calculations for the last decade:

- the Edmonton area received an average of 110 cm +/- 33 cm of snow annually;
- The calculated average chloride loadings to the North Saskatchewan River from four major outfalls over the last decade (including high and low snow years) is 5,050,000 +/- 1,240,000 kg.

On an average snow year over the past decade that excludes snow outlier years (i.e., the highest and lowest snowfall years were removed and the averages were recalculated):

- the Edmonton area receives about 115 +/- 23 cm of snow[3].
- The chloride loadings to the North Saskatchewan River from the four major outfalls on average snow years (outliers removed) is about 5,110,000 +/- 7500,000 kg.

The significant scatter in the historic snow and chloride data is likely a reflection of variabilities in winter weather patterns and temperatures. For example, winter rain or icy conditions usually require higher than usual chloride based applications by the City, private industry, and residents for safety reasons. Regardless of the snowfall received, salty snow will melt at temperatures below zero degrees Celcius; it follows that temperate winter periods will result in saline snowmelt discharge to the storm sewer at any time of the year. The data presented in Table 7, Figure 2 and Figure 3 serves as a benchmark for comparison.

To summarize, data from the four major drainage outfalls shows that:

- During unusually high snowfall years, total chloride loadings are noticeably higher;
- During unusually low snowfall years, total chloride loadings are noticeably lower;
- During typical snow years the chloride loadings are variable, but the data over the last decade may be reasonably described as 5,000 tonnes +/- 800 tonnes of chloride discharged from four major drainage outfalls in Edmonton.
- This data is used as a benchmark for comparison to evaluate the 2017/2018 anti-icing impacts to outfalls.

The chloride contributions from calcium chloride brine used during the anti-icing pilot produced no discernable impact on the quality of the City's stormwater that discharges to the North Saskatchewan River compared to the available historical data.

[3] Based on snow data from the Edmonton International Airport

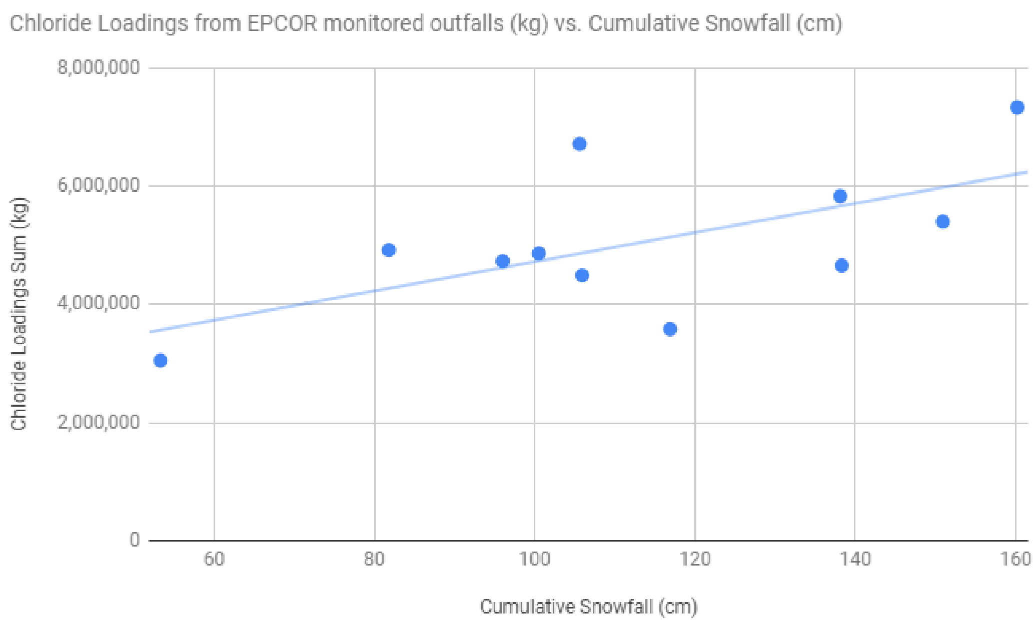

Figure 2: Chloride loadings at the four major outfalls compared to snowfall, 2007 to 2018.

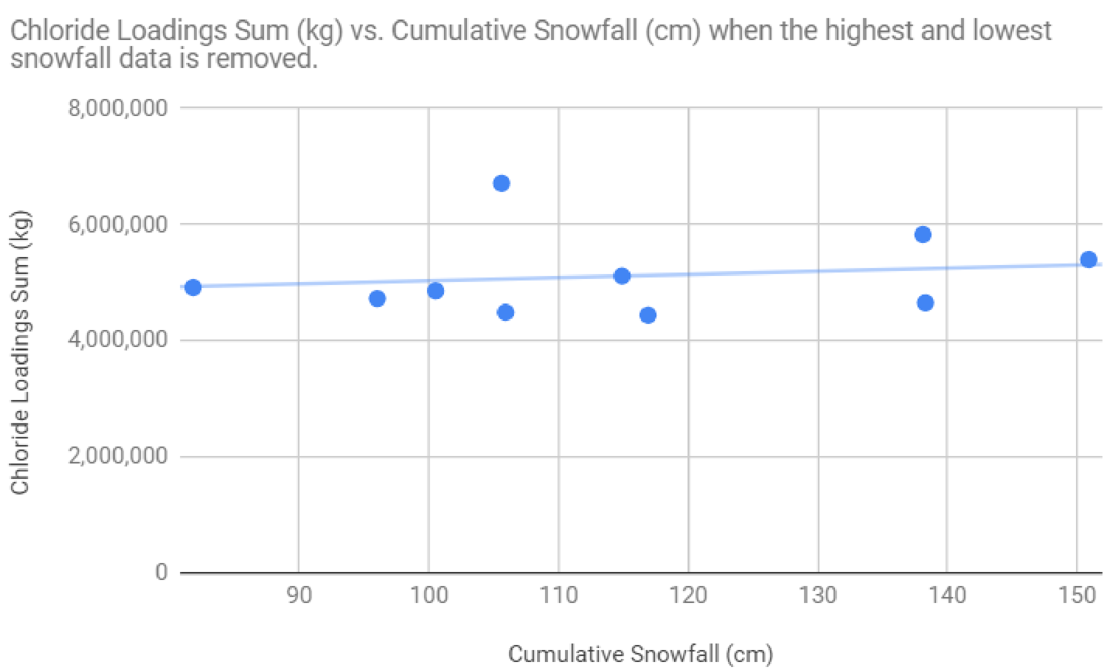

Figure 3: Chloride loadings at the four major outfalls compared to snowfall, 2007 to 2018 with the highest and lowest snowfall years excluded from the data set.

5.3 Spring Freshet

The majority of chloride loadings to the North Saskatchewan River from storm sewer outfalls occur during the spring thaw (March, April, and May). Table 8 compares the percentage of chloride loadings that occur during the spring melt season compared to the total annual chloride loadings.

Based on data provided to the City from the four major outfalls, spring melt is responsible most of total chloride that discharges to the North Saskatchewan River each year (80% of the time, half to two thirds of the total chloride discharge occurs from the beginning of March to the end of May).

Table 8
Major Outfalls: Historic Spring Freshet Chloride Contribution
(spring loading compared to entire season loading, %)

Year March - May	30th Ave Outfall (%)	Groat Road Outfall (%)	Kennedale Outfall (%)	Quesnell Outfall (%)	Years With Similar Snowfall to 2017/2018
2002/2003	61	-	-	-	
2003/2004	44	-	-	-	✓
2004/2005	43	-	-	-	
2005/2006	50	-	-	-	
2006/2007	55	-	-	-	
2007/2008	61	78	68	70	
2008/2009	63	37	81	72	✓
2009/2010	52	15	87	72	
2010/2011	56	91	73	64	
2011/2012	46	82	73	55	
2012/2013	63	79	81	66	
2013/2014	66	55	71	58	
2014/2015	41	36	57	53	✓
2015/2016	40	33	63	51	
2016/2017	55	59	68	59	
2017/2018	62	85	91	72	✓

5.4 Snow Storage Sites

The City's five snow storage sites accumulate snow that is plowed from City roads and stockpiled until the snow melts and ultimately drains into their respective outfalls. Two of the five snow sites discharge to major outfalls where water sampling data is collected are: Poundmaker and Kennedale. Figure 4 shows the location of snow storage sites and their respective outfalls. Table 9 presents the annual loadings calculated from meltwater samples and flow rates. There is considerable variability in the apparent amount of chloride picked up with snow from season to season and no clear relationship between snowfall and the amount of chloride discharged.

Table 9
Annual Chloride Loadings per Snow Storage Site (kg)

Year Oct - Oct	17 Street Snowsite (kg)	Poundmaker Snowsite (kg)	Kennedale Snowsite (kg)	Horsehills Snowsite (kg)	Ellerslie Snowsite (kg)	Annual Snowfall (mm)	Years With Similar Snowfall to 2017/2018
2007/2008	263,200	-	137,000	-	-	96	
2008/2009	-	-	-	-	-	106	✓
2009/2010	-	-	-	-	-	82	
2010/2011	529,639	264,681	463,057	-	422,389	160	
2011/2012	7,765	1,533	-	-	2,587	101	
2012/2013	268,866	170,043	86,304	-	66,426	138	
2013/2014	324,410	125,985	N/A	214,900	103,387	151	
2014/2015	152,784	112,410	61,867	76,803	75,170	106	✓
2015/2016	44,375	7,768	N/A	17,189	13,178	53	
2016/2017	79,111	179,115	19,127	7,339	22,792	138	
2017/2018*	264,871	192,659	160,568	73,186	181,207	117	✓

Notes:
Absent Data:

- AEP first requested chloride loadings data from snow sites in 2007/2008. An estimate was made based on a small data set using simple methodology. **Low quality data.**
- During 2008/2009 the flow monitoring equipment was not functional due to equipment failure. Data was sporadic and not considered defensible. 2011/2012, Kennedale, flow rate instrumentation failure. **Poor data.**
- The first year of operation for Ellerslie snow site was 2010/2011.
- The first year of meltwater flow monitoring for the Horsehills snow site was 2013/2014.
- N/A Kennedale Snowsite was not operational in 2013/2014 and 2015/2016.
  *Data collected as of July 28, 2018

The Kennedale and Poundmaker snow storage sites discharge to the storm sewer system that connects to the Kennedale and Quesnell outfalls, respectively. These two snow sites were examined more closely to evaluate the chloride contribution of snowmelt water from snow storage sites to the total chloride loadings measured at the monitored outfalls.

Table 10
Kennedale Outfall:
Chloride Contribution from Kennedale Snow Storage Site

Year Oct - Oct	Kennedale Snowsite Chloride Loadings (kg)	Kennedale Outfall Chloride Loadings (kg)	Kennedale Snowsite Contribution to Outfall (Kennedale Snowsite ÷ Kennedale Outfall) (%)
2007/2008	137,000	1,336,430	10
2008/2009	N/A	1,031,072	N/A
2009/2010	N/A	606,719	N/A
2010/2011	463,057	1,406,272	33
2011/2012	N/A	651,455	N/A
2012/2013	86,304	735,494	12
2013/2014	N/A	599,002	N/A
2014/2015	61,867	454,802	14
2015/2016	N/A	319,803	N/A
2016/2017	19,127*	644,283	3*
2017/2018	160,568	531,996	30

*Kennedale Snow Storage Site was not in service in 2013/2014 or 2015/2016, and used minimally in 2016/2017.

Between 10 and 33 percent of chloride loadings measured at the Kennedale outfall over the last decade might be reasonably attributable to snow removed from City streets and stored at the Kennedale Snow Storage Site.

Table 11
Quesnell Outfall:
Chloride Contribution from Poundmaker Snow Storage Site

Year Oct - Oct	Poundmaker Snowsite Chloride Loadings (kg)	Quesnell Chloride Loadings (kg)	Poundmaker Snowsite Contribution to Outfall (Poundmaker Snowsite ÷ Quesnell Outfall) (%)
2007/2008	N/A	2,370,651	N/A
2008/2009	N/A	2,752,217	N/A
2009/2010	N/A	2,212,397	N/A
2010/2011	264,681	2,462,978	11
2011/2012	1,533	1,792,382	0.1
2012/2013	170,043	2,648,155	6
2013/2014	125,985	2,605,377	5
2014/2015	112,410	1,935,754	6
2015/2016	7,768	1,477,608	1
2016/2017	179,115	1,781,876	10
2017/2018	192,659	1,026,746	2

Less than 1 to 11% of the chloride loadings measured at the Quesnell outfall over the last decade might be reasonably attributable to snow removed from City streets and stored at the Poundmaker Snow Storage Site. The unusually low chloride loading in 2011/2012 and 2015/2016 was verified from the monitoring data, and likely reflects the inherent variations in the nature of winter snow clearing (routes, snow event volume, temperature).

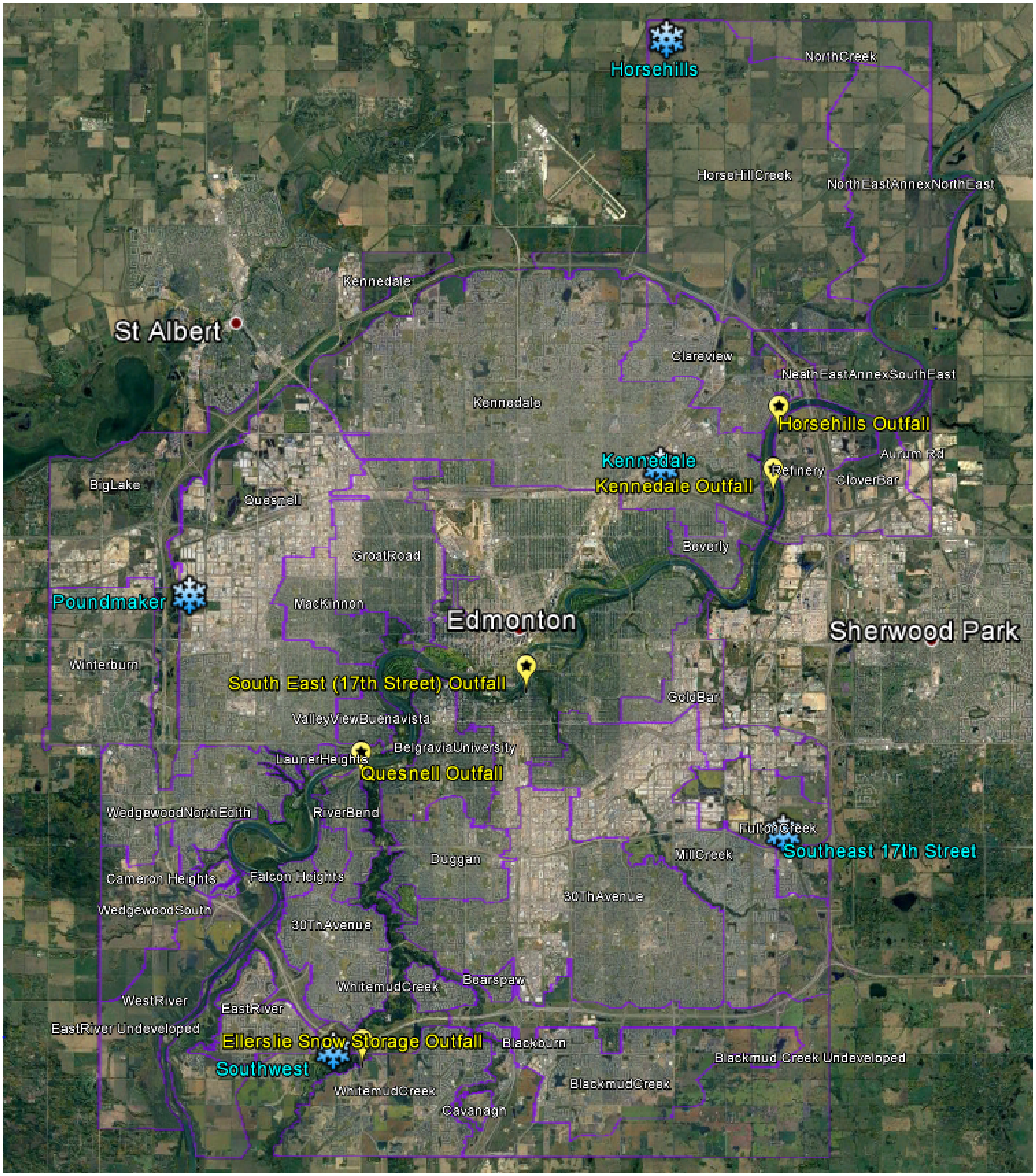

Figure 4: [Location of City snow storage sites](#) (❄), major outfalls and snow storage site outfalls.

The four major outfalls discussed herein do not completely represent loadings from the entire storm sewer system in Edmonton. The City-wide stormwater system discharges to 225 major and minor outfalls. Stormwater also travels by overland flow and infiltrates into the subsurface. Chloride contributions from private business and citizens due to winter deicing is unknown.

The outfall data trends are critical environmental indicators for the environmental performance of the 2017/2018 anti-icing pilot and the key resource used to establish related impacts.

6.0 Corrosion

Quality Assurance testing is routinely conducted on City roadway maintenance materials. The test data included here summarizes the historic corrosion data collected during routine testing. Further corrosion testing and research will be undertaken in 2018/2019.

The Infrastructure Operations section trialled three brine products with various corrosion inhibitor additives during the 2017/2018 anti-icing pilot:

- Calcium chloride brine with an organic corrosion inhibitor. The inhibitor is similar in odor and color to molasses (a typical byproduct of the sugar beet industry).
- Calcium chloride brine with magnesium hydroxide additive as a corrosion inhibitor (the common name for magnesium hydroxide is “milk of magnesia”)
- Calcium chloride brine with a phosphate based additive as a corrosion inhibitor.
- Sodium chloride brine with beet juice corrosion inhibitor.

Representative brine samples were collected from shipments to the roadway maintenance yards. Samples were sent to Analytical Laboratories, Inc. in Boise, Idaho who specialize in road salt and brine tests. The quality indicator parameters analyzed include:

- freezing point,
- corrosion rate,
- total suspended solids and settleable solids (important for efficient equipment operations to avoid clogging)
- biological oxygen demand (important to water health)
- Chemical parameters: pH, major ions, calcium chloride content, ammonia -nitrogen.

The parameters critical to corrosion and corrosion inhibitors are discussed in this section: ***freezing point, corrosion rate, and biological oxygen demand***. The results of the corrosion analyses are presented in Table 12.

Freezing point is a key operational parameter for effective road maintenance strategies.

Corrosion rate testing was conducted in accordance with the Pacific Northwest Snowfighters *Snow and Ice Control Chemical Products Specifications and Test Protocols for the ONS Association of British Columbia, Colorado, Idaho, Montana, Oregon and Washington* ("PNS Standard"). The PNS Standard is a modification of the National Association of Corrosion Engineers (NACE) Standard TM0169-095. The PNS standard requires that brines for winter road use have a ***corrosion value*** that is 30% of the corrosion rate of sodium chloride salt or lower.

Biological oxygen demand (BOD) is critical to river and surface water health and may be affected by the amount of organic corrosion inhibitor added. Salt and brine have little or no biological oxygen demand. Organic substances impact water quality because aquatic microbes use them as food, consuming dissolved oxygen in the process. Oxygen depletion can be harmful to fish, aquatic insects and plants. The biological oxygen demand related to corrosion inhibitor additives is an important consideration for product selection.

Table 12
Corrosion Related Quality Indicators in Brine used during the 2017/2018 Pilot

Sample	Freezing Point (°C)	Average Corrosion Rate (expressed as % of the Corrosion Rate of NaCl salt)	Biological Oxygen Demand (BOD) (mg/L)
Calcium chloride brine with organic corrosion inhibitor (similar to molasses)	-39	20.5	28,400
Calcium chloride brine with organic corrosion inhibitor DUPLICATE (similar to molasses)	-42	21.5	23,400
Calcium chloride brine with MgOH Inhibitor (“milk of magnesia”)	-44	**88%**	<3,400
Calcium chloride brine with Phosphate Inhibitor	-47	**85 %**	<800
Calcium chloride brine with Phosphate Inhibitor DUPLICATE	NA	**90 %**	<2,000
Sodium Chloride brine with beet juice corrosion inhibitor(lab tests only, not trialled on roads)	**-23.5**	15.1	334,000
PNS Standard	≥ - 39	< 30	-

Results in **BOLD RED** do not meet the PNS Standards as outlined in the specification agreement between the City of Edmonton and the supplier.

The PNS standard requires that brines for road use to have a corrosion value that is 30% of the corrosion rate of sodium chloride salt or lower.

BOD is an important environmental monitoring parameter that is measured at the river..

Data reported as “less than” (<) a number means that the lab result is lower than the minimum laboratory detection limit. The detection limits are high when compared to typical water quality laboratory detection limits because brines are so concentrated with salt constituents that dilutions are required in order to do analysis.

The quality assurance laboratory test results show that brine with organic inhibitors have a lower corrosion rate than brine with inorganic inhibitors, such as phosphate or magnesium hydroxide. The organic inhibitors have a higher biological oxygen demand than inorganic inhibitors. However, external research shows laboratory corrosion rates may not be representative of field corrosion rates for salt and brine use[4]. Further research is underway to evaluate field corrosion due to salt and brine use in Edmonton.

Environmental Impacts of Organic Corrosion Inhibitors

BOD is defined in the previous section. Ammonia can cause nutrient over-enrichment and at elevated concentrations can have adverse effects to aquatic life. Phosphorus is an essential nutrient and a component of fertilizers, but at high concentrations can degrade water quality by overstimulating algae growth (which decreases dissolved oxygen).

EPCOR provided outfall compliance monitoring data for storm sewer outfalls which included the concentrations of key environmental indicators in water sample concentrations, flow rates and loading calculations for four major outfalls. The loadings for BOD, phosphorus and ammonia were compiled for each winter season over the last decade. Summer months were excluded from these comparisons in order to capture anti-icing impacts to the river and eliminate potentially elevated seasonal summer loadings due to warm weather, warm weather, regional fertilizer use or summer runoff that contains oxygen consuming waste:

- Table 13 provides historic annual winter season BOD loadings
- Table 14 provides historic annual winter season ammonia loadings
- Table 15 provides historic annual winter season phosphorus loadings

Table 16 provides the historic average and standard deviation for available data from the last decade. As a check on the sensitivity of the calculated average, the high and low snow years were discarded and the average and standard deviation was recalculated for comparison purposes only.

[4] Baroga, 2003. Washington State Department of Transportation 2002-03 Salt Pilot Project.

Table 13
Biological Oxygen Demand (BOD) Loadings Measured at Outfalls

Year (November - April)*	BOD loading (kg)	Years with Similar Snowfall to 2017/2018	Annual Snowfall (mm)
2007/2008	269,588		96
2008/2009	274,045	✓	106
2009/2010	221,079		82
2010/2011	558,366		160
2011/2012	320,878		101
2012/2013	390,247		138
2013/2014	372,012		151
2014/2015	460,675	✓	106
2015/2016	253,085		53
2016/2017	335,486		138
2017/2018	302,488	✓	117

Table 14
Total Phosphorus Loadings Measured at Outfalls

Year (November - April)*	Total Phosphorus (kg)	Years with Similar Snowfall to 2017/2018	Annual Snowfall (mm)
2007/2008	12,304		96
2008/2009	12,838	✓	106
2009/2010	9,608		82
2010/2011	25,902		160
2011/2012	13,128		101
2012/2013	18,564		138
2013/2014	17,114		151
2014/2015	19,421	✓	106
2015/2016	8,105		53
2016/2017	21,096		138
2017/2018	15,680	✓	117

*The summer months of monitoring data were excluded from the data in order to capture anti-icing related impacts and eliminate potentially elevated summer BOD levels due to warm weather and summer runoff that contains oxygen consuming waste.

Table 15
Ammonia-N Loadings Measured at Outfalls

Year (November - April)	Ammonia - N (kg)	Years with Similar Snowfall to 2017/2018	Annual Snowfall (mm)
2007/2008	24,422		96
2008/2009	25,792	✓	106
2009/2010	25,606		82
2010/2011	55,439		160
2011/2012	31,323		101
2012/2013	27,789		138
2013/2014	23,624		151
2014/2015	27,898	✓	106
2015/2016	24,061		53
2016/2017	57,787		138
2017/2018	33,828	✓	117

Table 16
Average Annual BOD, Phosphorus and Ammonia-N Loadings
At four Major Outfalls

Statistics	BOD (kg)	Total Phosphorus (kg)	Ammonia-N (kg)
Average winter and spring loadings, Last ten years	341,632	15,796	32,506
Standard Deviation, Last ten years	+/- 99,279	+/- 5,030	+/- 11,755
Average winter and spring loadings, high and low snowfall years excluded	327,389	15,528	30,897
Standard Deviation, high and low snowfall years excluded	+/- 72,391	+/- 3,596	+/- 9,997

BOD, phosphorus and ammonia-N discharge with stormwater to the North Saskatchewan River from the major monitored outfalls are variable; however, there are no discernible impacts the North Saskatchewan River due to the 2017/2018 anti-icing pilot project.

7.0 Results and Discussion

In the winter of 2017/2018, the City of Edmonton Parks and Roads Services Branch undertook an anti-icing pilot program on selected routes using calcium chloride brine, a naturally occurring liquid pumped from saline geologic formations. Calcium chloride brine for anti-icing is applied to roads in a thin layer before or during a snowfall with the intent to reduce the amount of snow that sticks to the road, making snow removal easier and more efficient. The winter material application tonnages and volumes compared to historical data revealed the following key findings.

Of the total chloride applied to Edmonton roads for road safety in 2017/2018, only 4.5% was related to the application of anti-icing brine.

The material inventory records clearly show that the calcium chloride brine applied for anti-icing using the approach adopted for the 2017/2018 anti-icing pilot project did not contribute significant amounts of chloride compared to sodium chloride salt.

However, a separate undertaking to reduce road sand appears to have resulted in an increase in sodium chloride salt use:

- In 2017/2018, sodium chloride salt applied to winter roads was greater than four previous winters that experienced similar snowfall by a factor of 1.7X to 3.0X.
- In 2017/2018, the quantity of sand applied to winter roads for traction purposes was half to three quarters of the sand applied during four previous winters that experienced similar snowfall.

In general terms, the reduction of winter sand application by half to three quarters of the amount applied during previous similar snowfall years was accompanied by an increase in dry salt application by a factor of 1.7X to 3.0X.

The sand reduction undertaking was not a part of the original Calcium Chloride Anti-icing Pilot Project Charter. The sand reduction efforts were implemented mid-season 2017/2018. It would be prudent to undertake a formalized sand reduction pilot project to evaluate the costs, benefits, and environmental implications.

It is worth noting for discussion purposes that, if the salt and sand application tonnages had been similar to previous similar snow years, the calculated relative contribution of chloride due to calcium chloride brine would have been about 10%, not 4.5%. It is suggested that a 10% chloride contribution might be useful for planning and projection purposes on pilot projects of a similar scale, to be reviewed and revised if the pilot project is expanded.

The evaluation demonstrates a significant amount of scatter in the data that is likely a reflection of variabilities in winter weather patterns and temperatures, rather than total snowfall amount. For example, regardless of how much snow was received, salty snow will melt at temperatures below zero degrees Celcius, so any temperate or warm winter periods can result in salty meltwater discharging to the storm sewer. Similar weather conditions may also create icy conditions that requires higher than usual chloride based applications by the City, private industry and residents for safety reasons.

To summarize, for the four major drainage outfalls:

- During unusually high snowfall years the chloride loadings are noticeably higher;
- During unusually low snow volume years the chloride loadings are noticeably lower;
- During typical snow years the chloride loadings are variable, but the historic data over the last decade may be reasonably described as 5,000 tonnes +/- 800 tonnes of chloride discharge from four major drainage outfalls in Edmonton.
- This data is used as a benchmark for comparison to evaluate the 2017/2018 anti-icing impacts to outfalls.

On an average snow year over the past decade (very high and very low snow years removed), the Edmonton area receives about 115 +/- 23 cm of snow. The loadings to the North Saskatchewan River from four major outfalls on average snow years is about 5,000 +/- 800 tonnes of chloride (October to October). The calculated chloride loadings to the North Saskatchewan River from the four outfalls during the 2017/2018 winter season was 4,400 tonnes, no statistical difference from historic data. The increased in salt application in 2017/2018 was not obvious in the data, potentially due to overland flow, discharge to other outfalls, infiltration and/or contributions of deicers from other sources such as private business and citizens that influences historical data. Infiltration is a concern for groundwater quality and soil quality.

The chloride contributions from calcium chloride brine used during the anti-icing pilot produced no discernable impact on the chloride loadings in stormwater discharge to four major North Saskatchewan River outfalls compared to the available historical data.

Between 10 and 33 percent of the chloride loadings measured at the Kennedale outfall over the last decade might be reasonably attributable to snow removed from City streets and stored at the Kennedale Snow Storage Site.

Between 1 and 11% of the chloride loadings measured at the Quesnell outfall over the last decade might be reasonably attributable to snow removed from City streets and stored at the Poundmaker Snow Storage Site.

Organic corrosion inhibitors are added to calcium chloride brine in minor quantities (a few percent). Organic corrosion inhibitors were used for part of the 2017/2018 anti-icing pilot project. In laboratory corrosion tests, calcium chloride brine with organic corrosion inhibitors has significantly lower corrosion rate than sodium chloride salt. Field research conducted by the Washington State Department of Transportation found that field use of corrosion inhibited chemicals did not result in the levels of corrosion reduction measured in the laboratory. Corrosivity of calcium chloride brine and sodium chloride salt varies depending on the metal (aluminum vs. steel). They found that corrosion-inhibited chemicals appear to reduce corrosion costs related to steel, and appear to increase corrosion related to aluminum. A research program in the City of Edmonton will be conducted to evaluate field corrosion due to the winter maintenance program.

The City's quality assurance laboratory test results show that brine with organic inhibitors have a lower corrosion rate than brine with inorganic inhibitors, such as phosphate or magnesium hydroxide. The organic inhibitors have a higher biological oxygen demand than inorganic inhibitors. There are potential environmental implications and product costs related to organic corrosion inhibitor additives that need to be considered when making decisions about the most appropriate product to purchase. The PNS Standard[5] recognizes the balance needed when making procurement decisions: *"corrosion rate is a Value Added consideration that is adopted as a bid preference which must be balanced with cost, environmental and operational performance".*

There were no discernible increases to BOD, phosphorus or ammonia loadings to the North Saskatchewan River due to the 2017/2018 anti-icing pilot project. Ongoing monitoring is necessary to evaluate potential impacts related to increased calcium chloride brine application as the result of any future decisions to expand the anti-icing program.

[5] Pacific Northwest Snowfighters, 2010. Pacific Northwest Snowfighters Snow and Ice Control Chemical Products Specifications and Test Protocols for the ONS Association of British Columbia, Colorado, Idaho, Montana, Oregon and Washington, Revision 12-10, 2010.
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8.0 Conclusions

The current and historical data provides the necessary information to clearly understand the environmental implications of changes to the City's winter road safety program.

The materials inventory records clearly show that the anti-icing brine applied using the approach adopted for the 2017/18 anti-icing pilot project does not contribute significant amounts of chloride when compared to the amount of sodium chloride salt applied. Of the total chloride applied to Edmonton roads for road safety in 2017/2018, only 4.5% was due to the application of anti-icing brine. The incremental contribution of anti-icing brine to environmental chloride loadings during this pilot year was minimal.

A separate program undertaken to reduce road sand was accompanied by increased sodium chloride salt application, resulting in an overall increase in salt usage in 2017/2018 compared to similar snow years. The reduction of winter sand application by half to three quarters of the amount applied during previous similar snowfall years was accompanied by an increase in dry salt application by a factor of 1.7X to 3.0X.

The four major outfalls where water sampling data is collected are the discharge points for major stormwater drainage basins in Edmonton and are key indicators of stormwater quality discharged to the river. The majority of chloride loadings measured in these outfalls occurs during spring freshet.

The loadings to the North Saskatchewan River from four major outfalls on average snow years may be reasonably described as 5,000 +/- 800 tonnes of chloride each winter season (October one year to October the next). The chloride contributions from calcium chloride brine used during the anti-icing pilot produced no discernable impact on the City's stormwater quality that discharges to the North Saskatchewan River. The increased in salt application in 2017/2018 was not obvious in the data, potentially due to overland flow, discharge to other outfalls, infiltration, and/or historic contributions of deicers from other sources such as private business and citizens. Infiltration is a concern for soil and groundwater quality.

Laboratory test results show that brine with organic inhibitors have a lower laboratory corrosion rate than brine with inorganic inhibitors such as phosphate or magnesium hydroxide. Brine samples with organic corrosion inhibitor additives consistently met the PNS standard requirement for corrosion value: 30% of the corrosion rate of sodium chloride salt or lower. However, field research conducted by the Washington State Department of Transportation found that field use of corrosion inhibited chemicals did not result in the levels of corrosion reduction measured in the laboratory and corrosivity was different for different metals. A research program in the City of Edmonton will be conducted to evaluate field corrosion due to the winter maintenance program.

Outfall data showed that there were no discernible impacts to BOD, phosphorus or ammonia loadings to the North Saskatchewan River due to the 2017/2018 anti-icing pilot project. Organic corrosion inhibitor is a minor component of brine, and brine represented only 4.5% of the total chloride applied for winter safety in 2017/2018. Ongoing monitoring is necessary to evaluate potential impacts related to increased calcium chloride brine application as the result of any future decisions to expand the anti-icing program.

9.0 Recommendations

The following recommendations are offered as the result of the preliminary findings:

1. It is recommended that the data and analysis made in this report be reviewed in the context of other monitoring and metrics undertaken for the Calcium Chloride Brine Anti-icing Pilot Project including safety, costs and efficiencies.

2. It is suggested that a 10% chloride contribution due to calcium chloride brine anti-icing strategies be used for planning and projection purposes in the future on pilot projects of a similar scale. It is recommended that this number be re-evaluated and revised if the pilot project is expanded.

3. Sodium chloride salt application procedures by the City for winter road safety would benefit from a review and optimization, with a focus on source reduction and the lowest reasonably achievable application rates.

4. Annual groundwater quality monitoring at City maintenance yards and snow storage sites should be reviewed to evaluate whether subsurface impacts related to increase salt usage during 2018/2019 are apparent in the data.

5. It is suggested that organic corrosion inhibitors are a value added consideration that must be balanced with cost, environmental protection and operational performance. Continued monitoring is necessary to ensure that BOD loadings at stormwater outfalls remains acceptable due to corrosion inhibited calcium chloride brine.

10.0 References

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