Presented To:	Operations Committee
Presented:	Monday, May 14, 2018
Report Date	Monday, Apr 30, 2018
Type:	Presentations

For Information Only

Use of Road Deicers

Resolution

For Information Only

Relationship to the Strategic Plan / Health Impact Assessment

This report refers to operational matters.

Report Summary

The report describes the City's road deicing operation.

Financial Implications

This report has no financial implications.

Signed By

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Use of Road Deicer

Background

Road deicing is a necessary part of winter maintenance. Deicing is the process of applying solids or liquids to a road surface to help melt snow/ice that accumulates during a winter event. There are many types of deicers that are used in North America to manage snow/ice. The most popular deicer is sodium chloride more commonly referred to as road salt (see table 1 for a comparison of what other Municipalities are using for chemical deicing). Road salt is an effective substance for deicing but can be detrimental to the environment. To mitigate its harmful effects, City operations has adopted a Salt Management Plan (SMP) which provides valuable information on the effective use for road salt.

In 2005 the City of Greater Sudbury retained BMA Management Consultants to undertake an Internal Audit of winter maintenance activities/practices utilized at the City. The review included but wasn't limited to an analysis of staffing, contracting, yards/deployment centres, fleet management, budget and actual expenditures, work practices, road classifications, service standards, storm tracking and responses as well as performance management. The report provided an overview of existing practices, analyzed opportunities to create efficiencies and improve service delivery, review best practices utilized in Ontario as well as to make recommendations for the delivery of winter control services. One of the key recommendations contained within the BMA report was the need for the City to develop a SMP. In response to this recommendation, the City retained Conestoga-Rovers & Associates to develop its first SMP in September 2005. Since that time, City staff have arranged to have the SMP updated periodically with the latest update completed in 2016 (see Appendix A for a copy of the latest SMP).

The main goal of the SMP was to optimize the use of salt without compromising road safety. As noted in the latest version of the plan "the SMP sets out a policy and procedural framework to ensure the City of Greater Sudbury's (City's) Roads Operations Section (Roads Operations) continuously improves the effective delivery of winter maintenance services and the management of road salt used in winter maintenance operations, as outlined in Environment Canada's Code of Practice for the Environmental Management of Road Salts (April 2004)". The SMP is meant to be a dynamic document that allows staff to evaluate and implement new approaches and technologies in winter maintenance activities in a fiscally responsible manner.

The SMP contains the following key principles:

- Periodic review and analysis of industry practices;
- Implementation and documentation of the SMP;
- Education and training of staff;
- Monitoring and analysis;
- Management review;
- Environmental review; and
- Practices and policy revision.

The principle objective of the SMP is summarized in the following policy statement; "The City of Greater Sudbury will take the actions necessary to provide effective winter maintenance to ensure the safety of road users in keeping with applicable legislation and accepted standards while striving to minimize adverse impacts to the environment. Road Operations will meet these commitments by:

- Adhering to the procedures contained within the SMP;
- Complying with applicable laws and regulations;
- Reviewing and upgrading the SMP periodically and incorporating new technology and development as appropriate;
- Committing to ongoing winter maintenance staff training and education; and
- Monitoring on an annual basis, the present conditions of the winter maintenance program, as well as the effectiveness of the SMP".

On June 30th, 2005 BMA Management Consultants made a presentation to Council outlining their findings. Subsequent to their presentation, resolution 2005-284 was approved by Council and reads as follows:

"**THAT** the BMA Internal Audit Winter Maintenance Report be adopted in principle;
AND THAT the report be made public and posted to the City's website;
AND THAT an implementation plan be developed by the General Manager of Infrastructure and Emergency Services."

The most significant developments in our current winter control policy occurred in 2007 when Council resolved to adopt the SMP and implement a number of service changes that were recommended, most notably;

- Increasing the design plow times on class 4 to 6 roadways from 8-12 hours to 24 hours;
- Reduction of one shift on arterial and collector salt routes (class 1 to 3) and the reintroduction of first 8 in 24 (employees are required to report to their first 8 hour shift at any time during the 24 hour period, Monday to Friday) reporting for City Employees which would split into 2 shifts for storm response to provide 24 hour coverage; and
- Changing a number of roads currently treated with salt to roads treated with sand.

Since 2007, staff has initiated many operational changes following the principles of continuous improvement as identified in the SMP, including;

- Staff training;
- Periodic review/revisions to the SMP;
- Use of automatic spreader controllers;
- Calibration of equipment (see table 2 and 3 for City/MTO application rates);
- Installation of onboard brine systems;
- Pre-wetting salt;
- Direct liquid application;

- Pavement and air temperature sensors;
- Value added meteorological services (VAMS, see table 4 for an example) and Road weather information systems (RWIS);
- Use of GPS and AVL technology; and
- Snow removal, disposal and management of snow dumps.

In 2015, the City adopted the Source Water Protection Plan which was subsequently signed by the Ministry of Environment and Climate Change (MOECC). Since completion, City staff has implemented and/or is working on the following items;

- Improved monitoring of road salting activities;
- Improve signage in the Source Water Protection areas; and
- Reviewed salt/sand storage and handling at the various CGS depot operations.

In 2017, CGS commissioned a Risk Management Plan (RMP) for the Frobisher Facility and a Salt Optimization Plan (SOP). Copies of each of these plans can be found in Appendix B and C respectively, of this report. The RMP for the Frobisher Facility suggested that there were two measures available to the CGS to manage the significant threat of road salt storage within the Ramsey Lake intake protection zone. They include;

- "Maintain Site operations and implement Best Management Practices (BMPs) with monitoring to evaluate the effectiveness of BMPs;
- Maintain Site operations and implement Best Management Practices (BMPs) with monitoring to evaluate the effectiveness of BMPs. Relocate the winter maintenance material storage to a new site, located outside of any area where road salt storage and handling is deemed a significant threat, preferably within an area of low salt vulnerability as identified in the CGS Salt Optimization Plan."

The RMP for the Frobisher Facility concluded "that considering the additional costs associated with relocating the depot, in association with the benefits provided by the low-lying down gradient swamp which provides salt attenuation and a buffer from salt travel, redeveloping the existing Site using BMPs (i.e., build a dome for the pickled sand, install a monitoring network) would be the most economical and practical option."

The SOP on the other hand has been commissioned to assess the potential risk/vulnerability to environmental receptors with the application of road salt with the CGS road network. To establish the plan, our Consultant compiled data contained from the following data sources;

- Source water protection (SWP);
- Wellhead protection areas (WHPAs);
- Intake protection zones (IPZs);
- Highly vulnerable aquifers
- Significant/sensitive groundwater recharge areas;
- Lake trout and fish spawning areas; and
- Wetlands, and provincially tracked species sensitive to salt application.

By combining and weighing each environmental receptor/vulnerable area cumulatively, areas and roadways within the CGS can be rated as low to high receptor risk related to salt exposure. Based on the identification of the salt vulnerable areas and their intersection with roadways, recommendations are provided to minimize the impact of salt onto these environmental receptors and provide direction to the CGS Road Operations staff and SWP Group (Working Group) to maintain a safe road network while protecting the environment. CGS has developed this SOP in an effort to remain proactive with its SMP initiatives and as a requirement of the MOECC.

The SMP considers best practices for road salting as developed by the Transportation Association of Canada's (TAC) Salt Management Guide. Within the guide TAC has studied alternative products and supports the use of road salt. Other products studied by TAC include (see appendix D for details);

- Calcium Chloride
- Potassium Chloride
- Magnesium Chloride
- Calcium Magnesium Acetate
- Potasium Acetate
- Sodium Acetate
- Urea
- Glycols
- Methanol
- Sodium Formate
- Organic Compounds (sugar by-products)

Alternatives to road salt are generally prohibitively expensive, not appropriate for use on public roadways, unproven in a large scale operation and in many instances an alternative form of salt.

Another recommendation contained within the SMP suggests City staff should participate in a user group of Municipal operators to identify trends in the industry and compare practices of other Municipalities to ensure that practices utilized by the City closely mimic practices used by other Municipalities. Up until recently, the City maintained active membership in the Ontario Road Salt Management Group (ORSMG) which was sponsored by the Ontario Good Roads Association (OGRA). Unfortunately the ORSMG disbanded last summer but was quickly replaced by another group whose mandate will include bringing together various Municipalities/agencies from across Ontario to continue the discussion on winter maintenance and other road activities. The second meeting of the new group is scheduled for this month and City staff will be participating.

Finally, CGS is currently undertaking a study of a number of watersheds across the City. The main purpose of the study is to establish an implementation plan for storm water best management practices. Based on the principles of the SMP, Roads Operations staff will need to consider the recommendations of the sub-watershed plan when performing winter maintenance activities.

Conclusion

As noted earlier in this report, the CGS has adopted a SMP which sets out a policy and procedural framework to ensure the City of Greater Sudbury's (City's) Roads Operations Section (Roads Operations) continuously improves the effective delivery of winter maintenance services and the management of road salt used in winter maintenance operations. The priority areas for continuous improvement identified in the most recent version of the SMP (2016) and RMP for the Frobisher Facility recommends that the CGS take steps to improve salt storage and handling at its existing sites. Over the coming months, staff will be presenting alternatives and recommendations to Council to address Infrastructure facility needs which includes the construction of new sand/salt handling facilities.

Tables

Table 1 - Use of deicers/winter sand on Roadways

Municipality/Agency	Do you use a chemical deicer to maintain your roadways? (1) (all/some/none)	Type of Deicer?	Do you use winter sand to maintain your roadways? (all/some/none)	Do you pre-wet your roadway deicer? (Yes/No)	Pre-wetting solution?	Do you perform a Direct Liquid Application (DLA) to your roadways? (Yes/No)	DLA Solution?
CGS	some	sodium chloride	some	Y	salt brine	Y	salt brine
City of Timmins	some	sodium chloride	some	N	n/a	N	n/a
City of Sault Ste. Marie	some	sodium chloride	some	N	n/a	N	n/a
City of North Bay	some	sodium chloride	some	Y	calcium chloride	Y	calcium chloride
City of Thunder Bay	some	sodium chloride	some	Y	calcium chloride	N	n/a
Region of Peel	All (only responsible for arterials)	sodium chloride	none	Y	salt brine or mag. chloride	Y	salt brine or mag. chloride
Region of York	all	sodium chloride	some	Y	salt brine	Y	salt brine
Region of Niagara	all	sodium chloride mag. chloride (pilot)	all (in colder temps)	Y	salt brine	Y	salt brine
City of Hamilton	some (85%)	sodium chloride	some	Y	sugar-beet juice product	Y	salt brine
City of Barrie	some	sodium chloride and treated salt	some	Y	salt brine and "Magic-0"	Y	salt brine
Ministry of Transportation	all	sodium chloride	some	Y	salt brine, mag. chloride or calcium chloride (depending on climate)	Y	salt brine, mag. chloride or calcium chloride (depending on climate)
Greater Toronto Airport Authority	all	sodium chloride or "Mountain Melt Deicer" (on terminal roofs only)	none	Y	salt brine	Y	salt brine
City of Mississauga	all	Mag. chloride treated salt	none	N planning to next year	salt brine when implemented	Y	salt brine

Note: (1) The use of chemical deicers is based on the assumption that the weather (air temperature) is conducive to their use.

Table 2 – CGS Salt/Sand Application Rates

Storm Response Guide							
Current Temperature	Current Pavement Condition	Current Precipitation	Possible Action	Salt/Sand Application Rates			
				Class 1 to 3 Roads			Class 4 to 6 Roads
				Brine (Litres)	Salt (Kg/2-Lane KM)	Sand (Kg/2-Lane KM)	Sand
0'C and above	Wet	Snow	Plow and Sand or Salt	65	60 to 90	Nil*	100 to 310
		Freezing Rain	Sand and Salt	65	150	Nil*	310
-4'C to 0'C	Wet	Snow	Plow and Sand or Salt	65	90 to 115	Nil*	100 to 310
		Freezing Rain	Sand and Salt	65	150	Nil*	310
-12'C to -4'C	Snow Packed	Nil	Plow and Salt	65	115 to 150	Nil*	Nil*
	Snow Packed	Snow	Plow and Sand or Salt	65	150	Nil*	100 to 310
	Dry	Snow	Plow and Sand or Salt	65	150	Nil*	200 to 310
Below -12'C	Snow Packed	Nil	Plow and Sand	Nil	Nil	200 to 310	200 to 310
	Dry	Snow	Plow and Sand	Nil	Nil	200 to 310	200 to 310

* Section Manager or designate may change protocol at their discretion based on actual road and weather conditions

Table 3 – MTO Salt Application Rates

Precipitation	Road Surface Temperature Range (°C)		
	Warmer than -5	-5 to –10	-10 to -18
Frost	50	70	70
Light Snow	70	100	130
Heavy Snow	130	130	170
Freezing Rain	130	170	170

Table 4 – Value Added Meteorological Report (VAMS)

MeteoGroup Weather Services Canada Precipitation Forecast for Sudbury

MeteoGroup

Issued at Sat, Apr 28, 2018 07:00 EDT

NO ENVIRONMENT CANADA WARNINGS IN EFFECT FOR GREATER SUDBURY AND VICINITY AT TIME OF ISSUE

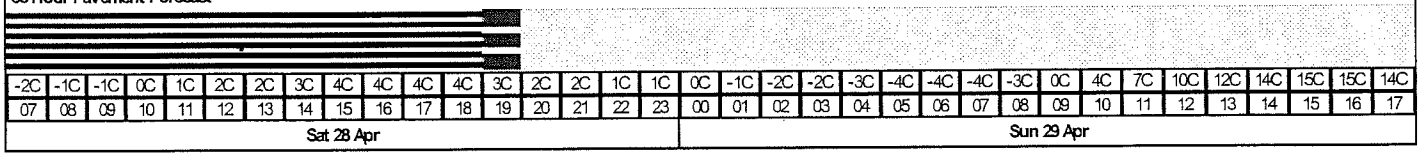
SATURDAY Blowing snow during the day, probability of precipitation 90%. Winds northerly 25km/h. Cloudy with flurries ending in the evening, clear overnight, probability of precipitation 50%. Winds northerly 20km/h.
SUNDAY Sunny during the day. Winds northwesterly 20km/h. Clear during the night. Winds light.

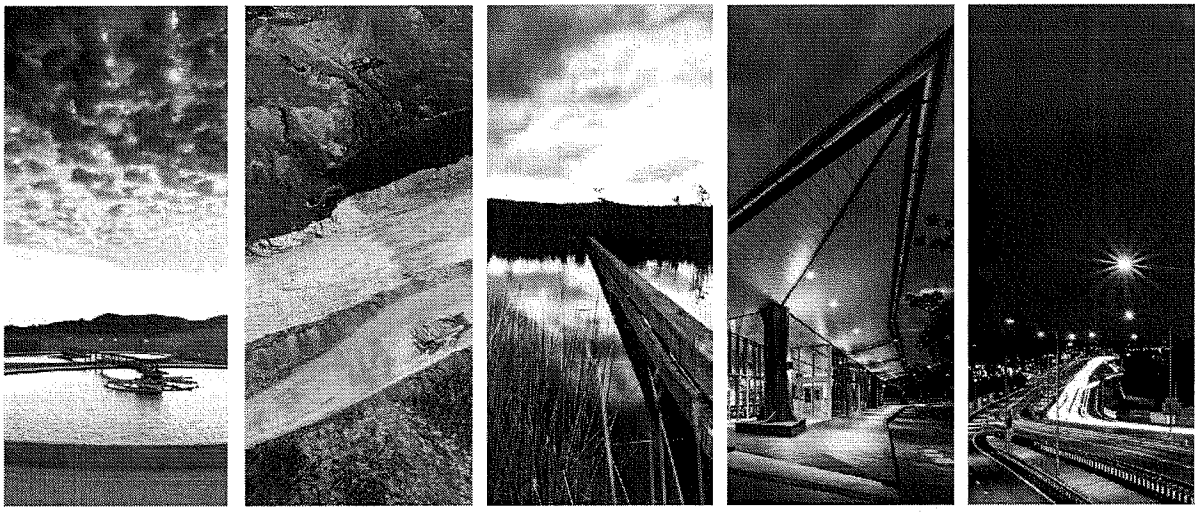
Day	Sat, Apr 28 2018																								Sun, Apr 29 2018																								Mon			
Period	Morning						Afternoon						Evening						Overnight						Morning						Afternoon						Evening						Overnight					
Local Time [24hr]	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5
Snow																																																			
Flurries	X	X	X	X			X	X	X		X	X	X																																						
Blowing snow					X																																														
SkyCondition	MAINLY CLOUDY												CLOUDY												SUNNY												SUNNY															
Sunshine (% period)	10												0												100												20															
Local Time [24hr]	6 - 9				9 - 12				12 - 15				15 - 18				18 - 21				21 - 0				0 - 3				3 - 6				6 - 9				9 - 12				12 - 15				15 - 18			
Snowfall (cm)	0.9				0.3				0.7				0.1				0.0				0.0				0.0				0.0				0.0				0.0				0.0				0.0			
POP (%)	90				80				90				80				50				30				20				20				20				10				10				10			
Air Temperature (°C)	-4				-4				-2				0				1				-1				-3				-6				-7				-2				4				9			
DewPoint (°C)	-5				-7				-7				-7				-7				-8				-9				-10				-10				-11				-9				-8			
Relative Humidity(%)	90				83				70				60				56				59				67				74				80				51				36				30			
Wind Direction (8-pt)	N				N				N				N				N				N				N				N				NW				NW				NW				NW			
Wind Speed (km/h)	26				28				28				26				22				19				19				19				19				19				19				19			
Wind Gusts (km/h)	49				53				53				51				47				38				35				36				35				36				36				36			
Wind Chill (*)	-11				-12				-9				-6				-5				-7				-9				-12				-14				-7				0							

Day	Mon, Apr 30 2018																								Tues, May 01 2018																								Wed			
Period	Morning						Afternoon						Evening						Overnight						Morning						Afternoon						Evening						Overnight					
Local Time [24hr]	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5
Showers																																																		X
Snow																																																		
Flurries																																																		
SkyCondition	SUNNY												SUNNY												VARIABLY CLOUDY												CLOUDY															
Sunshine (% period)	100												20												50												10															
Local Time [24hr]	6 - 9				9 - 12				12 - 15				15 - 18				18 - 21				21 - 0				0 - 3				3 - 6				6 - 9				9 - 12				12 - 15				15 - 18			
Rainfall (mm)	0.0				0.0				0.0				0.0				0.0				0.0				0.0				0.0				0.0				0.0				0.0				0.0			
Snowfall (cm)	0.0				0.0				0.0				0.0				0.0				0.0				0.0				0.0				0.0				0.0				0.0				0.0			
POP (%)	10				10				0				10				20				20				10				20				20				20				20				20			
Air Temperature (°C)	2				8				13				15				13				9				6				5				6				12				15				16			
DewPoint (°C)	-4				-2				-2				-1				0				1				2				3				4				6				7				7			
Relative Humidity(%)	67				49				37				35				40				57				73				82				83				67				58				55			
Wind Direction (8-pt)	W				SW				S				S				S				S				S				S				S				S				S				S			
Wind Speed (km/h)	9				11				15				19				19				13				11				11				11				15				19				22			
Wind Gusts (km/h)									30				37				37				31																30				38				41			
Wind Chill (*)	-1																								3																											

MONDAY Sunny during the day. Winds light. Clear during the night. Winds light. High 15, Low 5.
TUESDAY Variably cloudy during the day. Winds southerly 15km/h becoming 20km/h. Variably cloudy in the evening with showers developing overnight. Winds southerly 20km/h. High 16, overnight Low 12.
WEDNESDAY Cloudy with light rain during the day, probability of precipitation 80%. Winds southerly 20km/h becoming southwesterly 25km/h. Mainly cloudy during the night, probability of precipitation 40%. Winds light. High 16, Low 7.
THURSDAY Cloudy with light rain during the day, probability of precipitation 80%. Winds light. Cloudy with light rain during the night, probability of precipitation 80%. Winds light. High 10, overnight Low 6.
FRIDAY Cloudy with light rain during the day, probability of precipitation 70%. Winds northerly 15km/h shifting to westerly 20km/h. Variably cloudy in the evening, becoming mainly clear overnight, probability of precipitation 40%. Winds westerly 20km/h becoming 15km/h. High 12, Low 4.

36 Hour Pavement Forecast





2016 Salt Management Plan

City of Greater Sudbury

GHD | 96 White Oak Drive Sault Ste. Marie Ontario P6B 4J8 Canada

039382| 40 | Report No 6 | May 19 2017

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1. Purpose of this Document

This Salt Management Plan (SMP) sets out a policy and procedural framework to ensure the City of Greater Sudbury's (City's) Road Operations Section (Road Operations) continuously improves the effective delivery of winter maintenance services and the management of road salt used in winter maintenance operations, as outlined in Environment Canada's *"Code of Practice for the Environmental Management of Road Salts"* (April 2004) (Code of Practice).

Wintertime conditions can adversely impact public safety, limit road usage, increase travel time, and increase economic costs. By following the objectives stated in Environment Canada's Code of Practice, Road Operations works to ensure environmental protection while maintaining public safety during adverse road conditions. With proper monitoring and reporting, the recommendations made within the Code of Practice will result in improved safety and benefits to the environment, as well as potential benefits to Road Operations including improved efficiency and material usage savings.

This SMP also follows the Transportation Association of Canada's, Syntheses of Best Practices for Road Salt Management. Additional recommendations follow the Ministry of Transportation's (MTO's) Maintenance Manual for highway maintenance operations.

The SMP is meant to be dynamic allowing the municipality to evaluate and phase-in any changes, new approaches, and technologies in winter maintenance activities in a fiscally sound manner. At the same time, any modifications to municipal winter maintenance activities must ensure that roadway safety is not compromised. The following principals will be used for the continual improvement of the SMP:

- Periodic Review and Analysis of Industry Practices and Academic Research
- Implementation and Documentation of the SMP
- Education and Training of Staff
- Monitoring and Analysis
- Management Review
- Environmental Review
- Practices and Policy Revision

Managers are encouraged to negotiate adoption of the policies and procedures in the SMP to build a consensus with other parties involved in snow and ice control activities.

1.1 Salt Management - Objective

Road Operations is committed to continuously improving winter maintenance operations in a cost effective manner while ensuring public safety. This dynamic approach will allow Road Operations to optimize the use of winter maintenance materials containing chlorides on municipal roads while striving to minimize negative impacts to the environment. Road Operations staff will strive to provide safe winter road conditions for vehicular and pedestrian traffic as set out in the level of service

policy and within the resources established by City Council. Any deficiencies noted in current operations will be identified and corrective actions established.

1.2 Policy Statement

The City of Greater Sudbury will take the actions necessary to provide effective winter maintenance to ensure the safety of road users in keeping with applicable legislation and accepted standards while striving to minimize adverse impacts to the environment. Road Operations will meet these commitments by:

- Adhering to the procedures contained within the SMP
- Complying with applicable laws and regulations
- Reviewing and upgrading the SMP periodically and incorporating new technologies and developments as appropriate
- Committing to ongoing winter maintenance staff training and education
- Monitoring on an annual basis, the present conditions of the winter maintenance program, as well as the effectiveness of the SMP

2. Description of the Winter Maintenance Program

Road Operations is the authority responsible for maintaining the City's road system and sidewalks including conducting winter maintenance activities. The City is divided into five sections comprising the South, Southeast, Southwest, Northeast, and Northwest sections (see Figure 1). Each section has a designated central operations depot through which the section is managed. With the exception of the South and Southeast sections, each section also has additional, strategically-located, satellite depots where salt and/or sand stockpiles are maintained. The Southeast central operations depot, located at 1800 Frobisher Street, is also Road Operations' central headquarters (HQ) for the entire City. Each section also has one or more snow storage sites. The various winter maintenance depots and snow storage sites are shown on Figure 2. Details regarding the winter maintenance depots and snow storage sites are listed on Tables 1 and 2 respectively.

Winter conditions in Sudbury require plowing snow removal from roads and sidewalks. Road Operations uses road salting and sanding techniques, including pre-wetting the salt with a salt brine solution, to maintain a standard of safety on roads and walkways during the winter season, providing Sudbury's residents and visitors with safe, convenient, and affordable access to work, leisure, and other services.

The major winter maintenance activities conducted within the City of Greater Sudbury are as follows:

- Snow plowing
- Salt and sand spreading
- Salt and sand storage

- Snow removal and storage
- Sidewalk plowing and de-icing

Road Operations is responsible for conducting winter maintenance on roadways, sidewalks and bridges including the following:

Paved roads	2,448.2 lane kilometers (km)
Surface treated roads	621.7 lane km
Unpaved roads	625.9 lane km
Sidewalks	325 km maintained of a total of 440 km
Bridge Decks	55

The City's roadways are classified according to Ontario Regulation (O. Reg.) 239/02 *"Minimum Maintenance Standard"*, Municipal Act, 2001. Road classification (Class 1, 2, 3, 4, 5 and 6) is determined based on the posted/regulated speed limit and the annual average daily traffic (AADT).

Predetermined routes for plowing, sanding, and salting are followed. Salt and sand route maps and details are available at each section's central operations depot. The City's road inventory is included in Appendix A. City plowing/salting routes are provided on the City's website[1].

2.1 Level of Service Policy

Road Operations establishes a Level of Service (LOS) Policy for each road classification based on the requirements of O. Reg. 239/02 and direction from City Council. The LOS Policy defines winter storm response triggers and response times for corresponding winter maintenance activities. Changes to the LOS are reviewed and approved by City Council by resolution and are implemented by Road Operations.

The LOS policy currently meets or exceeds the Minimum Maintenance Standards (MMS) for snow accumulation and icy roads, as specified in O. Reg. 239/02. The City's LOS policy is summarized on Table 3. A comparison of the City's LOS with that of other northern municipalities is provided on Table 4.

2.2 Winter Patrol

The City's winter maintenance season commences on November 1st and is completed on April 30th. Road Operations winter maintenance program operates 24 hours a day, 7 days a week throughout the winter maintenance season. Winter Patrol and City's contract staff consists of the following operators: snowplows, snow loaders, salt/sand trucks, 4x4 plows, graders, sidewalk plows, anti-icers, as well as Forepersons (patrollers).

Road Forepersons work one 12-hour shift per day from 12:00 am to 12:00 pm plus overtime, as required on weekdays. On weekends, they are on 24-hour instantaneous call-out. All other winter service person personnel are also on 24-hour instantaneous call-out.

1 http://www.greatersudbury.ca/living/roads/winter-maintenance/salt-routes/

The Foreperson is responsible for mobilizing winter maintenance operators to ensure that roads are cleared in a timely fashion and remain in compliance with established service standards. The Forepersons are familiar with local conditions in their patrol area, and complete a "Road Patrol Record" during each shift. Summer and winter Road Patrol Record forms are provided in Appendix B.

The City's By-Law Department supports Road Operations winter patrol activities through vehicle ticketing and towing where operators report that vehicles block winter control operations.

2.3 Staffing and Hours of Work

Road Operations assigns an employee to each vehicle used for winter operations. Each vehicle is assigned a route for sanding/salting and/or plowing.

Road Operations adheres to the hours of work as set out in the Highway Traffic Act, O. Reg. 4/93 and the Employment Standards Act (ESA). When a driver has completed the standard eight hours of driving time, they are either spelled off by the next incoming employee or can remain to work overtime. Multi-function operators work on set shifts of midnight ("Shift A") and noon ("Shift B") during weekdays. All other winter control personnel commence work at 8:00am or on a first eight in twenty-four basis.

2.4 Winter Materials Used Annually

The Road Operations' winter maintenance program uses directly applied salt, as well as pickled sand (sand mixed with salt) for snow and ice control purposes. Pre-wetting of salt with a brine solution is also utilized. Direct liquid application (DLA) is used on bridge decks.

Current practice for application of road salt is dependent on temperature, upcoming weather conditions, and the amount of snow on the road. Sand is applied to City streets according to the same priority order as salt, in accordance with the LOS Policy. Road Operations' Storm Response Guide included on Table 5 includes general application rules. Sidewalks, which have been plowed, are sanded as necessary to maintain safe pedestrian walkways.

2.4.1 Salt

Based on 13 years of data (2003 to 2015), Road Operations uses an average of 19,876 tonnes of bulk coarse highway salt (NaCl) per season. Salt is delivered to the various depots, where it is placed into storage sheds or domes on impermeable floors. Annual salt usage records for the past 13 winter seasons are shown on Table 6, broken down by section.

Salt is applied to Class 1 to 3 roadways within the City in priority order in accordance with the LOS Policy. Pickled sand, rather than salt is applied to Class 4 to 6 roadways.

2.4.2 Pickled Sand

A mixture of sand and salt is used on roadways to improve traction. Sand is mixed with salt at a rate of five percent salt by volume to prevent the sand from freezing. Based on 11 years of data (2005 to

2015), Road Operations uses an average of 55,856 tonnes of sand per season. Annual sand usage records for the past 11 winter seasons are shown on Table 7, broken down by section.

Currently, all pickled sand is stored outside, uncovered at various depots throughout the City's five sections. This creates an ongoing concern regarding the potential for salt to leach from the sand during the course of the year.

2.4.3 Brine

Each section's central operating depot has a brine-making machine except for the Southwest section for which brine is produced at the Naughton depot where the salt is stored. The average brine concentration is 23 percent NaCl by weight. The brine is mixed in tanks and pumped into spreading equipment to pre-wet the salt during or just prior to application.

2.5 Equipment - Winter Maintenance Fleet

Road Operations maintains a variety of equipment including plows, spreaders, and combination units. All plows and new spreaders are equipped with ground speed electronic spreading controls. As discussed in the Section 2.4.3 (Brine), Road Operations' winter maintenance program currently uses salt pre-wetting with brine.

Road Operations conducts spreader calibration, annually prior to the winter season and before any new equipment is put into service, to determine the salt application rate.

The current winter maintenance fleet breakdown is as follows:

Equipment	Current Percentage of Overall Fleet
Electronic spreader controllers	90%
Pre-wetting equipment	60%
Direct liquid application	1%
Infrared thermometers	100%
GPS	100%
Other (Sidewalk plows with spreaders)	50 %

2.6 Operations Facilities

As previously discussed in Section 2.0 (Description of the Winter Maintenance Program), Road Operations maintains five sections within the City. Each section has a central operation depot where the following operations are conducted:

- Salt and sand storage
- Brine manufacturing (except at the Southwest section depot)
- Administrative functions
- Vehicle and equipment storage, maintenance and repair

With the exception of the South and Southeast sections, each section also has an additional satellite depot(s) strategically located within the section. Operations conducted at the satellite depots include salt and/or sand storage. Several depots also have snow dump areas, which are further discussed in Section 2.7.

Road Operations currently operates nine (9) active winter maintenance depots, which includes five (5) central operations depots and the main HQ, located at 1800 Frobisher Street, in the Southeast section. The depot locations are shown on Figure 2 and listed on Table 1. Figures 3.1 to 3.9 show the site layout of each active winter maintenance depot.

2.7 Snow Removal and Disposal

Street and sidewalk plowing operations create piles of snow, which accumulate along the sides of roadways. Snow banks are cut back and removed on an as-needed basis, when their size poses a sight line hazard to pedestrians and motorists at road intersections or threatens to impede traffic by encroaching into roadways.

Snow removed from roadways and sidewalks is deposited in various designated snow storage areas located throughout the City. Road Operations currently operates and maintains five snow storage sites, shown on Figure 2 and listed on Table 2. Figures 4.1 to 4.5 show the site layout of each active snow disposal site.

In selecting a site to establish a snow dump, Road Operations attempts to find locations that are centrally located within the service area, easily accessible, and separated from residential areas and from potentially vulnerable areas including watercourses.

The City's main snow dump site, located in the South Section on the east side of LaSalle Boulevard north of Nolin Creek, is used to dispose of snow removed from City streets and sidewalks as well as for snow removed from parking lots by private contractors. The site is secured with a key-card operated gate to prevent illegal dumping and is leased from the property owner.

Snow dump maintenance includes spring inspection and cleanup. Following snow melt, litter, debris and any other wastes are collected from all snow dump sites for appropriate disposal at a license landfill site. Road Operations does not currently conduct soil, surface or groundwater monitoring programs at any of the snow dump sites.

2.8 Weather Monitoring

Given the City's extensive land coverage and diverse topography, it is often affected by a variety of changing weather patterns. To obtain the most accurate weather descriptions/predictions, Road Operations relies on a number of resources including online RADAR imagery provided by

Environment Canada (http://weatheroffice.ec.gc.ca). Forepersons monitor weather forecasts provided by MeteoGroup weather forecasting service three times daily.

Road Operations supplements road patrol information with observations from municipal staff and customized weather forecasts (updated three times/day from the MeteoGroup) to determine an effective winter storm response and allocation of resources. Staff also monitors pavement temperatures by means of on-board infrared thermometers, which are mounted on the road patrol and supervisor trucks. Road Operations uses a Vaisala Road Weather Advisor, a Road Weather Information System (RWIS) installed on Municipal Road 8 in Levak to monitor and track air and pavement temperature and moisture, etc. Road Operations also has access to MTO's RWIS data and pavement temperature forecasts for the provincial highways located in various areas within the municipality. Historical weather data for the City can be obtained at the Southeast (Frobisher) section's central operating depot.

There are many ways for a municipality and its staff to receive notice that a winter storm event has commenced. In order to meet the requirements for Minimum Maintenance Standards, response is required (upon receipt by a member of staff, council, or the public). After becoming aware of a storm event, the personnel receiving notice immediately informs the public works supervisor (and/or patroller) and an appropriate response is initiated.

2.9 Communications

All winter maintenance vehicles are equipped with two-way communications (radios, cell, etc.). For all of the five sections, Road Operations HQ (311) serves as a hub for in/outgoing calls from staff, emergency services, and the general public during business hours. Outside of business hours, Northern Communication provides contact and answering services.

City Police inform Road Operations of any traffic accidents that may have been created by road conditions and City Transit informs Road Operations of areas of concern that could affect transit service. Calls are also received from other City staff as well as: school bus operators, and the public. This type of communication is typically logged into the City's (Active Citizen Requests) ACR system. ACRs are categorized by type (i.e. slippery/icy road, sidewalks, or stairs; plowing required on roads, sidewalks, stairs or cul-de-sacs; and snow banks blocking sight lines) and by year. Road Operations tracks the number of ACRs received in order to manage complaints, inquiries and questions about Road Operations Services.

Road Operations has taken a pro-active position with regard to winter maintenance rather than a reactive one. Road Operations operates a Traffic Studio, an automated, GPS-assisted storm response monitoring system. The Traffic Studio application monitors the progress of winter maintenance during a storm and displays results to supervisory staff. Traffic Studio is operational when there are eight or more centimeters of snow accumulation, or if there is an ice event. Traffic Studio was implemented fully during the 2015/2016 winter season.

Communications regarding the policies and procedures included in the SMP are relayed to Road Operations staff through annual mandatory training programs.

External communication with the general public ranges from media press releases to information posted on the City's web site regarding winter maintenance services and salt management practices. Individual inquiries are also addressed.

2.10 Training

Prior to the winter season, which commences on November 1, staff meet to discuss the strategy for winter maintenance, assign the spreading/plow responsibilities, and to review the safety issues.

A Road Operations staff member and/or external agency (such as OGRA) acts as training coordinator for the department. Winter control training includes video and power point presentations, as well as, hands-on instruction in operating the various types of winter maintenance equipment. Multi plow truck, grader, and loader truck operators receive a minimum of forty hours of practical, hands on field instruction and evaluation regarding the rules and regulations for operating winter maintenance equipment, health and safety considerations, and equipment operation. Management staff has received MTO RWIS training.

Monthly health and safety training is provided for all staff as per safety-related topics covered by the Occupational Health and Safety Act. Minimum required health and safety training requirements includes: WHMIS; cold stress; safe driving; 3-point contact; overhead wires; personal protective equipment; slips, trips, and falls; and workplace harassment.

Other training materials will be added and/or deleted as they become available and/or obsolete.

2.11 Record Keeping

Record keeping is important to evaluate the effectiveness of the SMP. Records produced as part of the SMP include:

- Training records
- Operator logs
    - Crew cards documenting operator daily activities such as hours worked, route taken, vehicle used, quantities of materials used, and details of work performed
    - Patrol records documenting the weather and road/sidewalk conditions and the type of winter event (e.g. drifting snow, ice covered, frost, slush) as well as details regarding any accidents that may have been noted.
- Electronic controller data
- Snow dump usage data
- Salt purchasing records
- Stockpile issue records documenting what type and how much materials was loaded onto a particular truck at a specific time
- Complaints received (Annual Complaints Reporting)
- Weather trends, historical data

- Calibration reports for winter maintenance vehicles and equipment
- Documentation of any corrective actions taken
- Structural inspection reports for salt domes/storage facilities

Road Operations maintains up-to-date records of training provided to staff. These include any certifications and course descriptions needed to maintain a record of each worker's competency. The records include the date, time, duration and subject of the training, as well as the source of the training and trainers. Records are maintained summarizing the percentage of staff trained in salt management at each level of the organization.

Road Operations winter maintenance staff complete operator logs detailing the date, shift, truck number, and the amount of salt and/or sand used on a particular route. Road Operations personnel track salt purchases to determine bulk usage.

With the use of infrared pavement thermometers, pavement temperature trends are recorded in daily logs, along with pavement conditions, weather conditions and winter treatment strategy. Road Operations also records storm statistics including the date and type of winter event encountered (i.e., local storm, minor storm, major storm). The RWIS also track and record weather information as well as pavement conditions.

3. Continuous Improvement Practices and Strategies

The current winter maintenance policies and practices form the baseline or benchmark upon which improvements can be made to manage the use of road salt more effectively and in turn its impact on the environment.

Beneficial improvement options and recommendations for upgrading salt management practices and strategies from year to year are assessed on the following:

- level of service policy
- equipment upgrading
- equipment calibration
- equipment washing
- material delivery, storage and handling
- record of material usage
- salt pre-treatment alternatives
- weather and pavement temperature forecasting
- storm response
- winter patrol
- training
- snow removal and disposal

- emergency response procedures (plan in place) training
- technical review of existing and new technology for Environmentally Sensitive/Vulnerable Areas
- communication strategy
- anti-icing and alternative anti-icing solutions (direct liquid application)

SMP summary table showing the current status for each of the above listed practices along with their recommendation is provided in Appendix C. The recommendations are made in accordance with the Ontario Good Roads Association (OGRA) SMP template and will assist with further developing Road Operations' winter maintenance policies, practices, and procedures. Road Operations has already implemented partially or fully (partially or fully) some of these recommendations.

4. Monitoring and Updating

An annual review of the SMP by management and staff will occur at the end of each winter season. As a result of this review, the SMP will be updated periodically to include any changes in department policy, strategies, and new techniques or equipment to be used in the upcoming winter season.

Tracking specific indicators and comparing these to the baseline that was benchmarked at the outset of the program will confirm progress of the implementation and effectiveness of the SMP. Any change from the established baseline needs to be analyzed to assess the degree of progress made. Monitoring should also take into account the type of winter experienced (winter severity index) to ensure that realistic conclusions are being drawn. Areas of monitoring should include the following:

- Annual Reports
- Salt Management Plans
- Road Operations Salt Storage Facilities
- Training
- Salt Management
- Vegetation Management
- Environmentally sensitive/vulnerable areas
- Surface Water Management

The following excerpt from the Transportation Association of Canada's (TAC's) Synthesis of Best Practices for Road Salt Management explains the need for monitoring and updating equipment and technology, training, and record keeping.

To optimize salt use, it is important to look continually at new and innovative technology as it becomes available. Some salt use "optimization factors" to consider when making equipment choices include:

- *Improved information and decision making tools will allow equipment, personnel and salt to be better utilized and salt applications better timed*
- *Efficient mechanical control of snow and ice will minimize the amount of snow and ice to be controlled by chemicals*
- *Proper equipment choices will help operators to place the exact amount of salt required at the precise location where it is needed, at the right time*
- *Chemical applications should occur at a time that prevents bonding of snow or ice to the surface*
- *Keeping good records of snow and ice control actions taken, along with material usage and a record of changing road conditions, will improve planning and budgeting and limit an organization's liability*
- *The safe and effective use of any equipment requires operators to be properly trained; this is particularly important when introducing new equipment and techniques*

4.1 Annual Reports

In accordance with Environment Canada's Code of Practice, a Monitoring and Measuring Progress report should be compiled and submitted to Environment Canada by June 30 each year (following the winter season).

Road Operations has submitted a report to Environment Canada on an annual basis since the adoption of the Code of Practice for the Environmental Management of Road Salts in 2005. It is recommended that Road Operations continue to submit annual reports as required under the Code of Practice.

4.2 Salt Management Plans

Road Operations contracted GHD to develop the first salt management plan in 2005 and has updated the SMP on a three-year cycle since that time. It is recommended that Road Operations continue to update the SMP on a regular schedule.

4.3 Road Operations Salt Storage Facilities

All road salts managed by Road Operations are stored under cover on impermeable surfaces. Pickled sand, however, is stored outdoors in uncovered piles. Housekeeping practices employed by Road Operations include sweeping up tracked salt. Road Operations does not have any runoff collection systems or a formal plan for managing salt-impacted drainage. Road Operations contracts with a structural specialist to conduct inspections of salt storage facilities as required.

It is recommended that Road Operations conduct regular inspections of all salt storage facilities, including structural integrity of the salt domes and storage sheds, the integrity of the paved pads

beneath and in front of salt storage structures, the amount of salt staining/tracking in front of the salt storage structures, and the integrity of brine storage tanks. It is recommended that, where possible, sand mixed with salt be stored under cover and that Road Operations implement storm water management at sites where rainwater and snowmelt water have the potential to wash salt into waterways.

4.4 Training

Road Operations should monitor the extent to which staff is performing with respect to expected learning goals. This review should be completed on an ongoing basis through observations of staff behaviour. Driving habits, accident reports, and absences are several of the deficiencies identified by Road Operations training staff. A plan to re-train staff in the appropriate areas should be developed.

It is current Road Operations practice to maintain documentation of the training received by staff members including sign off sheets indicating attendance at specific training events including health and safety meetings and practical training courses. As discussed in Section 2.10, Road Operations provides staff with training in accordance with the Transportation Association of Canada's best management practices.

4.5 Salt Management

Road Operations monitoring efforts for should focus on the following areas, which can adjusted as required.

- amount of salt and pickled sand being placed for each route
- inventory of fleet equipped with electronic spreaders
- inventory of fleet equipped with pre-wetting or direct liquid options
- record keeping of equipment calibrations

Road Operations currently records all salt purchases and shipments. The amount of salt used during the year is monitored and reconciled at year end. It is standard procedure for spreader operators to record the amount of salt used for each route. Monitoring is also used in the pickling of sand at a ratio of five percent salt to sand, decreased from the previous six percent.

Road Operations currently implements the following recommended practices:

- Use of electronic spreader controls on 90% of the winter maintenance fleet
- Use of pre-wetting equipment on 60% of the winter maintenance fleet
- Use of various road weather information systems to obtain accurate weather information/predictions
- Use of pavement temperatures to assist in winter maintenance decisions
- Implementation of an equipment calibration program

It is recommended that any new winter maintenance equipment purchased be outfitted with the electronic spreader controls and pre-wetting capability. Pavement temperature monitoring equipment and electronic spreader controls should be checked and calibrated regularly to ensure they are in good working order. Calibration should be documented and records kept for confirmation purposes.

4.6 Vegetation Management

Road Operations should conduct regular visual monitoring for impacts to vegetation from salt spray or drainage from snow disposal sites. It is recommended that an annual inspection of vulnerable areas be conducted to observe and record impact to vegetation, if any, and to observe and record whether changes to the winter maintenance program have resulted in any change with regard to vegetative stress.

4.7 Environmentally Sensitive/Vulnerable Areas

It is important to understand the impacts of the City's winter maintenance policies and practices on environmentally and agriculturally sensitive areas. Environment Canada's Code of Practice outlines the following areas of concern for consideration when identifying vulnerable areas:

- Areas draining into bodies of water, such as:
  - lakes and ponds with low-dilution and long residence times
  - watercourses that experience the cumulative effects of a dense network of highways/roads
- Provincially significant wetlands adjacent to roadways
- Areas draining into small, moderately deep lakes
- Areas where the addition of road salts has the potential to raise the chloride concentration, after mixing, to levels that could harm local fish or fish habitat
- Areas adjacent to salt sensitive vegetation
- Areas where the addition of road salts has the potential to harm the integrity of a life cycle (e.g., spawning grounds, nursery, rearing, food supply, migration areas for birds, etc.)
- Areas where the addition of road salts has the potential to harm a habitat necessary for the survival or recovery of a wildlife species listed on the List of Wildlife Species at Risk (Schedule 1 of the Species at Risk Act)
- Areas draining into sources of drinking water (surface water or ground water, including wells)
- Areas draining into groundwater recharge zones or that have an exposed or shallow water table with medium to high permeability soils

As listed in Annex B of the Code of Practice, additional salt management measures in vulnerable areas may include:

- Using technologies that further optimize the use of road salts
- Using environmentally, technically and economically feasible alternatives to road salts

- Increasing monitoring and measuring of chlorides and/or their impacts
- Locating patrol yard and snow disposal sites outside of vulnerable areas
- Considering location and protection of vulnerable areas in the design of new roads and/or upgrading of existing roads

Appendix D provides details regarding potentially vulnerable water areas within the City, as identified by Road Operations.

Based on a review of the Ministry of Natural Resources and Forestry (MNRF) values maps (i.e., species at risk, significant wetlands, areas of natural or scientific interest), sensitive receptors were not identified within a one kilometer radius of any of Road Operations depots, satellite depots, or snow disposal sites. The MNRF values maps are not an exhaustive source for sensitive receptors and it is recommended that the development of any new Road Operations site where salt, pickled sand or snow will be stored should be evaluated to identify sensitive receptors.

4.8 Drinking Water Resources

The Greater Sudbury Source Protection Plan[2] (Source Protection Plan) identifies six licensed municipal residential drinking water systems, five within the City of Greater Sudbury and one outside of the City. The drinking water systems located within the City comprise 22 municipal groundwater wells and three surface water sources (Ramsey Lake, Wanapitei River, and Vermillion River).

The Source Protection Plan was developed in accordance with Ontario Regulation 287/07 under the Clean Water Act and was approved by the Ministry of the Environment and Climate Change (MOECC) on September 19, 2014. The Source Protection Plan, which took effect on April 1, 2015, was developed to address specific threats to drinking water quality by identifying areas where water resources are vulnerable to contamination, identifying existing drinking water issues, and by assessing threats to drinking water quality. The Source Protection Plan identifies wellhead protection areas (WHPAs) and intake protection zones (IPZs) established for each drinking water system and also includes policies developed to protect drinking water resources within these vulnerable areas. Maps showing the WHPAs and IPZs including the locations of all source water protection signs are provided in Appendix E. An explanation of how these maps were developed is provided in the Greater Sudbury Source Protection Area Assessment Report[3] (Assessment Report), which is available at http://sourcewatersudbury.ca/en/assessment-report.html

Various activities are prescribed as drinking water threats under Ontario Regulation 287/07 including:

2 Greater Sudbury Source Protection Area Source Protection Plan, Prepared on Behalf of the Greater Sudbury Source Protection Committee, Under the Clean Water Act, 2006 (Ontario Regulation 287/07), Approved September 19, 2014, http://www.greatersudbury.ca/sudburyen/assets/File/Greater_Sudbury_Source_Protection_Area_Approved_SPP_Sept_19.pdf

3 Greater Sudbury Source Protection Area Assessment Report, Approved on September 2, 2014.

- Road salt application
- Road salt handling and storage
- Snow storage

Based on a review of WHPA and IPZ maps, the Suez Depot is located within the WHPA of municipal drinking water wells and a portion of the Frobisher Depot including salt and pickled sand storage areas, is located within the intake protection zone (IPZ-3) for Ramsey Lake. The Source Protection Plan recognizes sodium as a drinking water issue for the Ramsey Lake drinking water system and identifies the application, storage, and handling of road salt, and the storage of snow as significant threats within the Ramsey Lake IPZ-1, an area defined as a circle with a radius of 1,000 metres with its center located at the drinking water intake.

Section 10 of the Source Protection Plan provides the following policies regarding salt and snow management within the City:

- Create and deliver an education and outreach program for residents, businesses, institutions, and contractors who may handle, store or apply road salt or store snow in vulnerable areas.
- Identify vulnerable areas were winter maintenance activities could be a significant threat.
- Optimize the use of road salt and minimize losses.
- Prioritize snow removal and street sweeping and cleaning from primary, arterial and collector roads located in vulnerable areas during or soon after the spring melt.
- Include information about the Source Protection Plan and drinking water source protection in annual staff training programs.
- Conduct risk management planning for parking areas that are greater than or equal to one hectare, where application of road salt and snow storage could be a significant threat.
- Conduct risk management planning for sites located within vulnerable areas where 500 kg or more of road salt is stored. Additionally, store salt and pickled sand under cover and on an impermeable surface, and collect and treat drainage where salt or pickled sand are stored in vulnerable areas.
- Prohibit the future road salt storage 500 kg or more within vulnerable areas.
- Prohibit the future establishment of a commercial or municipal snow storage site within vulnerable areas.

The policies of the Source Protection Plan require the City to optimize the use and management of road salt to minimize loss into the environment and impact on drinking water resources. The SMP helps to minimize the impact of road salt and road salt products on drinking water resources by providing a framework for periodic assessment of the City's winter maintenance program in comparison with up to date industry best practices and research. The SMP includes review and documentation of:

- Salt and snow management practices and strategies
- Winter patrol program

- Level of service
- Quantities of winter maintenance materials used
- Facilities inspections
- Recommendations for beneficial improvement options in various areas

It is recommended that the City implement all policies of the Source Protection Plan. GHD understands that the City is currently in the process of preparing risk management plans as required.

4.9 Surface Water Management

Visual monitoring of runoff from roadways, salt and sand storage sites, or snow disposal sites will provide a means to identify areas of potential environmental impact.

It is recommended that Road Operations staff conduct regular site inspections of snow and sand storage sites to ensure that erosion control measure are in place and functioning properly. Consideration should be given to preparing storm water management plans for the various sites, particularly those that are located close to waterways. This will help to ensure the proper control of surface water to prevent erosion, flooding, and/or the direct discharge of salt laden runoff into waterways. Individual snow storage sites should be monitored annually for usage by measuring the length, width, and height of the snow pile.

5. 2016 Inspection Results

In October 2016, an inspection of the winter maintenance depots and snow dump sites was conducted by GHD. Findings associated with various Road Operations sites are summarized in Appendix F.

- Repair/replace salt dome at St. Clair Depot or consider discontinuing use of the site for salt storage
- Consider placing pickled sand piles under cover with priority given to depots located adjacent to waterways and/or wetland areas such as Frobisher, St. Clair, and Naughton
- Move snow and pickled sand piles away from areas where erosion can carry salt laden sediment and runoff directly into waterways
- Install and regularly inspect/maintain sediment and erosion controls where required
- Keep snow and pickled sand storage separate
- Conduct inspections to ensure that snow storage sites are not being misused for waste disposal
- Conduct regular housekeeping to keep salt within storage structures

All of Which is Respectfully Submitted,

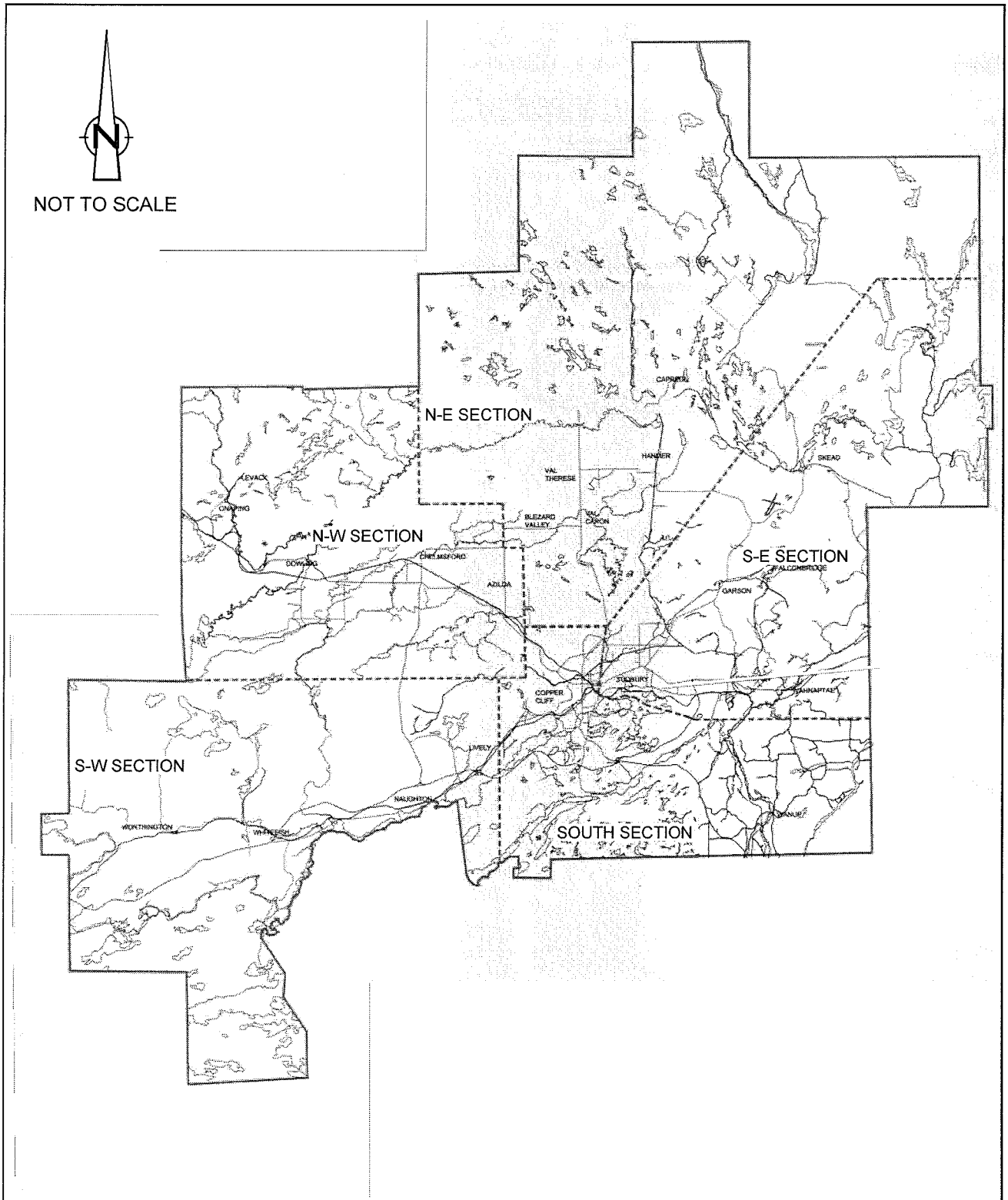
GHD

Sarah Ackert Ferguson

Sarah Ackert Ferguson, P.Eng.

Robert Bressan

Robert Bressan, P.Eng.

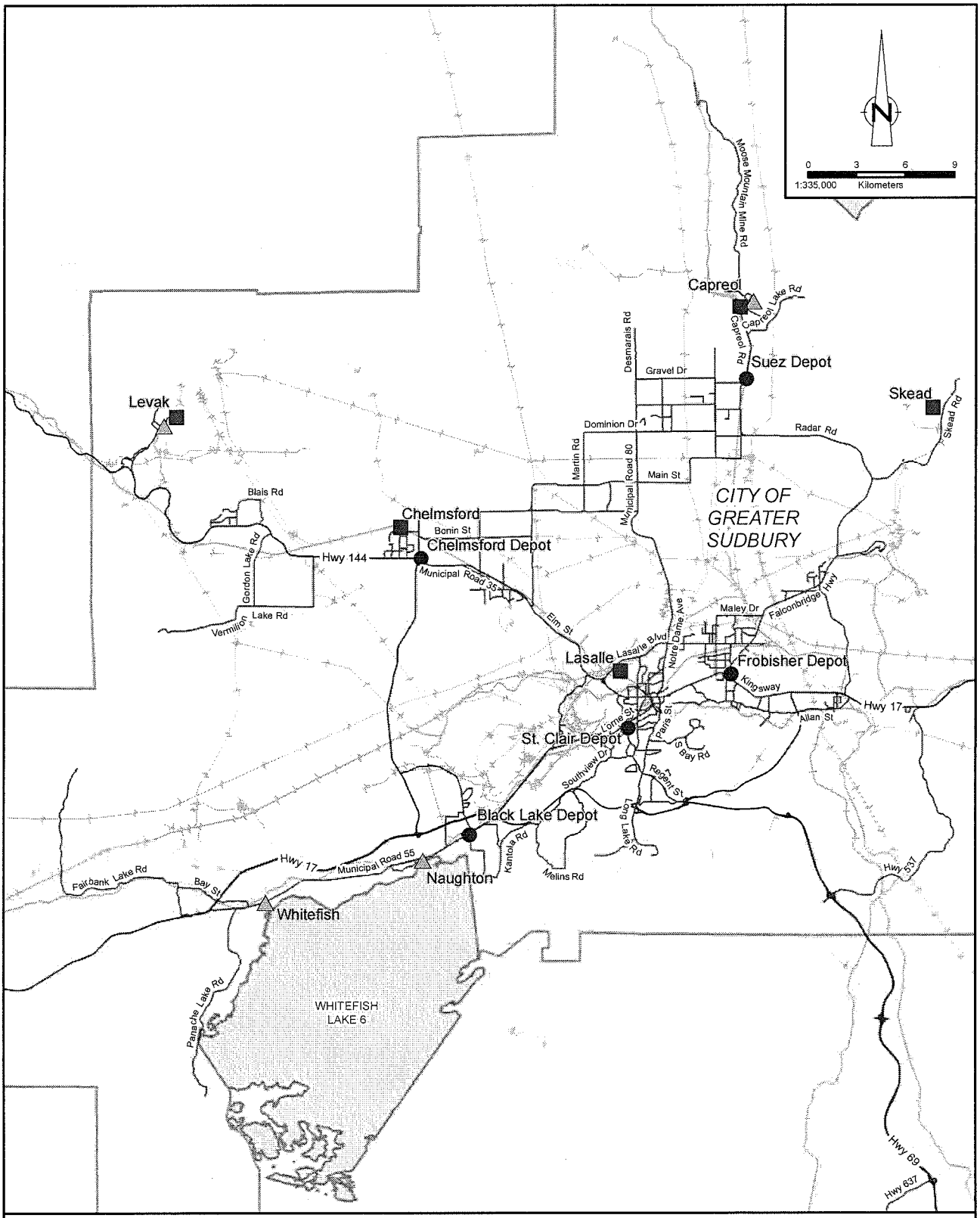


SOURCE: GREATER GRAND SUDBURY INFRASTRUCTURE - NEEDS AND ASSESSMENT STORM DRAINAGE SYSTEM DRAWING.

figure 1

SECTIONAL BREAKDOWN OF GREATER SUDBURY
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

39382-40(006)GN-WA001 JAN 26, 2017



Source: MNRF NRVIS, 2014. Produced by GHD under licence from Ontario Ministry of Natural Resources and Forestry, © Queen's Printer 2017;
Coordinate System: NAD 1983 UTM Zone 17N

figure 2

LEGEND

- Snow Dumps
- Depots
- Satellite Depot

SITE LOCATION MAP
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

039382-40(006)GIS-OT001 May 11/2017

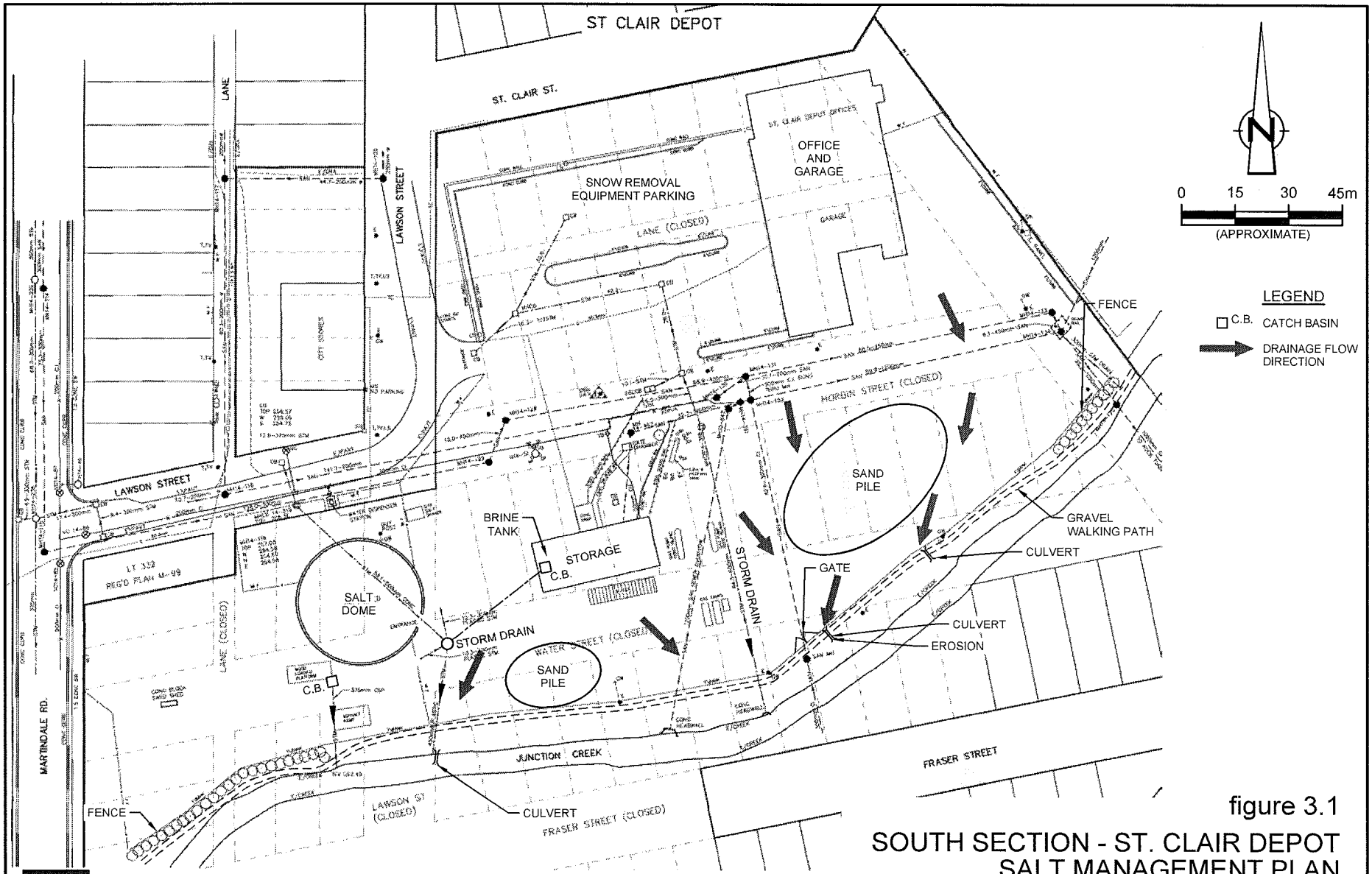


figure 3.1

SOUTH SECTION - ST. CLAIR DEPOT
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

SOURCE:
PROVIDED BY GREATER GRAND SUDBURY,
DRAWING NAME: SITE PLAN, ST. CLAIR DEPOT,
CAD NUMBER: C5459-1, DATE: 2008-03-06.

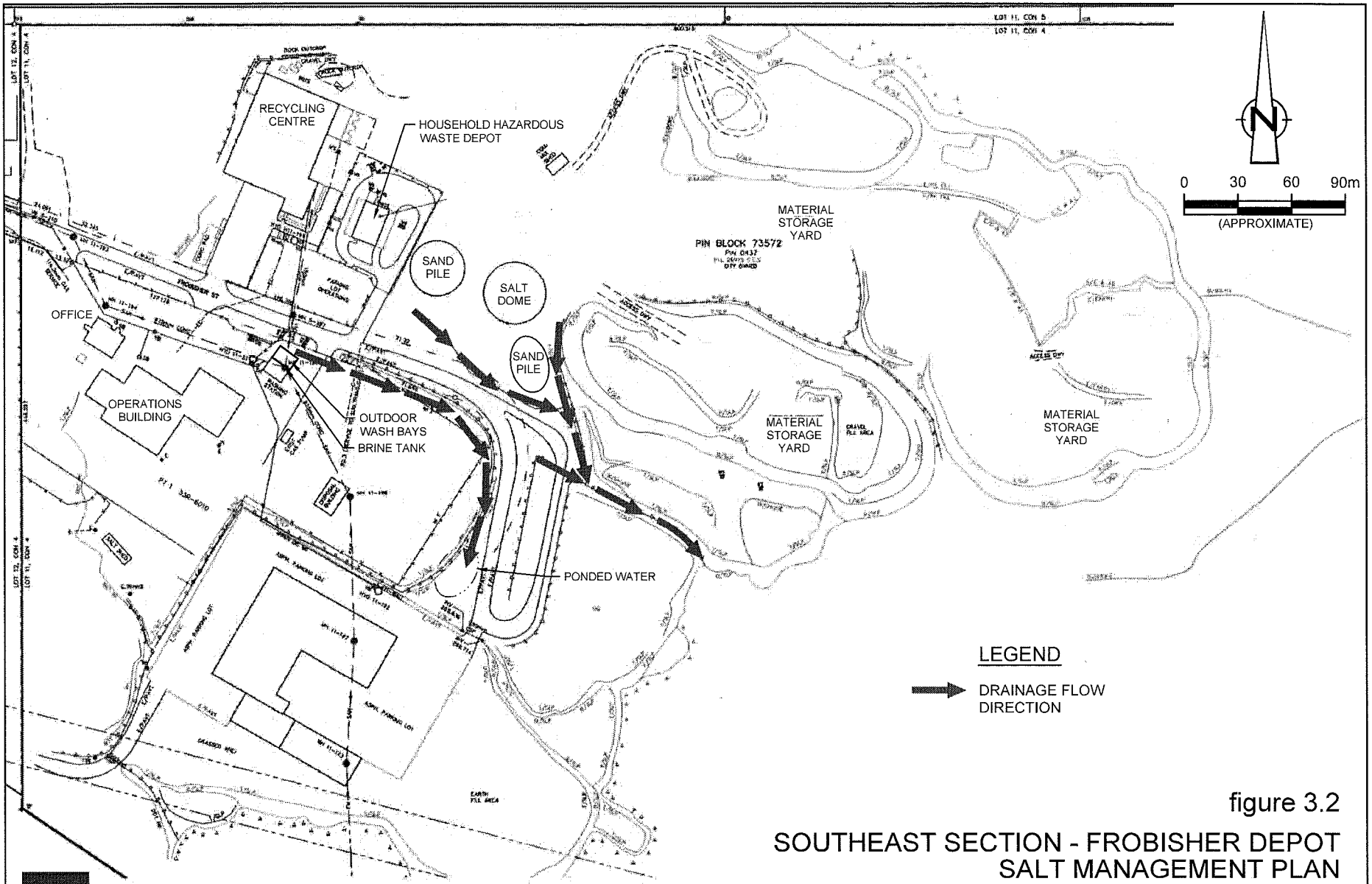


figure 3.2

SOUTHEAST SECTION - FROBISHER DEPOT
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

SOURCE:
PROVIDED BY GREATER GRAND SUDBURY,
DRAWING NAME: SITE PLAN, FROBISHER DEPORT,
CAD NUMBER: C5458-1, DATE: 2008-03-04.

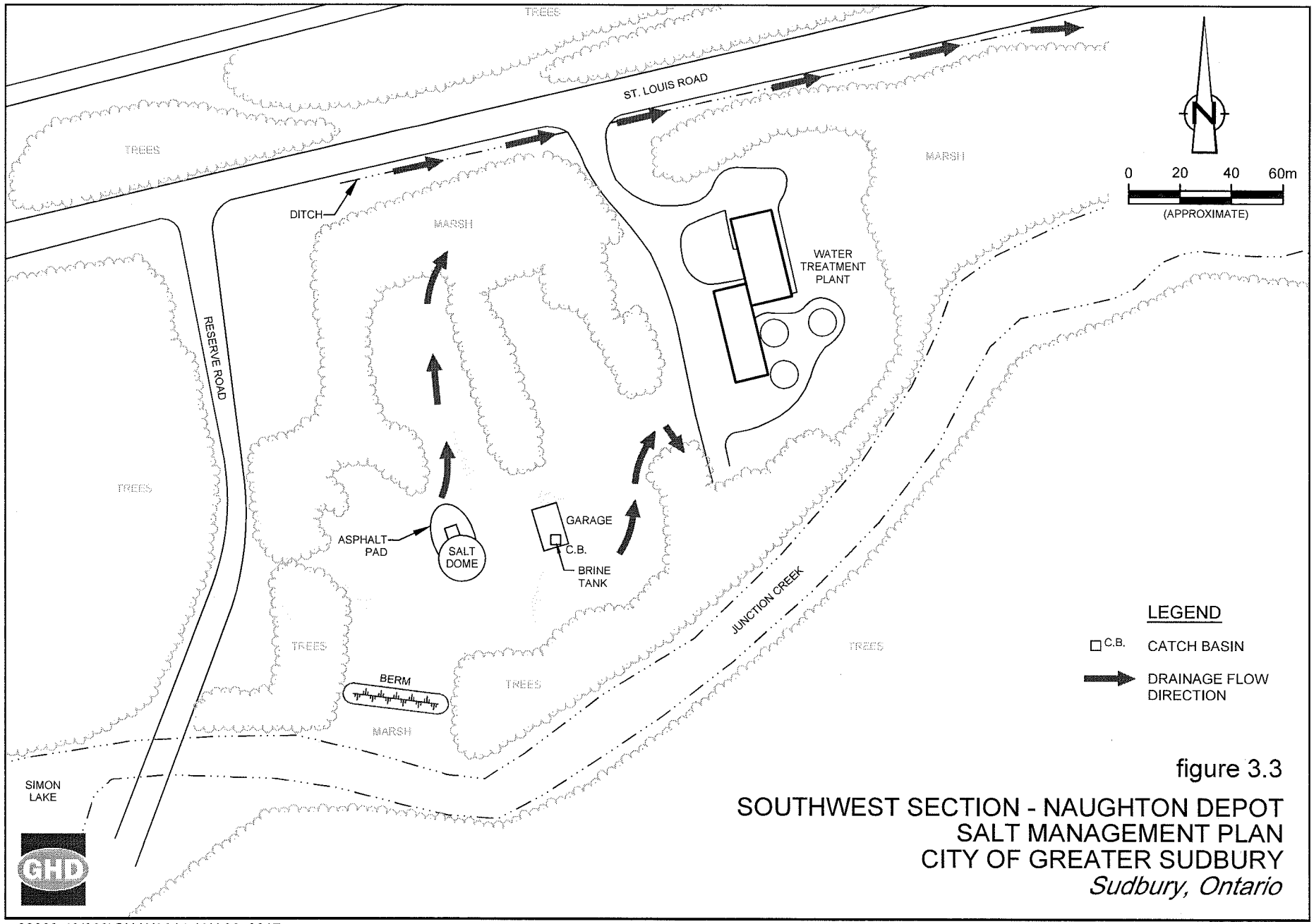


figure 3.3

SOUTHWEST SECTION - NAUGHTON DEPOT
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

39382-40(006)GN-WA014 JAN 26, 2017

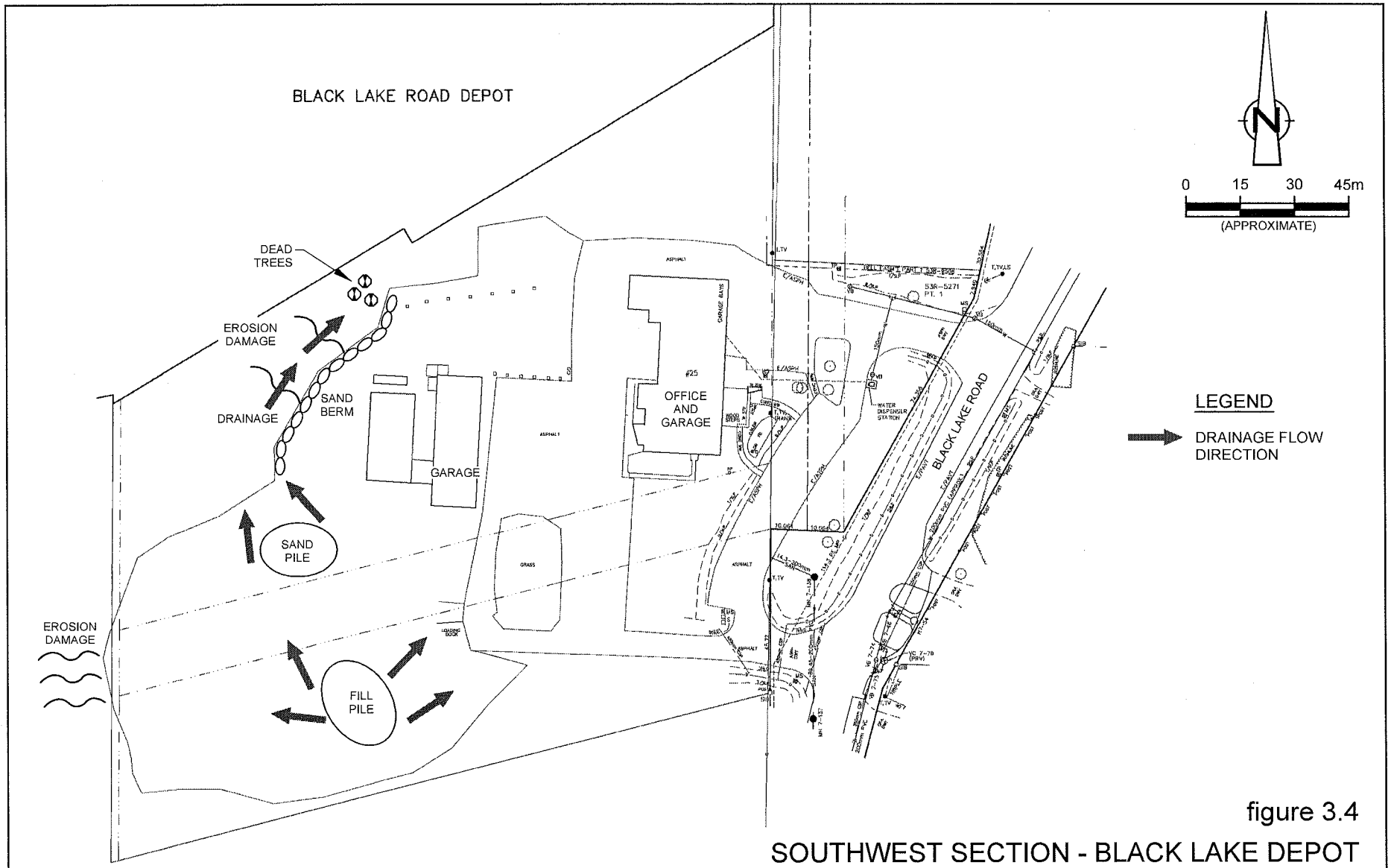


figure 3.4

SOUTHWEST SECTION - BLACK LAKE DEPOT
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

SOURCE:
PROVIDED BY GREATER GRAND SUDBURY,
DRAWING NAME: SITE PLAN, BLACK LAKE DEPORT,
CAD NUMBER: C5456-1, DATE: 2008-06-27.

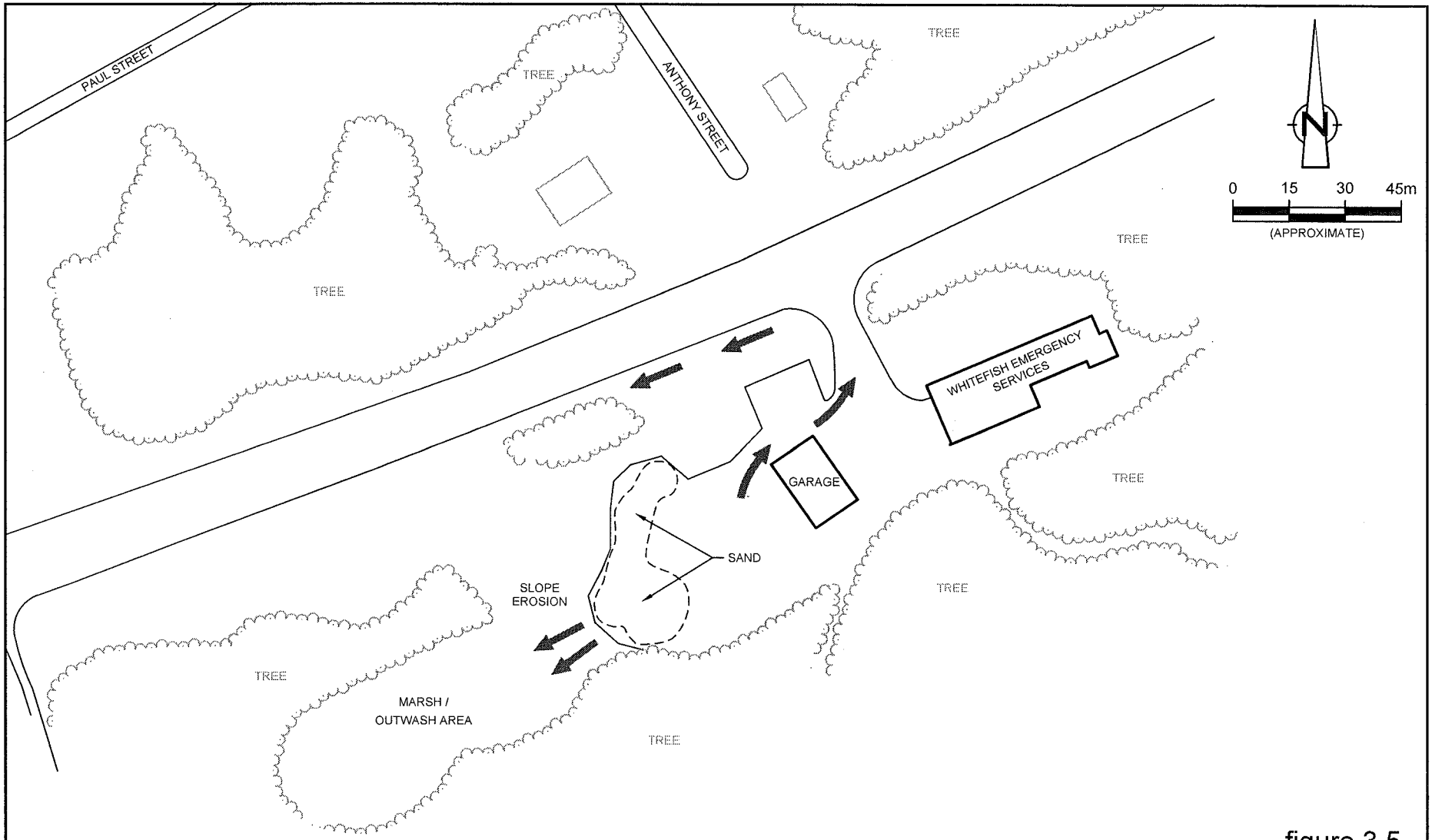


figure 3.5

SOUTHWEST SECTION - WHITEFISH DEPOT
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

LEGEND

DRAINAGE FLOW DIRECTION

GHD

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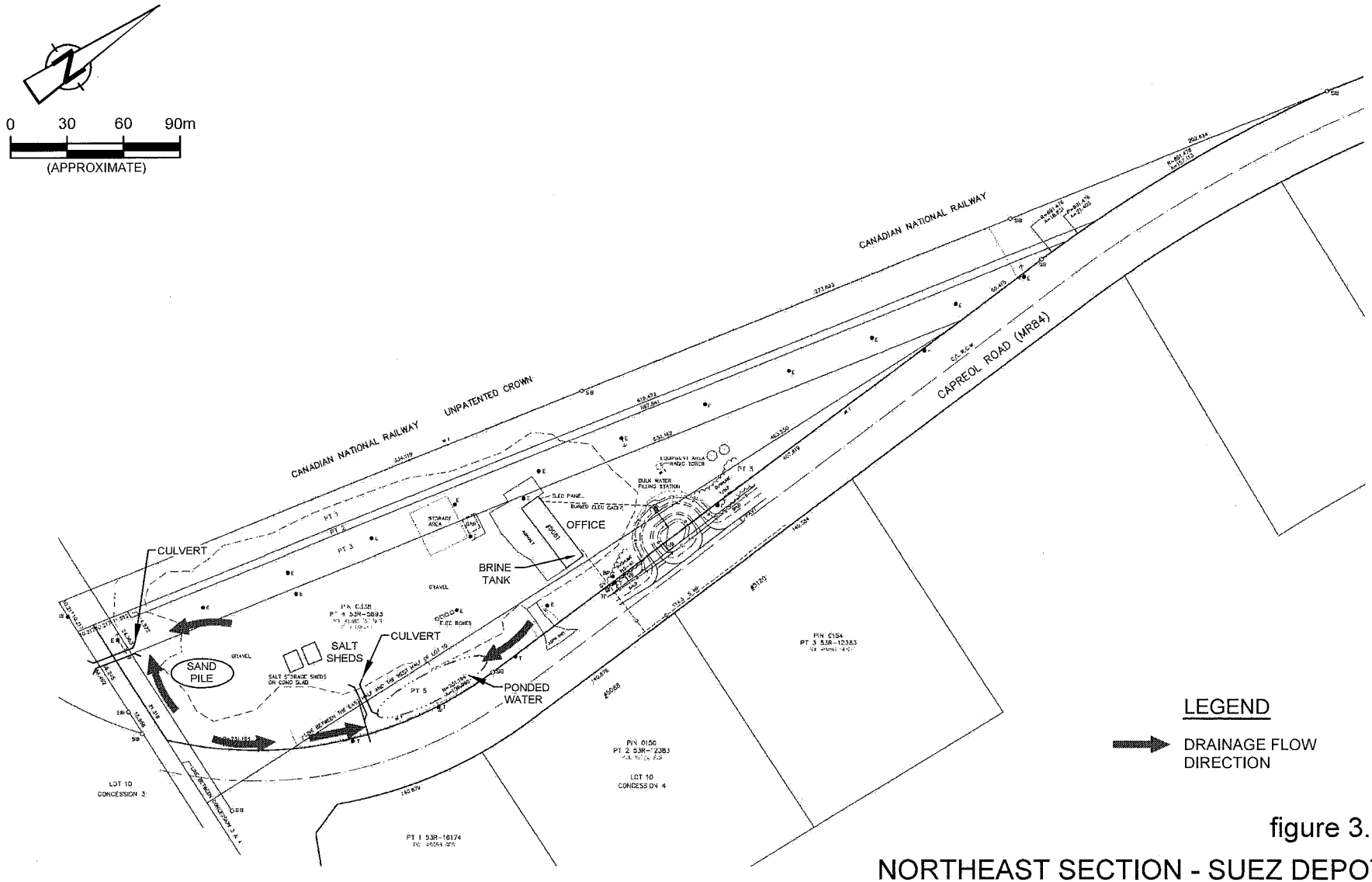


figure 3.6

NORTHEAST SECTION - SUEZ DEPOT
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

SOURCE:
PROVIDED BY GREATER GRAND SUDBURY,
DRAWING NAME: SITE PLAN, SUEZ DEPORT,
CAD NUMBER: C5455-1, DATE: 2008-06-26.

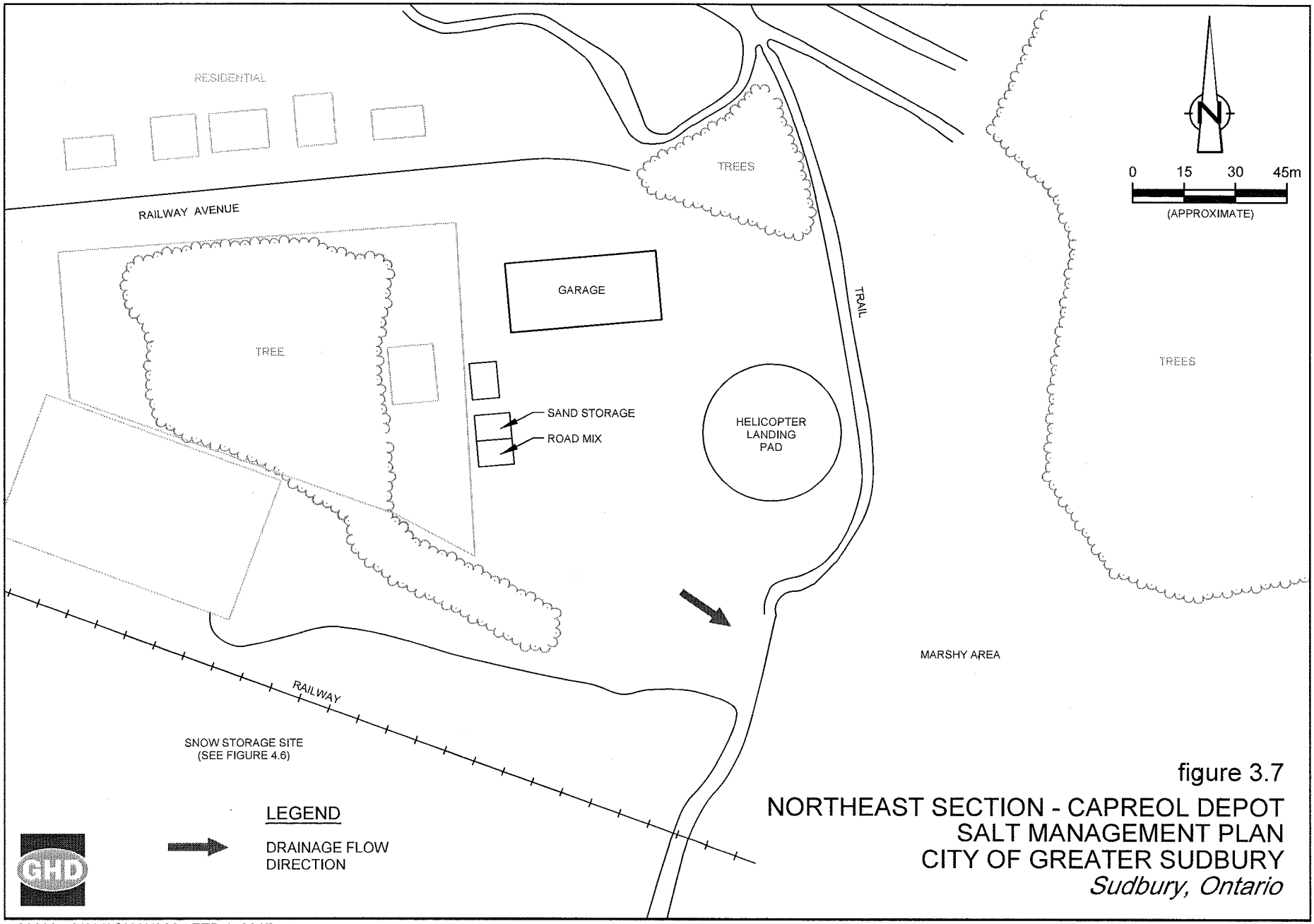


figure 3.7

NORTHEAST SECTION - CAPREOL DEPOT
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

39382-40(006)GN-WA005 FEB 1, 2017

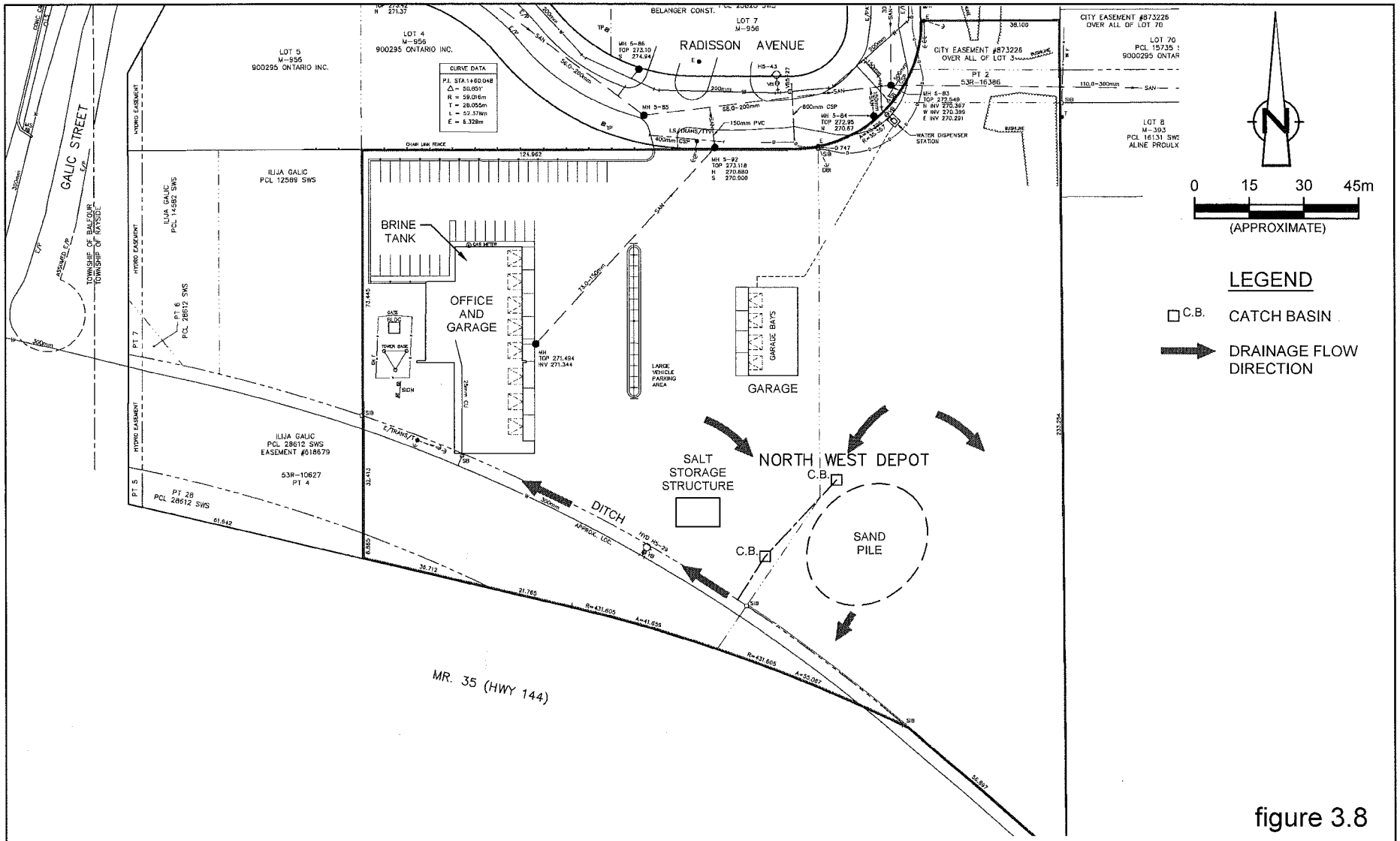


figure 3.8

NORTHWEST SECTION - CHELMSFORD DEPOT
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

SOURCE:
PROVIDED BY GREATER GRAND SUDBURY,
DRAWING NAME: SITE PLAN, NORTHWEST DEPORT,
CAD NUMBER: C5457-1, DATE: 2008-03-13.

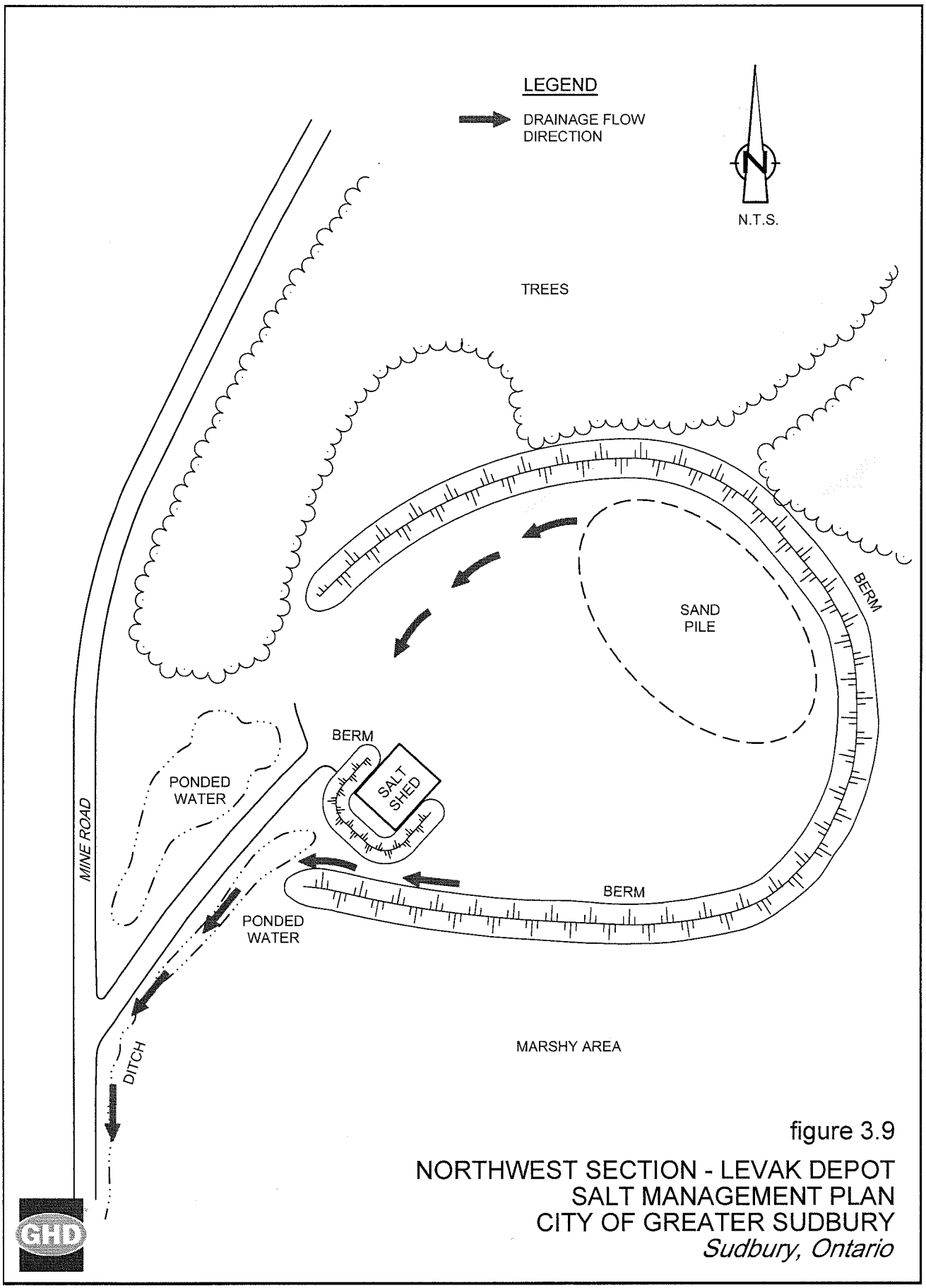


figure 3.9

NORTHWEST SECTION - LEVAK DEPOT
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

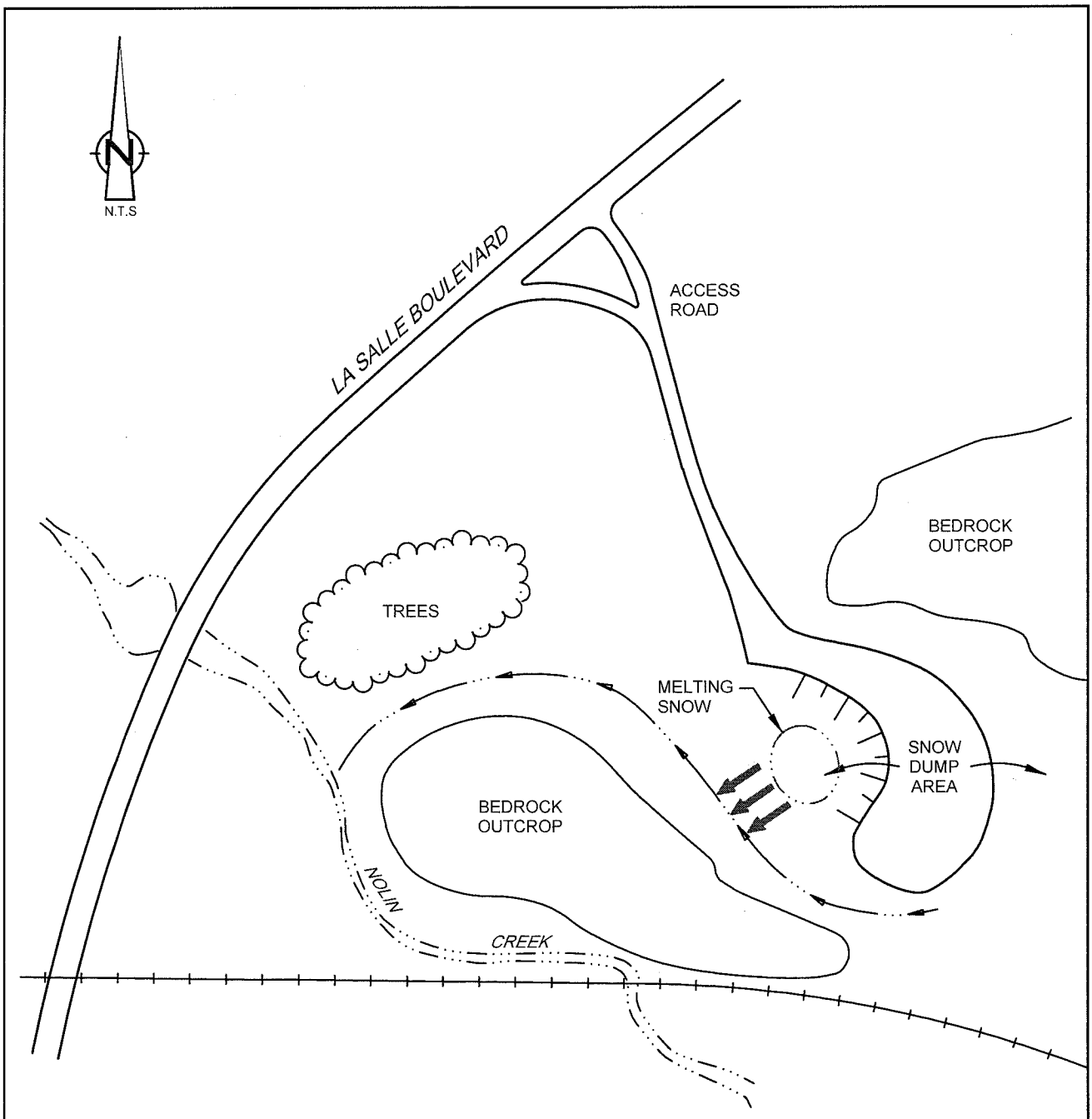
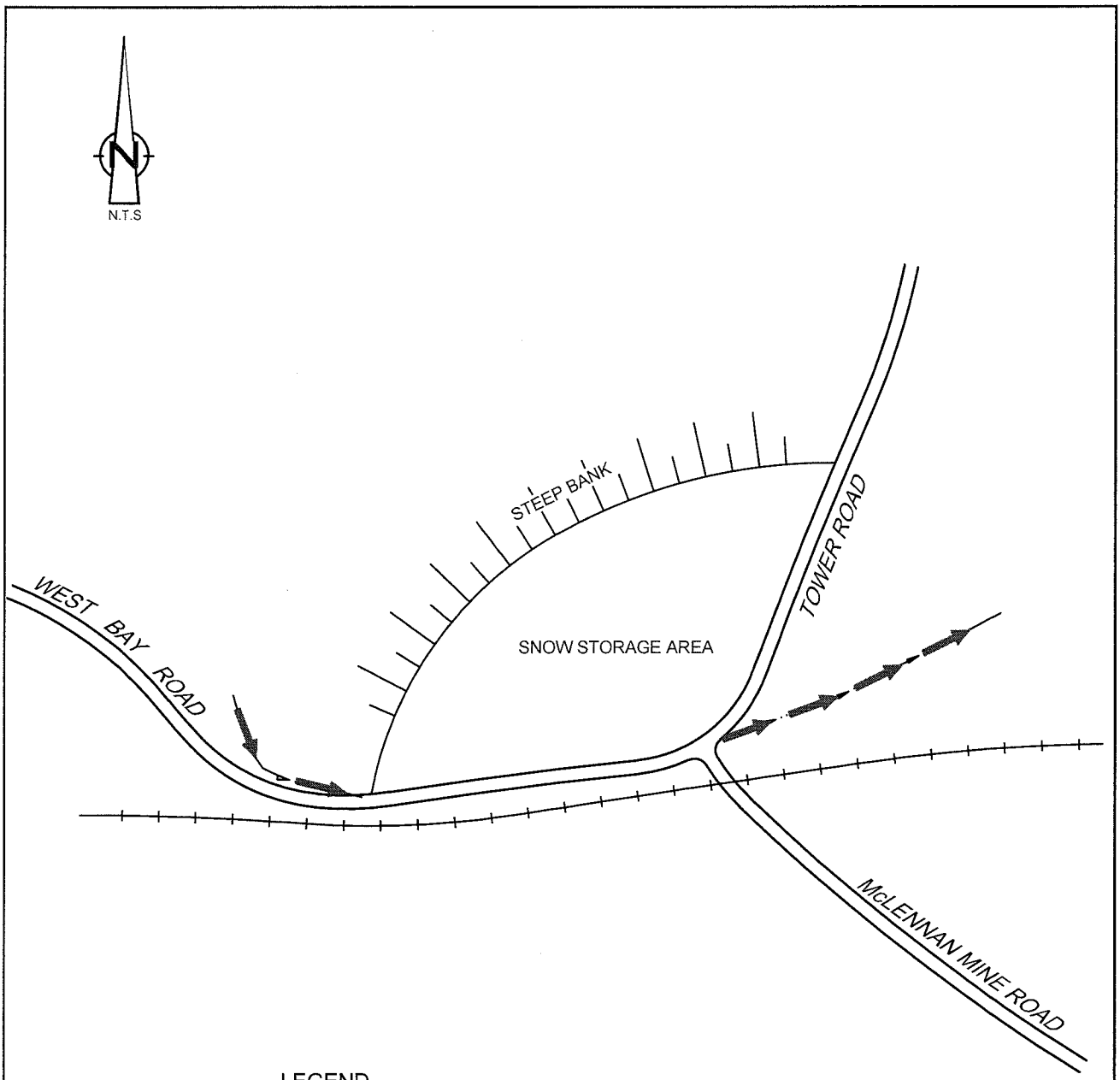


figure 4.1

SOUTH SECTION - LASALLE SNOW STORAGE SITE
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

39382-40(006)GN-WA013 JAN 26, 2017



LEGEND

LEGEND

RAILWAY TRACKS

CREEK

DRAINAGE DITCH

DRAINAGE FLOW DIRECTION

figure 4.2

SOUTHEAST SECTION - SKEAD SNOW STORAGE SITE
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

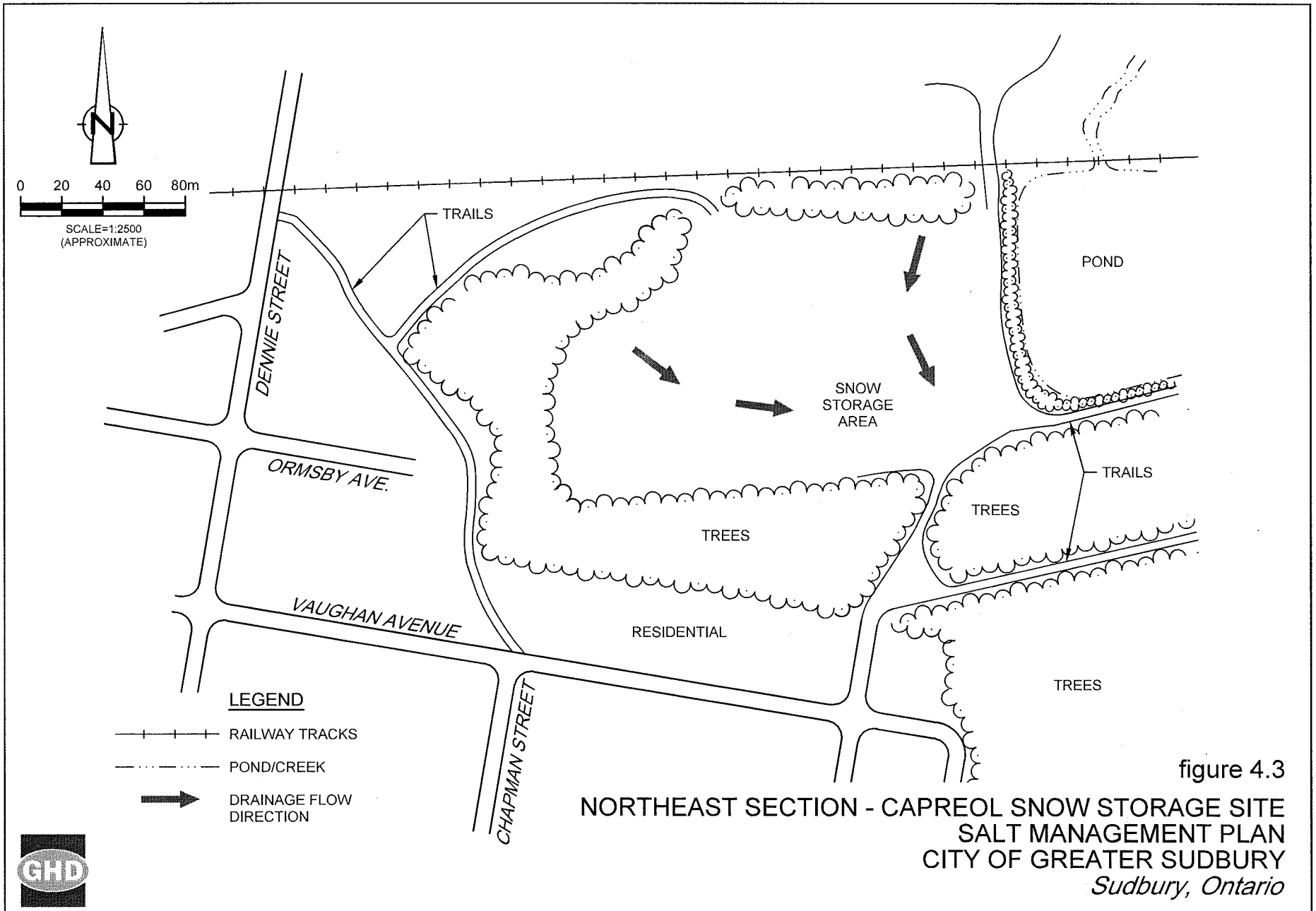


figure 4.3

NORTHEAST SECTION - CAPREOL SNOW STORAGE SITE
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

39382-40(006)GN-WA013 JAN 26, 2017

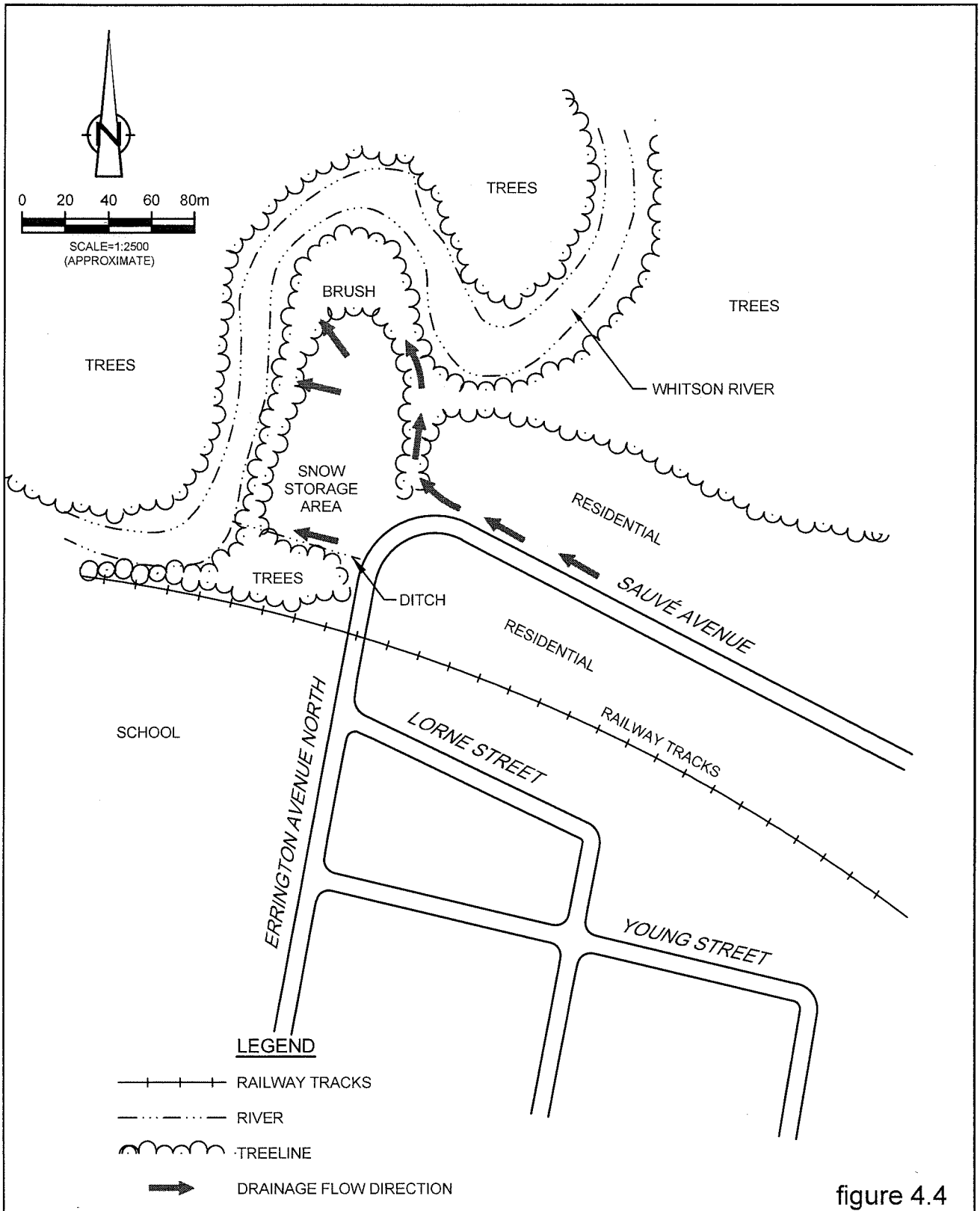


figure 4.4

NORTHWEST SECTION - CHELMSFORD SNOW STORAGE SITE
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

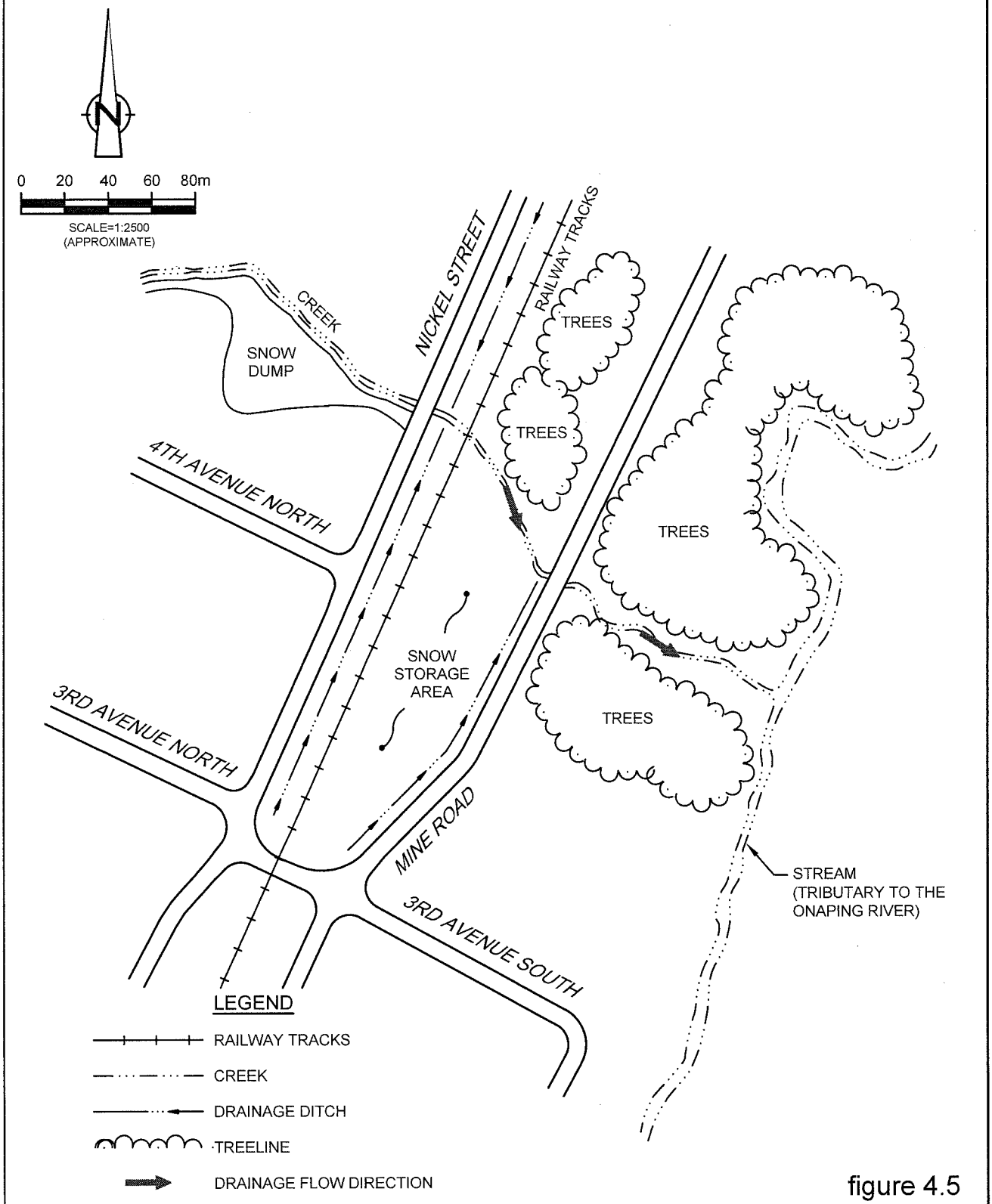


figure 4.5

NORTHWEST SECTION - LEVAK SNOW STORAGE SITE
SALT MANAGEMENT PLAN
CITY OF GREATER SUDBURY
Sudbury, Ontario

Table 1

Road Operations Winter Maintenance Depots By Section
Salt Management Plan
City of Greater Sudbury, Ontario

Section	Depot	Location	Material Storage		Brine Tank	Receiving Water Body	Watershed	Comments
			Salt	Sand				
South	St. Clair [1]	474 St. Clair Street	Y	Y	Y	Junction Creek	Upper Junction Creek	
Southeast	Frobisher [1], [2]	1800 Frobisher Street	Y	Y	Y	Marshy area to the east of the Site	Ramsey Lake	Salt and sand storage just outside of the Lake Ramsey Drinking Water Intake Protection Zone -3
Southwest	Naughton	1425 Municipal Road 55, south side of roadway, east of Reserve Road	Y	Y		Simon Lake / Mud Lake	Lower Junction Creek	
	Black Lake	25 Black Lake Road	Y	Y	Y	Drainage ditch on south side of Municipal Road 55	Lower Junction Creek	
	Whitefish	4895 Municipal Road 55, south side of roadway, between King and Caroline Street		Y		Marshy area to the west of the Site, draining into a tributary of the Vermillion River	Lower Vermillion River	
Northeast	Suez [1]	5081 Municipal Road 84, west side of roadway, north of Suez Drive	Y	Y	Y	Water infiltrates ground surface	Whitson River	Located within a Well Head Protection Area with a vulnerability score of 6
	Capreol	65 Railway Avenue, south side of roadway, south of the Emergency Services building	Y	Y		Large pond/marshy area located east of the Site, which drains into a tributary of the Vermillion River	Upper Vermillion River	
Northwest	Chelmsford [1]	101 Radisson Avenue	Y	Y	Y	Drainage ditches along Municipal Road 35, Radisson Avenue and the NW By Pass	Whitson River	
	Levak	Mine Road, east side of roadway		Y		Marshy area southwest of Site and drainage ditches along Mine Road to the south, draining to a tributary of the Onaping River	Onaping River	

NOTES:
(1) Road Operations Sectional Central Operations Depots
(2) Road Operations Central Head Quarters

Table 2

Road Operations Snow Storage Sites by Section
Salt Management Plan
City of Greater Sudbury, Ontario

Section	Snow Storage Site	Location	Size	Drainage / Receiving Water Body	Watershed	Comments
South	LaSalle	East side of LaSalle Boulevard extension, between Elm Street and Frood Road	25 ha	Water flows into a drainage ditch located on the south side of the site, at the base of the tipping slope, which flows into Nolin Creek	Upper Junction Creek	Main snow dump for the City
Southeast	Skead	West Bay Road at intersection of Tower Road and MacLennan Mine Road	0.2 ha	Water infiltrates the ground surface or flows overland to ditches on the south side of West Bay Road	Lake Wanapitei	Local snow only
Northeast	Capreol	North end of Shaw Street	1.5 ha	Water infiltrates ground surface or flows overland to a large pond/marshy area located east of the Site, which drains into a tributary of the Vermillion River	Upper Vermillion	
Northwest	Chelmsford	Northwest corner of Errington and Sauve Avenue Intersection, Chelmsford, ON.	2 ha	Whitson River located immediately adjacent to the west side of the site	Whitson River	
	Levak	Between Mine Road and the train tracks at 3rd Avenue	3 ha	Drainage Ditch located on the east side of the site, along Mine Road discharges to a small creek north of the Site	Onaping River	

Table 3

Level of Service Policy Summary - Storm Response Triggers, Actions, and Response Times
Salt Management Plan
City of Greater Sudbury, Ontario

Road Winter Maintenance - Snow Events			Service Timelines [1]		City Policy	City Practice
Road Classification	Protocol/Action	Snow Accumulation	Complete Round #1/Initial Deployment	Clear/Material Application		
Class 1 - 3	Apply Brine/Salt	N/A	Within 2 - 4 Hours of Significant Snowfall	-	Yes	Yes
	Plow Roads	5 cm [2]	Within 3 - 8 Hours after 5 cm Threshold	3 - 8 Hours after Storm Ends, If Required	Yes	Yes
	Salt/Brine/Sand Roads	N/A	Within 3 - 8 Hours after 5 cm Threshold	3 - 8 Hours after Storm Ends, If Required	No	Yes
Class 4 - 6	Plow Roads	8 cm [3]	Within 24 Hours after reaching 8 cm Threshold	24 Hours after Storm Ends, If Required	Yes	Yes
	Spot Sand Roads	N/A	Within 24 Hours after reaching 8 cm Threshold	24 Hours after Storm Ends, If Required	Yes	Yes

Road Winter Maintenance - Ice Events			Service Timelines [1]		City Policy	City Practice
Road Classification	Protocol/Action	Ice Detection	Complete Round #1/Initial Deployment	Clear/Material Application		
Class 1 - 3	Salt/Brine/Sand Roads	Detected	Within 2 - 4 Hours of Ice Detection	2 - 4 Hours after Storm Ends, If Required	Yes	Yes
Class 4 - 5	Sand Roads	Detected	Within 12 - 16 Hours of Ice Detection	12 - 16 Hours after Initial Application, If Required	Yes	No
Class 4 - 6	Sand Roads	Detected	Within 24 Hours of Ice Detection	24 Hours after Initial Application, If Required	No	Yes

Sidewalk Winter Maintenance - Snow Events			Service Timelines [1]		City Policy	City Practice
Sidewalk Classification	Protocol/Action	Snow Accumulation	Complete Round #1/Initial Deployment	Clear/Material Application		
Downtown	Plow & Sand Sidewalks	N/A	Midnight to 8:00 am, Weekdays	-	Yes	Yes
Class 1 [4]	Plow & Sand Sidewalks	8 cm [6]	Within 4 - 24 Hours of Reaching 8 cm Threshold	12 - 24 Hours after Storm Ends, If Required	Yes	Yes
Class 2 [5]	Plow & Sand Sidewalks	8 cm [7]	Within 8 - 24 Hours of Reaching 8 cm Threshold	12 - 24 Hours after Storm Ends, If Required	Yes	Yes

Sidewalk Winter Maintenance - Ice Events			Service Timelines [1]		City Policy	City Practice
Sidewalk Classification	Protocol/Action	Ice Detection	Complete Round #1/Initial Deployment	Clear/Material Application		
Downtown	Plow & Sand Sidewalks	N/A	Midnight to 8:00 am, Weekdays	-	Yes	Yes
All Sidewalks	Sand or Salt	Detected	Within 2 - 24 Hours of Ice Detection	2 - 24 Hours after Initial Application, If Required	Yes	No
All Sidewalks	Sand Sidewalks	Detected	Within 24 Hours of Ice Detection	24 Hours after Storm Ends, If Required	No	Yes

NOTES:

(1) Winter Control Supervisors may alter any policy statement to suit actual weather conditions
(2) Accumulation of 5 cm was chosen as a mid point of the MMS depth of the snow accumulation range (2.5 - 8 cm) for Class 1 - 3 roads.
(3) Accumulation of 8 cm was chosen since it was the lesser of the MMS depth of the snow accumulation range (8 - 10 cm) for Class 4 - 6 roads.
(4) Class 1 Sidewalks - Sidewalks located adjacent to Class 1 - 3 Roads
(5) Class 2 Sidewalks - Sidewalks located adjacent to Class 4 - 6 Roads
(6) Accumulation of 8 cm was chosen as a mid point of the MMS depth of snow accumulation range (2.5 - 15) for Class 1 sidewalks.
(7) Accumulation of 8 cm was chosen as a mid point of the MMS depth of snow accumulation range (5 - 15) for Class 2 sidewalks.

Table 4

Storm Response Triggers, Actions, and Response Times - Comparison With Other Northern Municipalities
Salt Management Plan
City of Greater Sudbury, Ontario

Road Authority	Winter Control Category	Road/Sidewalk	Snow Trigger	Response	Other Notes
Sudbury	Snow Plowing - Roads	Class 1 - 3 Roads	5 cm	3 - 8 hr	Roads are salted, 17 Beats (includes 4 Echelon Beats)
	Snow Plowing - Roads	Class 4 - 6 Roads	8 cm	Up to 24 hr	Roads are sanded, 28 Beats
	Snow Plowing - Sidewalks	All Sidewalks	8 cm	12 to 24 hr	Business area plowed throughout the work week, 20 Beats
	Snow Removal	Completed when sight lines at major intersections are hindered or lane widths narrow. Snow is removed in the business sections on average twice per season and as required. Snow Benching in the rural areas is done to increase snow storage. One main snow dump with an average round trip haul time of one hour. Various smaller snow dumps located in outlying areas.			
Timmins	Snow Plowing - Roads	Class 1 - 3 Roads	8 - 10 cm	8 - 12 hr	Roads are sanded
	Snow Plowing - Roads	Class 4 - 6 Roads	8 - 10 cm	8 - 12 hr	Roads are sanded, 13 Total Beats
	Snow Plowing - Sidewalks	All Sidewalks	8 - 10 cm	8 - 16 hr	All sidewalks plowed throughout the work week, 6 Beats
	Snow Removal	Completed when snow banks reach three feet in the business sections, when sight lines are hindered, or when lane widths narrow on any street. Snow removal operations are continuous after December of every year, excluding winter event days. Eight snow dumps are in operation. The farthest haul distance is 4 km and the average round trip haul haul time is 10 minutes.			
North Bay	Snow Plowing - Roads	Class 1 - 3 Roads	MMS	8 - 12 hr	Roads are salted
	Snow Plowing - Roads	Class 4 - 6 Roads	MMS	8 - 12 hr	Roads are sanded, 13 Total Beats
	Snow Plowing - Sidewalks	All Sidewalks	MMS	Up to 12 hr	5 Beats, spot sand all sidewalks
	Snow Removal	Completed when sight lines at major intersections are hindered, lane widths narrow, and in the business sections when snow banks exceed two feet or as required. Largely a complaint/investigation/action driven system is incorporated for snow removal. One snow dump with a round trip distance of 20 minutes.			

Table 4

Storm Response Triggers, Actions, and Response Times - Comparison With Other Northern Municipalities
Salt Management Plan
City of Greater Sudbury, Ontario

Road Authority	Winter Control Category	Road/Sidewalk	Snow Trigger	Response	Other Notes
Sault Ste. Marie	Snow Plowing - Roads	Class 1 - 3 Roads	5 cm	Up to 12 hr	Roads are salted
	Snow Plowing - Roads	Class 4 - 6 Roads	5 cm	Up to 24 hr	Roads are sanded, 17 Total Beats
	Snow Plowing - Sidewalks	All Sidewalks	5 cm	Up to 12 hr	All sidewalks plowed throughout the work week, 9 Beats
	Snow Removal	Completed when snow banks are halfway up the parking meters in the business sections. Snow is removed from all streets when sight lines are hindered or when lane widths narrow. Benching of snow in the rural areas occurs. Seven designated snow dumps in operation. The longest haul distance is 3 km.			
Thunder Bay	Snow Plowing - Roads	Class 1 - 3 Roads	5 cm	Up to 12 hr	Roads are salted
	Snow Plowing - Roads	Class 4 - 6 Roads	5 cm	Up to 72 hr	Roads are salted, 34 Total Beats
	Snow Plowing - Sidewalks	High Priority Sidewalks	5 cm	14 - 36 hr	
	Snow Plowing - Sidewalks	Low Priority Sidewalks	5 cm	Up to 72 hr	15 Total Beats
	Snow Removal	Completed when sight lines at major intersections are hindered, lane widths narrow, and in the business sections as required. Snow removal has not happened anywhere in the City for the past few years (conditions have not warranted). All roads are essentially bare due to City wide salting operation, which minimizes the need for snow removal.			

NOTES:
Information provided by City of Sudbury Public Works Department

Table 5

Storm Response Guide
Salt Management Plan
City Of Greater Sudbury, Ontario

Current Temperature	Current Pavement Condition	Current Precipitation	Possible Action	Application Rates			
				Class 1 to 3 Roads			Class 4 to 6 Roads
				Brine (L/ MT of Salt)	Salt (kg/2-Lane km)	Sand (kg/2-Lane km)	Sand (kg/2-Lane km)
0°C and above	Wet	Snow	Plow and Sand or Salt	65	60 to 90	Nil (1)	100 to 310
		Freezing Rain	Sand and Salt	65	150	Nil (1)	310
-4°C to 0°C	Wet	Snow	Plow and Sand or Salt	65	90 to 115	Nil (1)	100 to 310
		Freezing Rain	Sand and Salt	65	150	Nil (1)	310
-12°C to -4°C	Snow Packed	Nil	Plow and Salt	65	115 to 150	Nil (1)	Nil (1)
	Snow Packed	Snow	Plow and Sand or Salt	65	150	Nil (1)	100 to 310
	Dry	Snow	Plow and Sand or Salt	65	150	Nil (1)	200 to 310
Below -12°C	Snow Packed	Nil	Plow and Sand	Nil	Nil	200 to 310	200 to 310
	Dry	Snow	Plow and Sand	Nil	Nil	200 to 310	200 to 310

NOTES:

The Superintendent or his designate may change protocol at his/her discretion based on actual road and weather conditions
kg - kilogram
km - kilometre
L - litre
MT - metric tonne

Table 6

Summary of Annual Salt Usage - 2003 To 2015
Salt Management Plan
City Of Greater Sudbury, Ontario

Season	*Total salt use per season for each city section (tonnes)* [1]					*Total Salt (tonnes)*
	South	*Southeast*	*Southwest*	*Northeast*	*Northwest*	
2003	4,460	5,379	2,827	2,412	1,503	16,581
2004	4,080	5,321	2,744	3,037	1,334	16,516
2005	4,420	5,266	2,603	2,544	1,279	16,112
2006	5,828	6,900	4,722	3,198	1,735	22,383
2007	5,164	7,125	3,556	3,385	1,918	21,148
2008	10,179	10,700	5,002	5,635	2,898	34,414
2009	3,335	3,387	2,014	2,145	1,166	12,047
2010	4,301	5,630	3,019	3,338	1,887	18,175
2011	3,577	5,005	2,835	2,992	2,021	16,430
2012	4,749	6,226	3,465	3,495	2,499	20,434
2013	7,563	8,728	4,753	4,608	3,457	29,109
2014	5,715	6,757	3,899	3,630	2,624	22,625
2015	3,166	3,519	1,825	2,257	1,649	12,416
Average	5,118	6,149	3,328	3,283	1,998	19,876

NOTES:
(1) Quantities include salt used for brine manufacturing and salt used to pickle sand

Table 7

Summary of Annual Sand Usage - 2005 To 2015
Salt Management Plan
City of Greater Sudbury, Ontario

Season	*Total sand use per season for each city section (tonnes)*					*Total Sand (tonnes)*
	South	*Southeast*	*Southwest*	*Northeast*	*Northwest*	
2005	14,224	12,286	15,183	9,647	11,267	62,607
2006	11,959	8,026	12,844	6,997	7,674	47,500
2007	7,599	7,908	7,408	5,925	6,939	35,779
2008	19,302	15,537	12,114	11,146	16,547	74,646
2009	9,729	7,136	7,304	6,187	6,151	36,507
2010	9,395	9,909	10,035	7,730	9,679	46,748
2011	10,107	11,928	9,684	8,252	9,533	49,504
2012	12,487	11,323	10,351	10,932	8,888	53,981
2013	14,430	16,491	13,061	15,042	12,396	71,420
2014	16,933	15,208	18,031	13,781	12,060	76,013
2015	14,236	12,100	13,308	11,231	8,831	59,706
Average	12,764	11,623	11,757	9,715	9,997	55,856

Appendices

Appendix A
Road Inventory

Inventory by Maintenance Class

12/21/2016

	NE	NW	S	SE	SW	Totals
Class 1						
Lane / Km	51.0	29.2	46.7	32.6	34.9	194.4
%	**26.2**	**15.0**	**24.0**	**16.8**	**18.0**	
Centerline / Km	14.8	7.3	18.6	12.5	8.7	61.9
%	**23.9**	**11.8**	**30.0**	**20.2**	**14.1**	
Class 2						
Lane / Km	28.3	16.9	126.8	117.6	5.5	295.1
%	**9.6**	**5.7**	**43.0**	**39.9**	**1.9**	
Centerline / Km	7.5	6.0	30.6	30.8	2.8	77.7
%	**9.7**	**7.7**	**39.4**	**39.6**	**3.6**	
Class 3						
Lane / Km	69.6	58.2	66.0	97.4	73.9	365.1
%	**19.1**	**15.9**	**18.1**	**26.7**	**20.2**	
Centerline / Km	31.4	28.9	31.3	44.7	36.8	173.1
%						
Class 4						
Lane / Km	234.8	173.6	177.6	151.6	135.7	873.3
%	**26.9**	**19.9**	**20.3**	**17.4**	**15.5**	
Centerline / Km	117.4	86.5	87.7	75.8	67.9	435.3
%	**27.0**	**19.9**	**20.1**	**17.4**	**15.6**	
Class 5						
Lane / Km	242.0	235.2	481.7	473.5	324.3	1756.7
%	**13.8**	**13.4**	**27.4**	**27.0**	**18.5**	
Centerline / Km	123.8	118.1	243.3	238.2	162.9	886.3
%	**14.0**	**13.3**	**27.5**	**26.9**	**18.4**	
Class 6						
Lane / Km	5.8	24.9	6.9	19.0	71.5	128.1
%	**4.5**	**19.4**	**5.4**	**14.8**	**55.8**	
Centerline / Km	3.0	15.0	3.7	9.9	38.7	70.3
%	**4.3**	**21.3**	**5.3**	**14.1**	**55.0**	
Totals						
Lane / Km	631.5	538.0	905.7	891.7	645.8	3612.7
Centerline / Km	297.9	261.8	415.2	411.9	317.8	1704.6

Class 1 / 2	16.2	9.4	35.4	30.7	8.3	100.0
Class 1 / 2 / 3	17.4	12.2	28.0	29.0	13.4	100.0
Class 1 / 2 / 3 / 4	22.2	16.1	24.1	23.1	14.5	100.0
Class 1 / 2 / 3 / 4 / 5	18.0	14.7	25.8	25.0	16.5	100.0
Class 1 / 2 / 3 / 4 / 5 / 6	17.5	14.9	25.1	24.7	17.9	100.0
Class 6 / 5	13.1	13.8	25.9	26.1	21.0	100.0
Class 6 / 5 / 4	17.5	15.7	24.2	23.4	19.3	100.0

Inventory by Planning Class

12/21/2016

	NE	NW	S	SE	SW	Totals
Arterial						
Lane / Km	171.9	57.0	227.0	278.8	91.0	825.7
%	**20.8**	**6.9**	**27.5**	**33.8**	**11.0**	
Centerline / Km	59.0	24.8	62.4	105.2	36.6	288.0
%	**20.5**	**8.6**	**21.7**	**36.5**	**12.7**	
Collector						
Lane / Km	115.4	135.4	139.6	117.6	113.6	621.6
%	**18.6**	**21.8**	**22.5**	**18.9**	**18.3**	
Centerline / Km	57.7	67.4	68.1	57.6	56.8	307.6
%	**18.8**	**21.9**	**22.1**	**18.7**	**18.5**	
Local						
Lane / Km	357.9	334.5	569.8	544.5	444.3	2251.0
%	**15.9**	**14.9**	**25.3**	**24.2**	**19.7**	
Centerline / Km	181.8	170.2	286.9	274.1	225.8	1138.8
%	**16.0**	**14.9**	**25.2**	**24.1**	**19.8**	
Totals						
Lane / Km	645.2	526.9	936.4	940.9	648.9	3698.3
%	**17.4**	**14.2**	**25.3**	**25.4**	**17.5**	
Centerline / Km	298.5	262.4	417.4	436.9	319.2	1734.4
%	**17.2**	**15.1**	**24.1**	**25.2**	**18.4**	

Appendix B
Road Patrol Record Forms

Greater Sudbury Grand

Summer Patrol Record

Weather	
Clear	Time
Partly Cloudy	Time
Overcast	Time
Rain	Time
Fog	Time
Air Temperature:	Time
Pavement Temperature:	Time
Visibility: Good Fair Poor	
Wind: Light Moderate Strong Direction_____	

Date:

Patrolled by:

Truck #:

Hours of Work: _____to_____

On Call ORS:

Condition Codes
× **Needs Service**
A blank space indicates conditions meet standard
Time to be recorded using a 24 hour clock

Accident/Damage	Time
Police Response yes no	Police Report #
Location	
Description	

Highway Patrolled (Area)				Road Classification	Roadway						Signs & Markers		Sidewalks		Bridges		Other	Notes
					Pothole	Shoulder Drop Off	Surface Discontinuities	Debris	Drainage (MH, CB, Sewers & Culverts)	Requires Other Maintenance	Safety Devices	Road Signs	Surface Discontinuities	Requires Other Maintenance	Deck Spalls	Requires Other Maintenance	Other Required Maintenance	
Name	**Time**	**From**	**To**															

Greater | Grand Sudbury

Winter Patrol Record

Weather		Date:
Clear	Time	
Partly Cloudy	Time	Patrolled by:
Overcast	Time	
Rain	Time	Truck #:
Snow	Time	
Freezing Rain	Time	Hours of Work: _____ to _____
Fog	Time	
Visibility: Good Fair Poor		On Call ORS:
Wind: Light Moderate Strong Direction_____		

Condition Codes
× Needs Service
A blank space indicates conditions meet standard
Time to be recorded using a 24 hour clock

Accident/Damage	Time
Police Response yes no	Police Report #
Location	
Description	

Highway Patrolled (area)				Road Classification	Air Temperature	Pavement Temperature	Ambient Condition						Winter Event Condition							Sidewalks		Notes
Name	Time	From	To				Bare & Dry	Bare & Wet	Track Bare	Center Bare	Snow Covered	Snow Packed	Snow Accumulation (cm)	Drifting	Ice Covered	Spot Ice	Black Ice	Frost	Slush	Requires Maintenance (Snow)	Requires Maintenance (Ice)	

Appendix C
Continuous Improvement Practices

Appendix C
Continuous Improvement Practices and Strategies
Salt Management Plan
City of Greater Sudbury, Ontario

Salt Management Plan - (City of Greater Sudbury)							
Continuous Improvement Options (1)	**Forecasted Implementation Schedule**						**Comments**
	Currently Reviewed and Updated As Needed	**Need for Review and Updating**	**Requires periodic review to maintain continuous improvement**	**Currently Implemented or Completed**	**Not Currently Considered**	**To be Implemented (Date)**	
Level of Service Policy - Review & Update			X	X			Council Approved Changes as required
Equipment Upgrading							
Spreading Equipment - equipped with:							
Pavement infrared thermometer	X			X			
Pre-wetting hardware	X			X			
Electronic Controllers	X			X			
GPS			X	X			
Patrol Trucks - equipped with:							
Pavement infrared thermometer				X			
Loader weigh bucket option - Added to all loader vehicles		X		X			Not used very much
Equipment Calibration							
Stipulate application rates for all materials used	X		X	X			
Pre-Winter Season Calibration				X			
Mid-Winter Calibration		X					
Calibration after installation or repair work done on spreading equipment		X		X			
Benchmarking of routes for theoretical amount of required winter materials prior to winter season		X	X				
Record and storage of calibration data for comparison and development of application rates		X	X				
Equipment Washing							
Wash all vehicles indoors		X					
Salt water retention/treatment area installed at all yards		X			X		Long term goal, no implementation date set
Oil/water separators installed at all patrol yards		X					

Appendix C
Continuous Improvement Practices and Strategies
Salt Management Plan
City of Greater Sudbury, Ontario

Salt Management Plan - (City of Greater Sudbury)							
Continuous Improvement Options (1)	**Forecasted Implementation Schedule**						**Comments**
	Currently Reviewed and Updated As Needed	**Need for Review and Updating**	**Requires periodic review to maintain continuous improvement**	**Currently Implemented or Completed**	**Not Currently Considered**	**To be Implemented (Date)**	
Material Delivery and Handling							
Reduction of percentage of salt used in salt/sand mix to min. amount to prevent sand from freezing (2-5%)			X		X		
Salt/sand piles covered to prevent leaching		X			X		
Salt deliveries covered while in transport and delivered in good weather	X			X			
Clean loading pads following transfer of material indoors					X		
Brine transfer from tank to truck conducted on solid impermeable flooring		X			X		
Records kept: Weigh tickets with truck number for each delivery				X			
Timing of transfer of material indoors		X					
Cleaning of loading pad after material transfer					X		
Discontinue summer storage of pickled sand		X			X		
Records of Material Usage							
Record material usage for each route/each truck/each storm event		X		X			Noted on crew cards
Compare material usage to benchmarked usage		X		X			
Adjust material usage based on weather and pavement conditions		X		X			
Use material tracking system to rationalize amount of materials used with the amount ordered and the residual amount at the end of the season		X	X				
Download and compare material usage from electronic spreader controls to that in the material tracking system		X	X				
Record patrols that are performed	X			X			
Record of responses made to winter storm events	X			X			
Weather and Pavement Temperature Forecasting							
Use of a value added meteorological service	X			X			
Use of MTO's RWIS sites pertaining to the Greater Sudbury area	X			X			
Storm Response							
Record of air and pavement temperature during a storm event	X			X			
Record of temperature rising or falling at end of storm event	X			X			
Effect of heat gain during daylight hours along with time of day				X			
Record Traffic volumes with time of day (assists with breaking snow/ice bond with pavement)	X				X		
Record of wind direction	X			X			
Note Frost penetration into pavement base and effects on pavement temperature		X					
Snow fence program for drifting conditions	X			X			

Appendix C
Continuous Improvement Practices and Strategies
Salt Management Plan
City of Greater Sudbury, Ontario

Salt Management Plan - (City of Greater Sudbury)							
Continuous Improvement Options (1)	**Forecasted Implementation Schedule**						**Comments**
	Currently Reviewed and Updated As Needed	**Need for Review and Updating**	**Requires periodic review to maintain continuous improvement**	**Currently Implemented or Completed**	**Not Currently Considered**	**To be Implemented (Date)**	
Winter Patrol							
Patrol coverage as Council directs for the winter season				X			
Patrol coverage 24 hours a day/7 days a week	X			X			
Patrol coverage for the shoulder season before and after the designated winter season to deal with frost and black ice	X			X			
Ensure patrollers are trained and under the supervision of a seasoned winter maintenance supervisor			X	X			
Emergency Response Procedures (Plan in Place)							
Training							
Sufficient training for equipment operators on controls and operating procedures	X		X	X			
Refresher training for operators on basic weather forecasting and tools to determine pavement temperature	X		X	X			
refresher training on basic weather forecasting and tools used to determine pavement temperature	X		X	X			
Operators trained in the application of materials for de-icing and anti-icing in order to obtain maximum effect	X		X	X			
Supervisors and Patrollers trained on basic weather and pavement temperature forecasting, RWIS	X		X	X			
Managers and Supervisors to attend workshops to learn about new technologies, techniques, and the experience of others with various products and materials	X			X			
Health and safety requirements for use of equipment and materials			X	X			
Technical review of existing and new technology	X			X			
Environmentally Sensitive/Vulnerable Areas							
Identify vulnerable areas and areas of natural and scientific interest			X				
Liaise with local potable water supply agencies within the City				X			
Monitor ground water and recharge areas					X		
Locate stockpiles and snow disposal sites outside of vulnerable areas		X					
Communication Strategy							
Prepare and distribute a winter maintenance guideline to the general public to ensure public awareness of the program that is being delivered			X	X			
Prepare an internal handbook for employees that communicates the Council approved winter maintenance policies and procedures and other important information such as, contact lists, shift assignments, etc.		X	X	X			
Provide winter maintenance information on the municipal website			X	X			

Notes:
Options shown are chosen from the Section 3.0 list of Continuous Improvement Practices And Strategies.
Some options will require updating and regular review there after.

Appendix D
Potentially Vulnerable Water Areas

Appendix D Potentially Vulnerable Water Areas City of Greater Sudbury, Ontario

SOUTHEAST SECTION

Sudbury

Lake Ramsey/Minnow Lake

- Downstream from the Sudbury East snow dump site
- May also be impacted by runoff from Hwy 17

Garson

Junction Creek

Coniston Creek

Coniston

Romford Creek

Falconbridge

Boucher Lake

Skead

Lake Wanapitei

- Downstream from the Skead snow dump site

SOUTHWEST SECTION

Panache Lake

- May be impacted by runoff from Regional Road 10, Panache North Shore Road, Hennessy Road, and Ojibway Road

Little Panache Lake

- May be impacted by runoff from Regional Road 10, Stoney Bay Road, Holmstedt Road

Vermilion River system

- May be impacted from pickled salt pile at the Naughton Depot
- May be impacted by runoff from Hwy. 17, Regional Road 55, Regional Road 10, McCharles Lake Road

Junction Creek

- May be impacted by runoff from Fielding Road, Hwy 17 Southwest Bypass, Mikkola Road, Black Lake Road, and Regional Road 55

Meatbird Creek

- May be impacted by runoff from Old Soo Road, Hwy 24, and old Hwy 17 West

NORTHEAST SECTION

Capreol

Vermilion River

- May be impacted by runoff from snow dump site between Ski Hill Road and CN railway
- May also be impacted by runoff from Hwy 84 and Lakeshore Street

NORTHWEST SECTION

Onaping and Levack

Onaping River

- May be impacted by runoff from Hwy 8, Strathcona Mine Road and High Street

Clear Lake

- May be impacted from Hwy 144 and Hwy 8

Chelmsford

Whitson Creek

- Has a high potential for impact as it is crossed by several city streets and Hwy 144

Azilda

Charlebois Creek

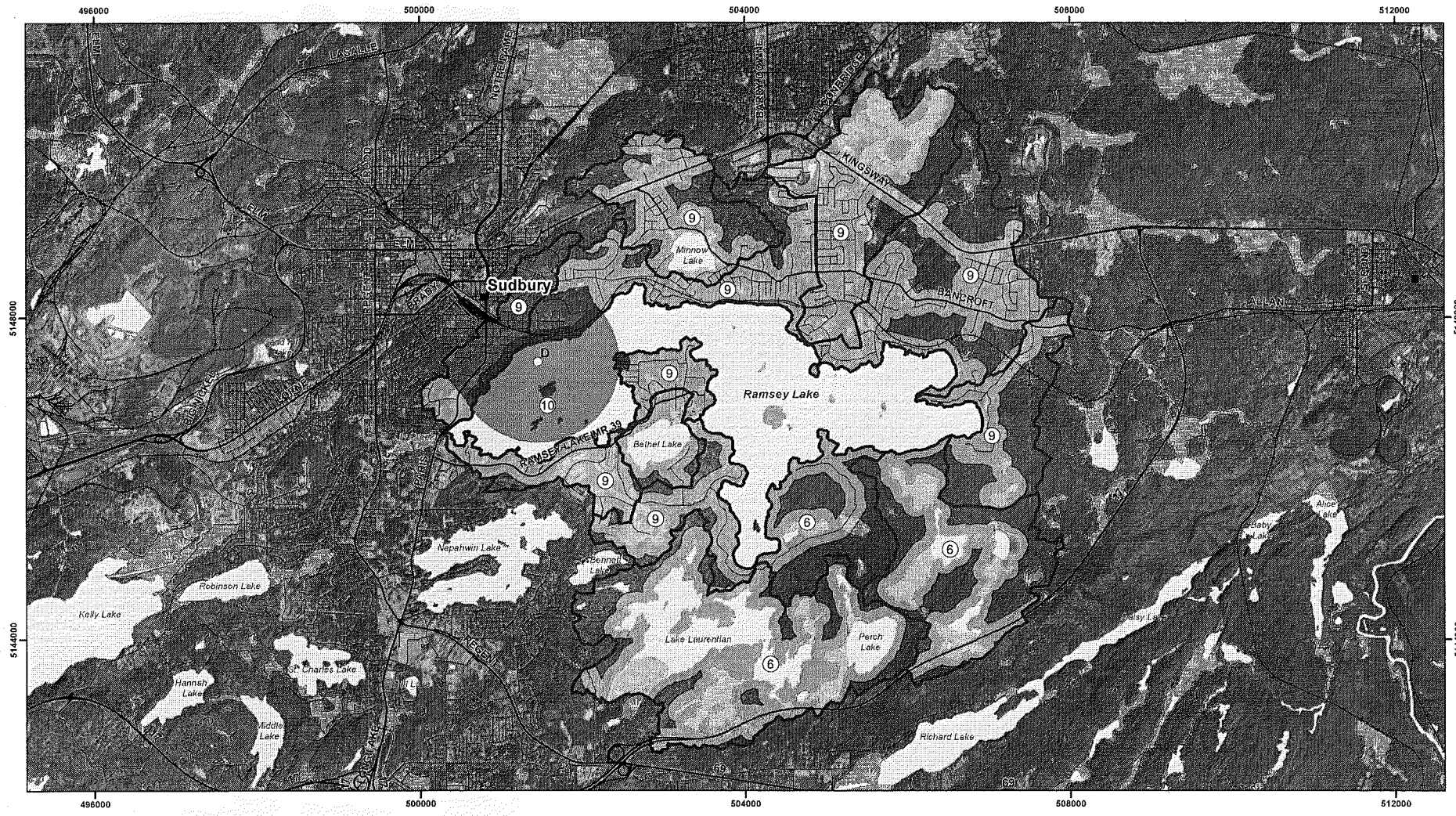
- Has a high potential for impact as it is crossed by several city streets and Hwy 35

SOUTH SECTION

The PWD has classified the following creeks and lakes as vulnerable waterbody areas all of which discharge into the Vermillion watershed:

Nolin Creek
Junction Creek
Ramsey Lake
Lilly Creek
Nepahwin Lake
Robinson Lake
Kelly Lake
Long Lake
Silver Creek
St. Charles Lake

Appendix E
Source Water Protection Maps and Signage



RAMSEY LAKE INTAKE PROTECTION ZONE

Legend

- Community
- Surface Intake Type D
- Road
- Railway
- River
- Subwatershed Boundary
- Waterbody
- Wetland

Intake Protection Zone (Surface Water)

- IPZ-1
- IPZ-2
- IPZ-3
- (#) Vulnerability Score

N W E S

0 0.5 1 2
Kilometers

Sudbury

Prepared By: Geographic Information Systems and Mapping Section, City of Greater Sudbury, 2013-04-25. Some digital data owned and used under agreement with the Nickel District Conservation Authority.

WANAPITEI RIVER INTAKE PROTECTION ZONE

Intake Protection Zones 1 & 2

Legend

- Community
- Surface Intake Type C
- Road
- Railway
- River
- Subwatershed Boundary
- Waterbody
- Wetland

Intake Protection Zone (Surface Water)

- IPZ-1
- IPZ-2
- IPZ-3
- (#) Vulnerability Score

N W E S

0 125 250 500 Meters

Sudbury

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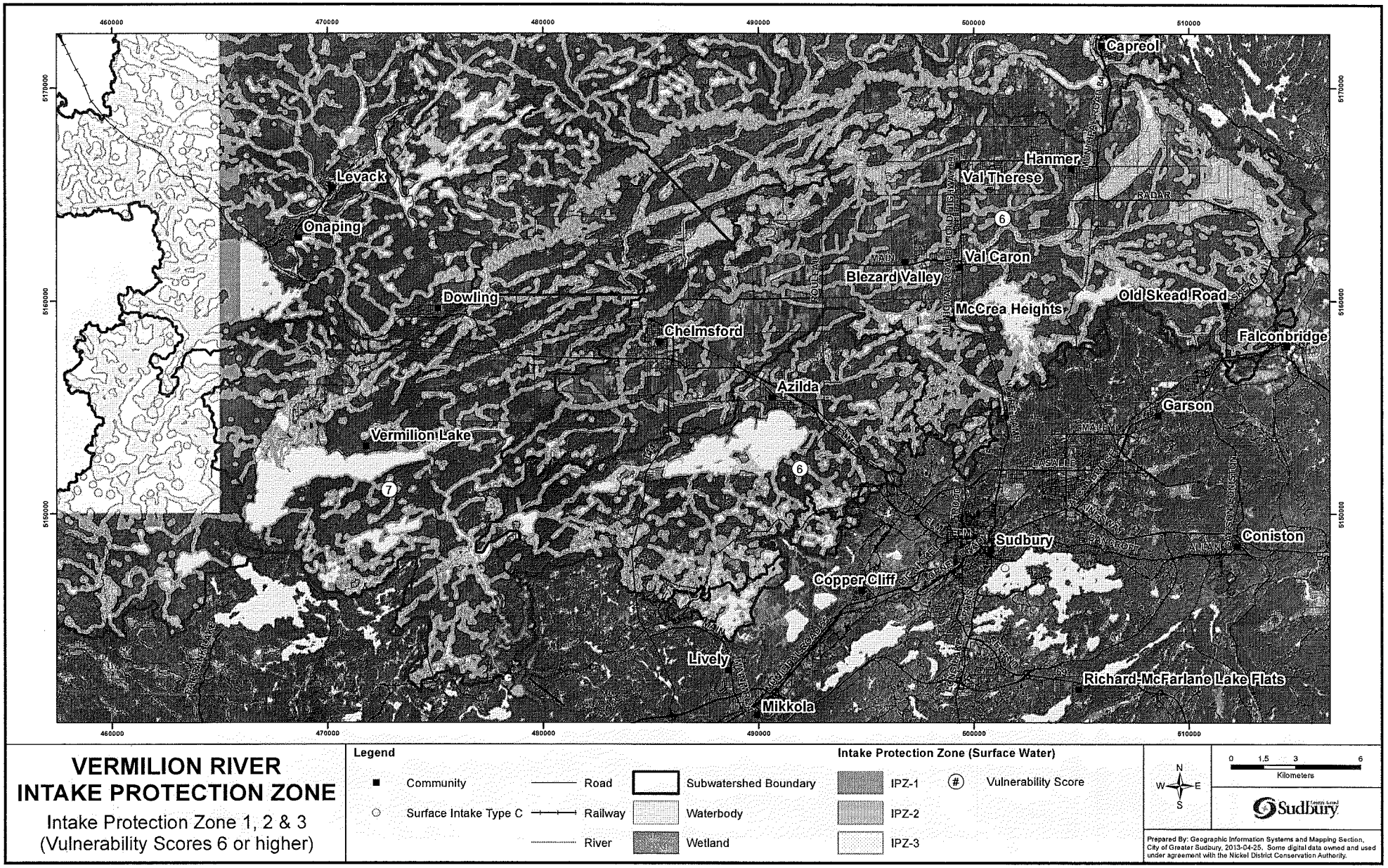

VERMILION RIVER INTAKE PROTECTION ZONE

Intake Protection Zone 1, 2 & 3
(Vulnerability Scores 6 or higher)

Legend

- Community
- Surface Intake Type C
- Road
- Railway
- River
- Subwatershed Boundary
- Waterbody
- Wetland

Intake Protection Zone (Surface Water)

- IPZ-1
- IPZ-2
- IPZ-3
- (#) Vulnerability Score

N W E S

0 1.5 3 6
Kilometers

Sudbury

Prepared By: Geographic Information Systems and Mapping Section, City of Greater Sudbury, 2013-04-25. Some digital data owned and used under agreement with the Nickel District Conservation Authority.

ONAPING WELLHEAD PROTECTION AREAS

Legend

- Community
- ProductionWells
- Road
- Railway
- River
- Waterbody
- Wetland

Wellhead Protection Areas (Groundwater)

- WHPA Vulnerability Score 10

N W E S

0 50 100 200
Meters

Sudbury

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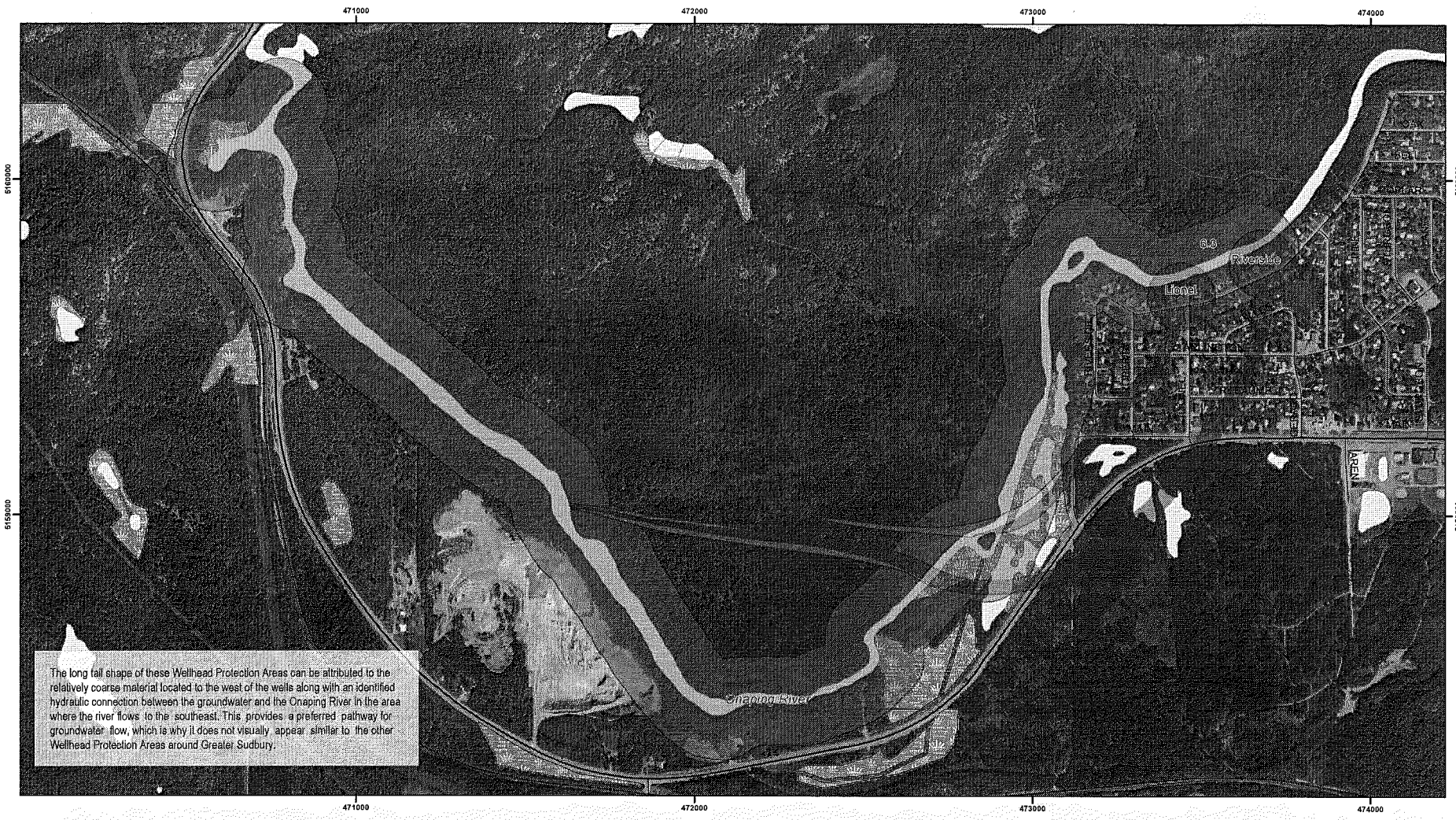

DOWLING WELLHEAD PROTECTION AREAS

Legend

- Community
- ProductionWells
- Road
- Railway
- River
- Waterbody
- Wetland

Wellhead Protection Areas (Groundwater)

- WHPA Vulnerability Score 6.3
- WHPA Vulnerability Score 8
- WHPA Vulnerability Score 10

N W E S

0 125 250 500
Meters

Sudbury

Prepared By: Geographic Information Systems and Mapping Section, City of Greater Sudbury, 2013-04-25. Some digital data owned and used under agreement with the Nickel District Conservation Authority.

VALLEY AND CAPREOL WELLHEAD PROTECTION AREAS

Legend

- Community
- ProductionWells
- Road
- Railway
- River
- Waterbody
- Wetland

Wellhead Protection Areas (Groundwater)

- WHPA Vulnerability Score 2
- WHPA Vulnerability Score 5.6
- WHPA Vulnerability Score 6
- WHPA Vulnerability Score 8
- WHPA Vulnerability Score 10

N W E S

0 0.25 0.5 1
Kilometers

Sudbury

Prepared By: Geographic Information Systems and Mapping Section, City of Greater Sudbury, 2013-04-25. Some digital data owned and used under agreement with the Nickel District Conservation Authority.

GARSON WELLHEAD PROTECTION AREAS

Legend

- Community
- ProductionWells
- Road
- Railway
- River
- Waterbody
- Wetland

Wellhead Protection Areas (Groundwater)

- WHPA Vulnerability Score 2
- WHPA Vulnerability Score 4
- WHPA Vulnerability Score 6
- WHPA Vulnerability Score 8
- WHPA Vulnerability Score 10

N W E S

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Meters

Sudbury

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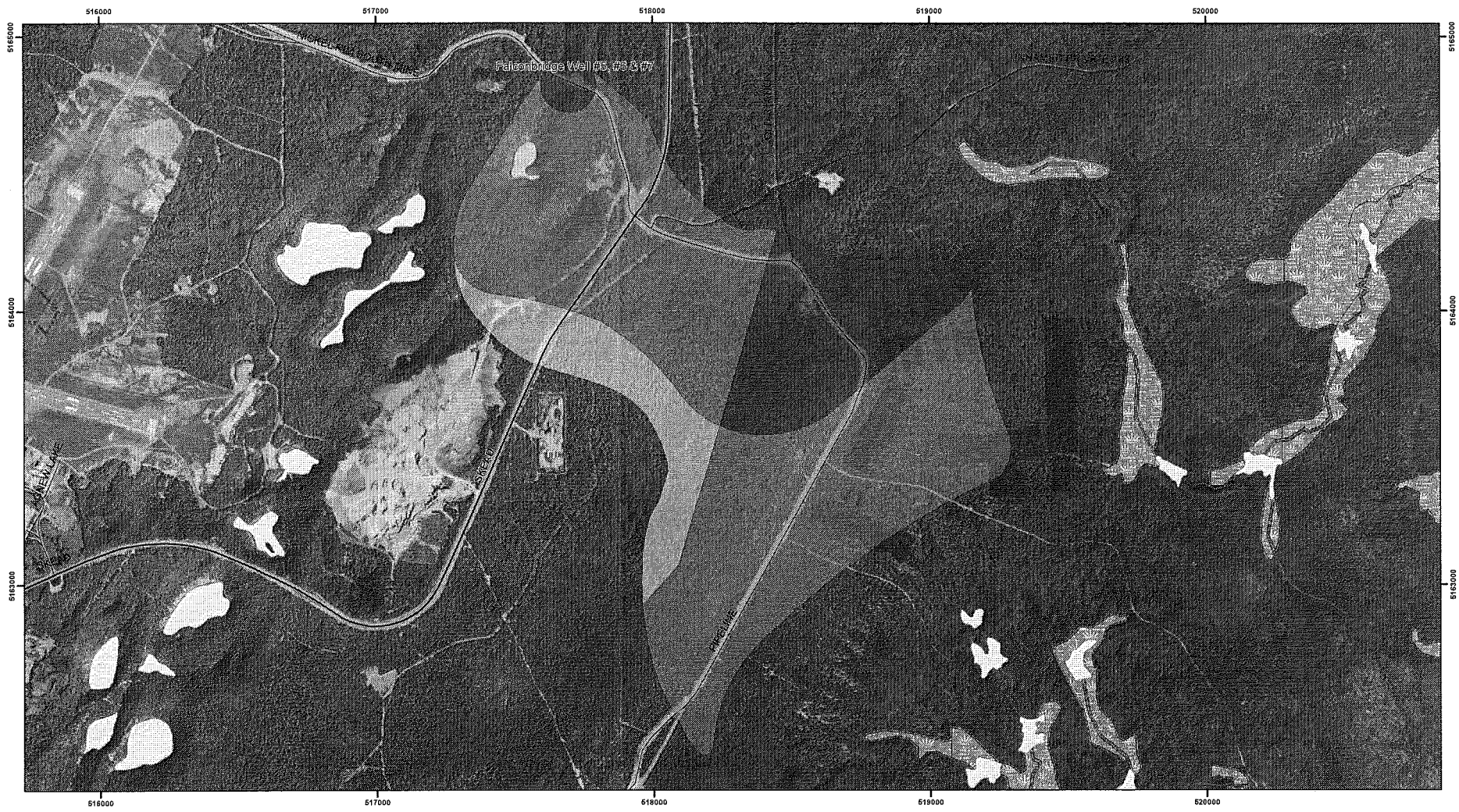


FALCONBRIDGE WELLHEAD PROTECTION AREAS

Legend

- Community
- ProductionWells
- Road
- Railway
- River
- Waterbody
- Wetland

Wellhead Protection Areas (Groundwater)

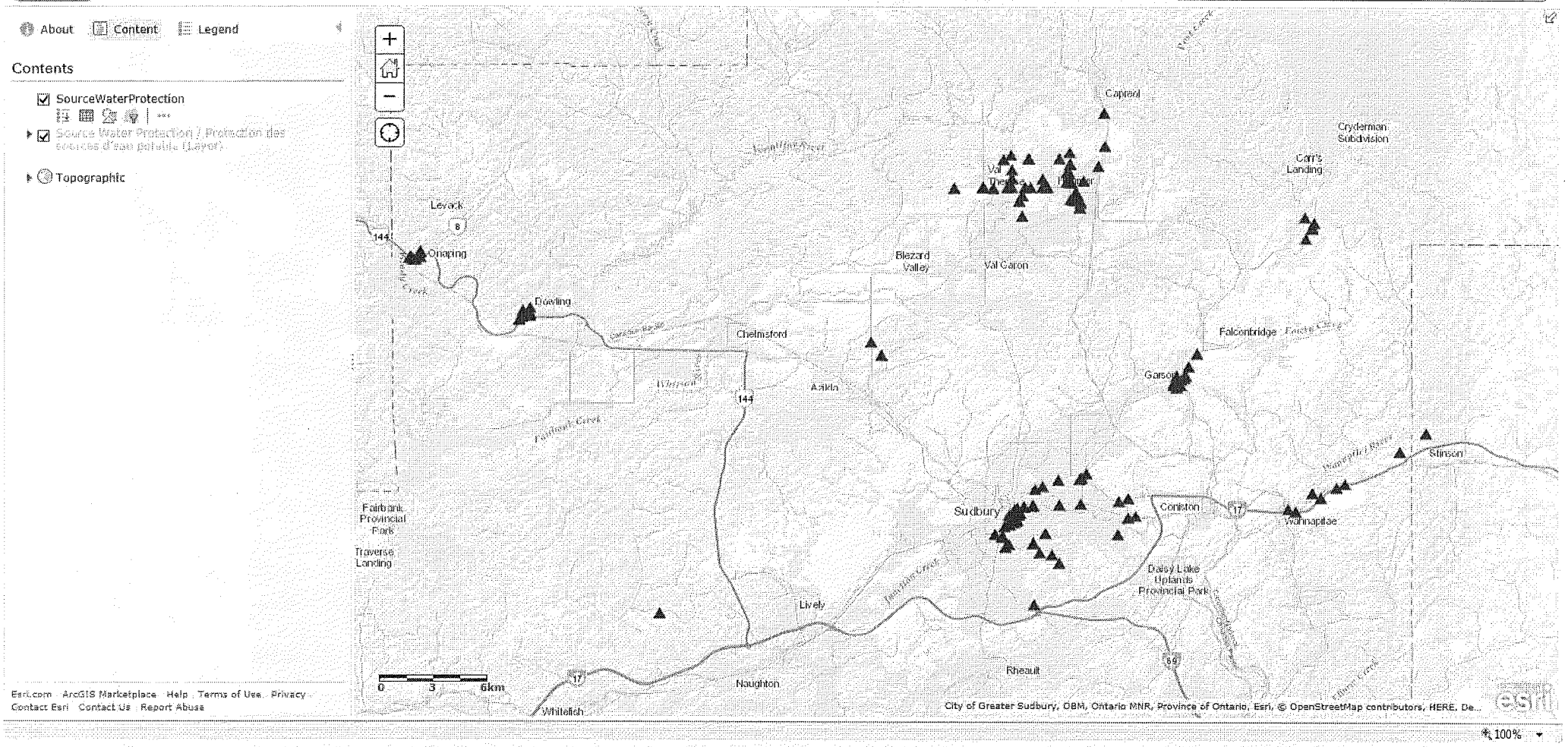
- WHPA Vulnerability Score 6
- WHPA Vulnerability Score 8
- WHPA Vulnerability Score 10

N W E S

0 125 250 500
Meters

Sudbury

Prepared By: Geographic Information Systems and Mapping Section, City of Greater Sudbury, 2013-04-25. Some digital data owned and used under agreement with the Nickel District Conservation Authority.


Home
Source Water Protection Signs-UPDATED JB-Copy
New Map
Create Presentation
Jessica
Details
Add
Edit
Basemap
Save
Share
Print
Measure
Bookmarks
Find address or place
About
Content
Legend
Contents
SourceWaterProtection
Source Water Protection / Protection des sources d'eau potable (Layer)
Topographic
Capreol
Cryderman Subdivision
Carr's Landing
Levack
Onaping
Blezard Valley
Val Caron
Dowling
Chelmsford
Falconbridge
Garson
Azilda
Fairbank Provincial Park
Traverse Landing
Sudbury
Coniston
Wahnapitae
Stinson
Lively
Daley Lake Uplands Provincial Park
Rheault
Naughton
Whitefish
0 3 6km
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Appendix F
Inspection Observations - 2016

Appendix F1

Road Operations Snow Storage Site Inspection Observations - 2016
Salt Management Plan
City of Greater Sudbury

Section	Depot	Inspection Observations	Recommended Actions	Activity Level [3]
South	LaSalle	High relief at the Site with a drop off of approximately 25 m along the south side		
		Snow is pushed up to the edge of the slope and down the slope into the valley		
		Silt fencing is placed along the bottom of the slope to prevent sediment and garbage entering stream	Conduct regular inspections to ensure silt fencing in good condition	2
		Garbage and debris observed on the Slope and at bottom	Conduct clean up to remove garbage	1
Southeast	Skead	Snow stored at the base of a steeply sloped, sandy cut		
		The Site is bounded by roadway on all other sides		
		Site is surfaced with gravel		
		Drainage towards the south		
		Site used to store local snow only		
Northeast	Capreol	Ground surface covered with sand		
		Drainage towards the west where water ponds		
		No vegetation observed on Site		
		Snow storage area surrounded by trees to the south, west, and north, no vegetative stress observed		
		Minor debris noted including bricks and garbage		
		Some fill noted including asphalt	Conduct periodic inspections to ensure that the Site is not being used as an illegal dump	1
Northwest	Chelmsford	Site is located on the edge of the Whitson River	Consider discontinuing use of this site for snow storage	3
		Drainage directly into the river	Build a berm around the site to contain and control melt water	2
		No buffer observed between the snow storage area and the river	Use visual markers so that dozer operator does not push snow piles too far	2
		Minor garbage and debris observed	Conduct clean up to remove garbage	1
		Drainage channel observed on the north side of the pile	Install erosion control with in the drainage ditch	2
	Levak	Located between Mine Road and train track/Nickel Street		
		Drainage is to the east to a ditch along Mine Road	Install erosion control at appropriate points along the drainage ditch	2
		Site surface is sand and gravel fill		
		Minor debris noted	Conduct clean up to remove garbage	1
		Overflow site located north of Nickel Street, surrounded by residential land use.	Conduct clean up to remove garbage/conduct regular inspections to ensure site is not used for illegal dumping	1
		- previous complaints of noise during snow disposal	Reduce noise - train operators/post signage	2
		- Site located adjacent to drainage ditch/creek	Install silt curtains at drainage outlets	1

NOTES:
(1) Road Operations Sectional Central Operations Depots
(2) Road Operations Central Head Quarters
(3) Activity Levels:
1 - Activity requires minimal effort/cost to implement.
2 - Activity requires minimal to moderate additional cost/effort to implement and will require short term planning and potential changes to department operations.
3 - Activity requires significant cost/effort to implement and may required long term planning.

Appendix F2

Road Operations Depots Site Inspection Observations - 2016
Salt Management Plan
City of Greater Sudbury

Section	Depot	Inspection Observations	Recommended Actions	Activity Level [3]
South	St. Clair [1]	Wooden salt dome in fair condition, staff reported that previous structural damage was recently repaired	Continue periodic structural inspections	1
		Outdoor sand pile, uncovered	Consider placing sand under cover to prevent salt from washing out	3
		Site is adjacent to creek (Junction Creek)	Consider discontinuing use of Site for salt and sand storage	3
		Surface water flow directed to Junction Creek. Staff report that hay bail sediment control is used.	Install and maintain sediment control.	1
		New brine tank (stainless steel), adjacent floor drains have unknown discharge point	Confirm the discharge location of floor drains.	1
Southeast	Frobisher [1], [2]	Two outdoor sand piles, uncovered, located adjacent to the salt dome on the north and south sides	Consider placing sand under cover to prevent salt from washing out	3
		Salt stored in a wooden salt dome		
		Brine tank on Site, staff report that the tank is inspected and maintained. Floor drains not observed adjacent to brine tank		
		Site is adjacent to a wetland area	Monitor wetland for signs of vegetative stress	2
		Drainage is to the south towards wetland area within the IPZ-3 of Ramsey Lake	Install and maintain sediment control and review SWP requirements	1
		Housekeeping required to sweep up salt outside of salt dome	Maintain housekeeping	1
Southwest	Naughton	Sand is no longer stored at the Site		
		Salt stored in a wooden salt dome with exterior asphalt paving around the entrance/exit	Maintain regular housekeeping to sweep up salt outside of salt dome	1
		New brine tank (stainless steel) in garage. Adjacent floor drain discharges into the ground		
		Site is adjacent to water way (Junction Creek, connecting channel between Mud and Simon Lakes)		
		Berm prevents direct drainage from salt dome area south/west into Junction Creek		
		Surface drainage is currently east towards the Site driveway and into a treed area and north into ditches along the highway (St. Louis Road)		
	Black Lake [1]	Outdoor sand pile, uncovered, located on the west side of the Site	Consider placing sand under cover to prevent salt from washing out	3
		Drainage from the sand pile is towards the north and west		
		A sand berm is located along the north side of the site at the top of the slope down to the highway		
		Erosion crack in the berm along the north side of the Site, where surface water has broken through	Repair berm and erosion crack	2
		Minor vegetative stress at bottom of slope in ditch beside MR55		
	Whitefish	Outdoor sand pile, uncovered, located on the west side of the Site at the top of a steep slope	Consider placing sand under cover to prevent salt from washing out	3
		Sand pile eroding into marshy area west of Site	Move sand pile back from the bank and use erosion control measures	2
		Outwash plane located west of site, no vegetation growing within in outwash area		
		Drainage towards the west, stream flowing westward from outwash area	Place erosion control measure at outlet of outwash area	2
Northeast	Suez [1]	Outdoor sand pile, uncovered, located on the south side of the Site	Consider placing sand under cover to prevent salt from washing out	3
		The site is surrounded by a berm on the east, which wraps around the south side of the property		
		Drainage towards the south and east. Water infiltrates the ground or flows through culverts within the berm and ponds within low lying areas along Capreol Road (MR84)	Maintain sediment control at culvert inlet	1
		Salt stored in two wooden salt sheds	Maintain regular housekeeping to sweep up salt outside of storage sheds	1
		No vegetation on Site, all filled with sand and gravel		
	Capreol	Sand stored within former salt shed		
		Drainage to the east, towards swampy area, no erosion observed		
Northwest	Chelmsford [1]	Tarped salt storage structure located on south side of the Site		
		Some salt staining on the ground in front of the storage structure and on the side	Maintain regular housekeeping to sweep up salt	1
		Outdoor sand pile, uncovered, located east of the salt storage structure	Consider placing sand under cover to prevent salt from washing out	3
		Drainage ditch located adjacent to sand pile	Place erosion control along the south side of sand pile and salt storage structure	1
	Levak	Salt stored in concrete and wooden salt storage shed	Maintain regular housekeeping to sweep up salt	1
		Outdoor sand pile, uncovered	Consider placing sand under cover to prevent salt from washing out	3
		A berm is built up around the north, east and west sides of the site to prevent direct runoff		
		Drainage is to a marshy area to the southwest that discharges to the ditches along Mine Road		

NOTES:
(1) Road Operations Sectional Central Operations Depots
(2) Road Operations Central Head Quarters
(3) Activity Levels:
1 - Activity requires minimal effort/cost to implement.
2 - Activity requires minimal to moderate additional cost/effort to implement and will require short term planning and potential changes to department operations.
3 - Activity requires significant cost/effort to implement and may required long term planning.

Appendix G
Definitions

Appendix G Definitions

Anti-icing	Means the application of liquid de-icers directly to the road surface in advance of a winter event otherwise known as direct liquid application (DLA).
De-icing	Means the application of solids, liquids, pre-treated material to the road surface after the on-set of the winter event.
Paved Road	Is a road with an asphalt surface, concrete surface, composite pavement, or Portland cement.
Pre-treat	Means the application of liquids (calcium chloride, sodium chloride, etc) to the sand pile or salt pile as the sand or salt is loaded into the storage facility.
Pre-wetting	Means the application of liquids (calcium chloride, sodium chloride, etc.) at the spinner of the truck just prior to application to the road surface.
Surface Treated Road	Is a road with bituminous surface treatment comprised of one or two applications of asphalt emulsion and stone chips over a gravel road.
Unpaved Roads	Is a road with gravel, stone or other loose traveling surface.
Winter Event	Is a weather condition affecting roads such as snowfall, wind blown snow, sleet, freezing rain, frost, black ice, etc. to which a winter event response is required.
Winter Event Response	Is a series of winter control activities performed in response to a winter event.
Continuous Winter Event Response	Is a response to a winter event with full deployment of manpower and equipment that plow/salt/sand the entire system.
Spot Winter Event Response	Is a response to a winter event with only a part deployment of manpower and equipment or with full deployment to only part of the system.
Winter Event Response Hours	Are the total number of person-hours per year (plowing, salting/sanding, winging back, etc.) to respond to winter events.

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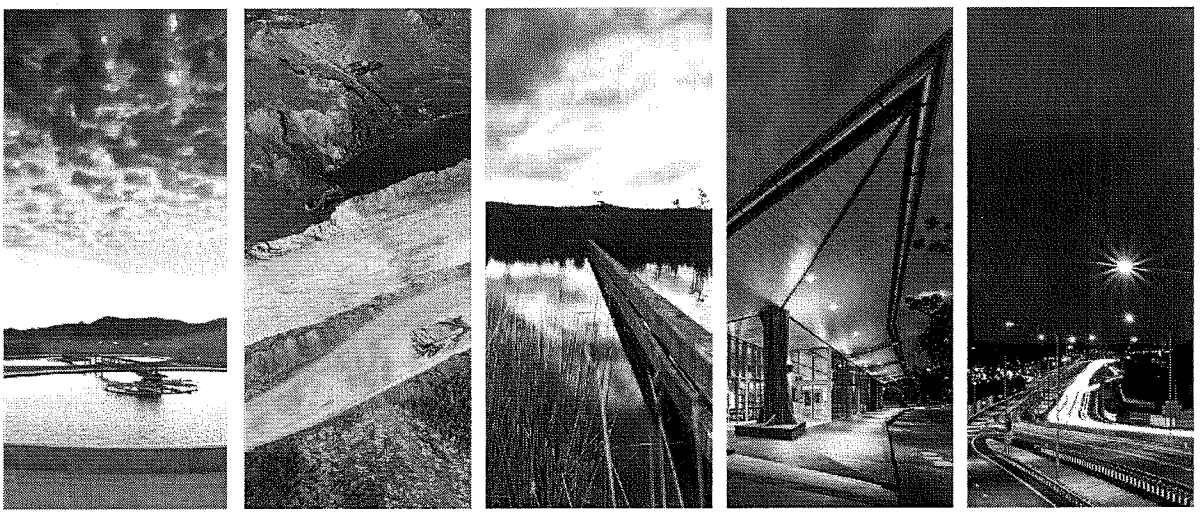

Risk Management Plan Assessment

Frobisher Depot
1800 Frobisher Street
Sudbury, Ontario

City of Greater Sudbury

GHD | 96 White Oak Drive Sault Ste. Marie Ontario P6B 4J8 Canada

039382| 42 | Report No 8 | January 18 2018

Executive Summary

GHD completed a Risk Management Plan Assessment (Assessment) for the Frobisher Depot located at 1800 Frobisher Street in Sudbury, Ontario (Site). The Site is an active winter maintenance depot operated by the City of Greater Sudbury (CGS). Winter maintenance activities conducted at the Site include salt and sand storage and handling; brine manufacturing; vehicle/equipment storage, maintenance, and repair; and administrative functions.

Road salt for the winter maintenance season is stored on Site in a covered salt storage dome with a relatively impermeable base. Pickled sand (i.e., sand mixed with salt at approximately five percent by weight) is stored on Site within and outside of the footprint of the former pickled sand dome located adjacent to the salt storage dome. Brine is prepared on demand in a separate building at the site. Application equipment used during the winter maintenance season is loaded at the site prior to deployment to respond to winter events.

Under the Clean Water Act (CWA), road salt handling and storage is a prescribed drinking water quality threat, which may contribute to the issue of rising sodium levels within Ramsey Lake. Based on the specific characteristics of road salt storage and handling at the Site (i.e. greater than 0.5 tonnes of road salt stored/handled) and the intersection of the Site with the Ramsey Lake Issues Contributing Area (ICA), the threat is deemed significant. As such, in accordance with the Greater Sudbury Source Protection Area Source Protection Plan Policy Sa-4E RMP, the Site requires a Source Water Risk Management Plan (RMP) for road salt handling and storage activities.

Surface water samples collected for sodium and chlorides, as part of the RMP Assessment, identified:

- Upgradient/background total sodium concentration of 152 milligrams per litre (mg/L) and chloride concentration of 117 mg/L.
- On-Site total sodium concentrations of 4,010 and 4,170 mg/L, and chloride concentrations of 6,220 and 6,430 mg/L.
- Downstream total sodium concentrations ranging from 181 to 313 mg/L, and chloride concentrations ranging from 322 to 558 mg/L. While total sodium concentrations generally remained the same downstream of Highway 55/Kingsway, chloride concentration generally slowly decreased with travel from 558 to 374/367 mg/L.

As expected, the highest sodium concentrations were observed immediately downstream of the salt depot where the pickled sand and mixing practices remain uncovered and exposed to the elements. Sodium concentrations were lower downstream. The on-Site (downgradient) low-lying swamp provides an excellent salt attenuation and buffer in minimizing the transport of salt from the Site towards the creek and eventually Ramsey Lake. No visual evidence of vegetative stress or deterioration was observed as a result of salt loadings from the Site.

As such, two measures available to CGS to manage the significant threat of road salt storage and handling within the Ramsey Lake ICA include:

- Maintain Site operations and implement Best Management Practices (BMPs) with monitoring to evaluate the effectiveness of BMPs.
- Relocate the winter maintenance material storage to a new site, located outside of any area where road salt storage and handling is deemed a significant threat, preferably within an area of low salt vulnerability as identified in the CGS Salt Optimization Plan.[1]

Considering the additional costs associated with relocating the depot, in association with the benefits provided by the low-lying downgradient swamp which provides salt attenuation and a buffer from salt travel, redeveloping the existing Site using BMPs (i.e., build a dome for the pickled sand, install a monitoring network) would be the most economical and practical option.

1 *"Salt Optimization Plan"*, Prepared by GHD on behalf of the City of Greater Sudbury, November 2017.

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Appendix Index

1. Introduction

GHD was retained by the City of Greater Sudbury (CGS) to develop a Risk Management Plan Assessment (RMP Assessment) for its existing Frobisher Depot located at 1800 Frobisher Street in Sudbury, Ontario (Site/Property). GHD was also retained to collect downstream surface water samples to establish a baseline condition in support of the RMP Assessment. A Site location map and Site layout showing the Frobisher Depot are provided on Figures 1 and 2.

CGS owns the Frobisher Depot, which is operated as a winter maintenance depot including road salt handling and storage. The Site is located within the Ramsey Lake Issues Contributing Area (ICA), established due to elevated and rising sodium levels within the lake, which is a major drinking water source for CGS. In accordance with the Greater Sudbury Source Protection Area Source Protection Plan Policy Sa-4E RMP, the Site requires a Source Water Risk Management Plan (RMP) for road salt handling and storage activities.

The objective of this RMP Assessment is to characterize the geological and hydrogeological conditions of the Site and surrounding area with regard to development of the property and to develop Risk Management Measures (RMMs) to mitigate further impacts on the Ramsey Lake Drinking Water System (DWS).

This Report is organized into the following Sections:

Section 1.0 – Introduction: outlines the purpose, objectives and scope of work, and presents the report organization.

Section 2.0 – Methodology: outlines the methodology undertaken to complete the assessment.

Section 3.0 – Background: provides a description of the existing Site conditions, operations, background information and surrounding land uses, including the regional environmental setting, including the physiography, topography, main surface water features surrounding the Site, and the surficial and bedrock geology. GHD's surface water sampling investigation also is presented to provide a baseline assessment of the Site and downstream water quality as it relates to salts and chloride loadings flowing into Ramsey Lake.

Section 4.0 – Risk Management Measures (RMMs): includes information on prevention/mitigation/ management measures, monitoring, and emergency response. Prevention information includes industry standards, regulations, best management practices, policies, etc. that are in place to help prevent contamination from the existing land use, as well as information on how the Site will be maintained to ensure it operates as intended/designed, where applicable.

2. Methodology

Cognizant of the objectives of the Assessment, the following activities were undertaken:

- Review of available background information: topography, physiography, geology and hydrogeology mapping and report information, including the results of the geotechnical and investigations completed on the Site by others.
- Documentation of the Site/Property information including geological and hydrogeological conditions and vulnerable areas (Ramsey Lake ICA).
- Collection and analysis of surface water samples to assess current water quality.
- Compilation of RMMs to be considered for a Source Water RMP.

3. Background

3.1 Site Description

The Site is located within the southeast section of the City of Greater Sudbury, within the Township of Neelon, Lot 11, Concession 4, Parcel 26975 SES, at 1800 Frobisher Street (Figure 2). The Site is irregular in shape and approximately 40 hectares (100 acres) in size.

The Site is located within an area of the City of Greater Sudbury that is mainly comprised of light industrial (M2) and mixed industrial/service commercial (M1) land uses as well as lands zoned "flood plain overlay" (FD). The Site is zoned M2 and is bordered to the north and east by M1 lands as well as FD zoned areas, which are comprised of undeveloped wetland with bedrock outcrops. M1 zoned lands are located west of the Site and M2 lands and Kingsway Road (Highway 55) are located to the south, with mixed residential, commercial, parkland, and FD zoned lands located further south.

The western portion of the Site is developed and has two paved access roads that enter the Site from the west side: Frobisher Street, which comprises the main access road, and a driveway off Kingsway Road (Highway 55). The eastern portion of the Site is undeveloped wetland area with bedrock outcrops.

Buildings/structures located on Site, south of Frobisher Street, include an office/administrative building; operations building/garage; washing station building; the former Transit Services garage/administration building; a fuel UST and associated pumping facility; and a truck weigh scale. The municipal recycling processing building, household hazardous waste building, the salt storage dome, and pickled sand pile are located on Site north of Frobisher Street. In addition, various smaller buildings/sheds are located throughout the Site.

Fill materials (concrete/asphalt grindings/gravel/rock) from historical CGS operations are located within the north central portion of the Site, north and east of the salt storage dome.

Surfaces within the western portion of the Site are mainly asphalt paved, providing roadways and parking areas as well as outdoor equipment storage around the buildings located in that area. The

north central area of the Site is surfaced with sand/gravel fill and the remainder of the Site is vegetated.

The ground surface at the Site generally slopes from north to south. There are no storm drains located on Site other than roadside ditches along Frobisher Street. Storm water runoff flows through ditches and/or overland from the west towards the east into a low area located at the centre of the Site. This low, wetland area is constrained to the south by Kingsway Road (Highway 55) and drains southward via a small creek, which discharges into Ramsey Lake approximately 2.2 kilometres (km) south of the Site. Based on mapping provided in the Greater Sudbury Source Protection Area Source Protection Plan[2] and Junction Creek watershed mapping[3], a small portion of the Site, located within the northwest corner, drains to the west into the Junction Creek watershed.

The Site is serviced with municipal water supply and sanitary sewers.

3.2 Site Operations

CGS has owned and operated the Site as a municipal services depot for more than 40 years. The following activities are currently conducted on Site:

- Storage, maintenance, and repair of municipal road and winter maintenance equipment
- Fuel storage and handling
- Storage and handling of winter maintenance materials (i.e. road salt and pickled sand)
- Salt Brine manufacturing, storage, and handling
- Storage and handling of fill materials (concrete/asphalt grindings/gravel/rock)
- Municipal recycling processing facility
- Household hazardous waste depot

Road salt for the winter maintenance season is stored on Site within a salt storage dome, which has a relatively impermeable concrete base. Pickled sand (i.e., sand mixed with salt at approximately five percent by volume); however, is stored outdoors in uncovered piles located either within the footprint of a former dome on an impermeable pad and/or outside directly on the ground west and south of the salt storage dome. Brine is prepared on demand in a separate building with spill containment at the Site. Application equipment used during the winter maintenance season is loaded at the Site prior to deployment to respond to winter events. Vehicle washing is currently being conducted both indoors and outside.

Housekeeping practices employed at the Site include sweeping up tracked salt as needed and a periodic structural assessment to inspect the structural integrity of the salt storage dome. The Site does not have a runoff collection system or a formal plan for managing salt-impacted drainage.

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2 "*Greater Sudbury Source Protection Area Source Protection Plan*", Prepared on Behalf of the Greater Sudbury Source Protection Committee Under the Clean Water Act, 2016 (Ontario Regulation 287/07). Approved September 19, 2014.

3 *"Flood Response Planning 2012 Junction Creek Watershed"*, https://www.greatersudbury.ca/live/emergency-services/emergency-planning/emergency-management-program/emergency-plans/watershed-maps/junction-creek/

3.3 Source Water Protection Areas

The Ramsey Lake surface water intake is located approximately 4.5 kilometres (km) southwest of the Site. The surface water Intake Protection Zones (IPZs) and vulnerability scores associated with the Ramsey Lake surface water intake are presented on Figure 3.

The Site borders on significant groundwater recharge areas (SGRA) that intersects with a highly vulnerable aquifer (HVA), south and west of the Site.

A large portion of the Site falls within the Ramsey Lake Intake Protection Zone 3 (IPZ-3). IPZ-3 includes the area of Ramsey Lake that may contribute water to the intake and includes a 120-metre setback from the high water mark. Transport pathways (contributing tributaries, storm sewers, and roadside ditches) are also included, and a 120 m setback is applied to these as well.

The vulnerability scores associated with the areas within IPZ-3 were determined by considering the vulnerability of the Ramsey Lake intake as well as that of the contributing areas/watersheds. An area vulnerability factor, a measure of how easily a contaminant would travel from the area to the surface water intake, was assigned to each of Ramsey Lake's sub-watersheds based primarily on land surface cover type and permeability. The area of IPZ-3 Frobisher that intersects with the Site is assigned a Vulnerability Score of 9 based on high levels of urban development within the area and the presence of shallow and exposed bedrock.

Due to elevated and rising sodium levels identified within Ramsey Lake, the Assessment Report, produced in response to legislative requirements under the CWA[4], included the establishment of the Ramsey Lake Issues Contributing Area (ICA). The ICA encompasses the total area where activities may contribute to the identified issue(s), in this case the increasing sodium levels, and includes the entire Ramsey Lake IPZ-3.

Under the CWA, road salt handling and storage is a prescribed drinking water quality threat, which may contribute to the issue of rising sodium levels within Ramsey Lake. Based on the specific characteristics of road salt storage and handling at the Site (i.e. greater than 0.5 tonnes of road salt stored/handled), the threat is assessed as significant within the Ramsey Lake ICA. In accordance with the Greater Sudbury Source Protection Area Source Protection Plan Policy Sa-4E RMP, the Site requires a Source Water Risk Management Plan (RMP) for salt handling and storage activities.

Fuel storage and handling is also a prescribed drinking water quality threat under the CWA, however, it is assessed as a moderate threat within the Ramsey Lake IPZ-3. As such, and in accordance with the Greater Sudbury Source Protection Area Source Protection Plan Policies, an RMP is not required for this activity.

The Site is not located within the well head protection area (WHPA) of any of CGS' municipal supply wells. The nearest WHPA is the WHPA-D (travel time of a groundwater contaminant is less than or equal to 25 years but greater than 5 years) for the Garson wells 1 & 3, located approximately 6.1 km northeast of the Site boundary.

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4 *"Greater Sudbury Source Protection Area Assessment Report"*, Prepared on Behalf of the Greater Sudbury Source Protection Committee Under the Clean Water Act, 2016 (Ontario Regulation 287/07). Approved September 2, 2014.

The Greater Sudbury Source Protection Area Assessment Report identifies elevated sodium levels within the Garson wells, however, sodium was not identified as a drinking water quality issue for the Garson DWS due to insufficient available data to determine the presence of a significant increasing trend.

3.4 Site Setting

The CGS is situated within Ecoregion 5E (Georgian Bay) and is located within the southern portion of the Precambrian Shield[5], which is characterized predominantly by exposed and shallow bedrock covered with a discontinuous layer of glacial till. Other landforms include glaciofluvial and galciolacustrine deposits as well as wetland deposits[6].

The topography of the area is generally rolling/undulating with elevated bedrock outcrops and is generally sloped to the south towards Ramsey Lake. The Site ranges in elevation from approximately 273 metres above mean sea level (AMSL) within the northwest corner of the Site to 270 mAMSL within the low, wetland area located adjacent to Kingsway Road (Highway 55). Bedrock outcrops within the area have elevations of 285 to 330 mAMSL.

A discussion of the geology and hydrogeology within CGS is provided in the Greater Sudbury Source Protection Area Assessment Report. These topics are briefly discussed in the following sections.

3.4.1 Geology

Based on regional surficial geology mapping of the area[7], lands in the area of the Site are predominantly underlain by thin discontinuous soils (less than 1 m thick) overlying Precambrian bedrock with low lying areas of peat, muck, and marl wetland deposits. Surrounding lands to the northwest and south are underlain by deposits of the Wanapitei Esker and comprise sand and silt glaciolacustrine and modern fluvial deposits[8].

Based on a review of the MOECC well records[9], the overburden underlying the Site and immediately surrounding areas ranges from less than 2.0 m to greater than 10 m in thickness. Bedrock outcrops to the north and east of the Site. The overburden generally increases in thickness towards Ramsey Lake. Bedrock in the area is described as quartz-feldspar sandstone with minor siltstone, agillite and conglomerate of the Middle Precambrian, Mississaugi Formation with areas of horneblende, gabbro, metagabbro and amphibolite of the Nipissing Diabase[10],[11].

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5 *The Ecosystems of Ontario Part 1: Ecozones and Ecoregions*, Ministry of Natural Resources, 2009

6 Ontario Geological Survey (1999), Surficial Geology Regional Municipality of Sudbury – Map P.3399, Scale 1:100,000

7 Ontario Geological Survey (1999), Surficial Geology Regional Municipality of Sudbury – Map P.3399, Scale 1:100,000

8 Greater Sudbury Source Protection Area Assessment Report, Prepared on Behalf of the Greater Sudbury Source Protection Committee Under the Clean Water Act, 2016 (Ontario Regulation 287/07). Approved September 2, 2014.

9 https://www.ontario.ca/environment-and-energy/map-well-records

10 Ontario Geological Survey (1991), Bedrock Geology of Ontario, Southern Sheet – Map 2544, Scale 1:1,000,000.

11 Ontario Geological Survey (1975), Sudbury-Cobalt Geological Compilation Series, Algoma-Manitoulin, Nippising, Parry Sound, Sudbury and Timiskaming District – Map 2361, Scale 1:253,440

3.4.2 Hydrogeology

In general, the hydrostratigraphic framework of the area corresponds to overburden, predominantly comprised of glaciolacustrine deposits, constrained by bedrock outcrops and wetland deposits. Hydrostratigraphic units within the area of the Site include the following:

- Aquifer (unconfined) – glaciolacustrine sand and silt
- Aquitard – wetland deposits
- Aquitard – bedrock (groundwater flow restricted to relatively small, localized fractures)

In general, the hydrogeology of the Site can be described as a thin, discontinuous fine to medium textured glaciolacustrine unconfined aquifer confined by areas of bedrock outcrop and wetland deposits and overlying bedrock aquitard.

Based on a review of the MOECC well records for the area, groundwater depth within the area is variable ranging from 3 to 10 mBGS.

GHD is not aware of any Site-Specific hydrogeological investigations. In the absence of such information, and based on the area topography including elevated bedrock outcrops northwest and southeast of the Site and the general north to south slope of the lower lying glacial deposits and wetland areas on Site, GHD assumes that groundwater flow direction at the Site is generally to the southwards, toward Ramsey Lake.

3.4.3 Salt Vulnerability

CGS recently retained GHD to prepare a Salt Optimization Plan for the City of Greater Sudbury.[12] This effort included an assessment of salt vulnerability throughout the City of Greater Sudbury based on multi criteria analysis of mapped salt sensitive areas including source water protection areas (i.e. WHPA, IPZ, ICA, HVA, SGRA), wetlands, fish spawning areas, Lake Trout lakes and provincially tracked species. A salt vulnerability index map was generated showing area ranging from low to high risk. Based on this assessment, the majority of the Site was assessed as having a low salt vulnerability cumulative score (see Figure 4).

3.4.4 Anthropogenic Transport Pathways

The Site is serviced with below grade utilities (sanitary sewers and water mains) located within the western portion of the Site. CGS personnel were not aware of the existence of any potable water wells or septic systems at the Site. Stormwater generated on Site either infiltrates into the ground surface or moves as runoff towards roadside ditches along Frobisher Street and towards the wetland area located southeast of the Site.

A 150-mm sanitary sewer forcemain conveys sanitary sewage from the residential subdivision south of Highway 55/Kingsway onto the Site where it discharges into an 825-mm sanitary sewer, which traverses the western portion of the Site from close to the southern boundary up to Frobisher Street and then proceeds westward off-Site. A 150-mm water main servicing the on-Site buildings is located within the western portion of the Site. The locations of these utilities are shown on Figure 2.

12 *"Salt Optimization Plan"*, Prepared by GHD on behalf of the City of Greater Sudbury, November 2017.

The sanitary sewer main bedding may provide a preferential pathway for groundwater to move from the area of Frobisher Street to the southern portion of the Site. The main is located approximately 120 m downgradient of the winter maintenance materials storage area at its' closest point; however the rate of groundwater flow at the Site is unknown.

According to CGS personnel, no USTs have been or are presently owned or operated at the Site.

3.5 Previous Investigations

The following background report for the Site was provided by CGS and was reviewed during this assessment:

- *"Preliminary Geotechnical Investigation City of Greater Sudbury 1800 Frobisher Street Sudbury, Ontario"*, prepared by Terraprobe, 2008.

In 2008, Terraprobe conducted a borehole and test pit program at the Site to investigate subsurface conditions including soil type and groundwater presence/elevation. The investigation included advancement of ten (10) boreholes and excavation of seven (7) test pits up to a depth of approximately 6 mBGS all within the western portion of the Site. Most of the investigative locations were located south of Frobisher Street, however one (1) borehole and one (1) test pit were located north of the salt storage dome. Two (2) boreholes were located along the edge of the low-lying wetland area.

Based on the investigation findings, Site soils within the developed area of the Site are described as fill up to 6 m thick overlying native sand and silt to clayey silt. Soils within the low lying wetland area are described as sandy silt to a depth of 1.5 mBGS overlying clayey silt to a depth of 2.3 mBGS overlying silt and clay. The silt and clay was wet and soft to very soft and extended to the full depth of the boreholes advanced within wetland area.

As monitoring wells were not installed as part of the investigation, groundwater depth was assessed based on the soil conditions encountered at the Site and estimated to range from 1.5 to 3.0 mBGS.

3.6 Surface Water Quality Investigation

On October 4 and 5, 2017, GHD collected surface water samples for sodium and chlorides analyses to assess the existing salt runoff contribution towards Ramsey Lake based on the current Frobisher Depot configuration. As part of GHD's surface water assessment, surface water samples were collected from ten (10) sampling locations, which included one (1) upstream/background sample, two (2) on-Site samples, and seven (7) downstream surface water samples collected between Highway 55 (Kingsway) and Korpela Park, located approximately 300 metres prior to discharge into Ramsey Lake.

Surface water samples were collected in accordance with the standard operating procedure (SOP) for collecting surface water samples attached hereto as Appendix A. Surface water samples were collected directly into the laboratory-supplied containers by submersing the inverted bottle into the water and tilting the bottle opening upstream to fill. The sample was collected with the sample bottle completely submerged to minimize the collection of floating debris within the container.

Samples were placed directly into laboratory-supplied containers, packed in a cooler on ice, and submitted under chain-of-custody protocol to AGAT Laboratories (AGAT), an accredited analytical laboratory located in Sudbury, Ontario. The surface water samples were analyzed for total and dissolved sodium, chloride, and total suspended solids (TSS).

The surface water analytical results are presented on Table 1.

A review of the analytical data indicated the following:

- Upgradient/background total sodium concentration of 152 milligrams per litre (mg/L) and chloride concentration of 117 mg/L.
- On-Site total sodium concentrations of 4,010 and 4,170 mg/L, and chloride concentrations of 6,220 and 6,430 mg/L.
- Downstream total sodium concentrations ranging from 181 to 313 mg/L, and chloride concentrations ranging from 322 to 558 mg/L. While total sodium concentrations generally remained the same downstream of Highway 55/Kingsway, chloride concentration generally slowly decreased with travel from 558 to 374/367 mg/L.

As expected, the highest sodium concentrations were observed immediately downstream of the salt depot where the pickled sand and mixing practices remain uncovered and exposed to the elements. The downgradient low-lying swamp provides an excellent buffer in minimizing the transport of salt from the Site towards the creek and eventually Ramsey Lake.

During the Site investigation, GHD did not observe any significant or moderate evidence of vegetation stress or deterioration as a result of salt loadings from the Site.

A copy of the laboratory analytical report is attached as Appendix B.

4. Risk Management Measures

This section provides the risk management measures (RMMs) and best management practices (BMPs) relevant to the road salt storage and handling.

CGS has used the Site for the storage of winter maintenance materials for several decades. Road salt is currently placed within a covered salt storage dome on a relatively impermeable concrete base, whereas pickled sand is currently stored with no cover, as the dome was demolished in or around 2005. The Site was selected based on accessibility and the surrounding commercial / industrial land use. The road salt storage and handling area is situated within the Ramsey Lake ICA and as such additional mitigation measures are needed to address the potential drinking water threat.

Two measures available to CGS to manage the significant threat of road salt storage and handling within the Ramsey Lake ICA include:

- Maintain Site operations and implement BMPs with monitoring to evaluate the effectiveness of BMPs

- Relocate the winter maintenance material storage to a new location outside of any area where road salt storage and handling is not deemed a significant threat/low vulnerability

4.1 Maintain Existing Site Operations and Implement BMPs

The road salt storage and handling facility at the Frobisher Depot is owned by CGS and operated by CGS staff. In 2016, CGS retained GHD to updated the City of Sudbury Salt Management Plan (2016 SMP). As part of that work, GHD conducted a Site inspection and provided the following observations:

2016 Site Inspection Observations.[13]

Observation	Recommended Actions	Activity Level
Outdoor pickled sand piles, uncovered, located adjacent to the salt storage dome	Consider placing sand under cover and on an impermeable base to prevent salt from washing out	3
Salt stored within a wooden salt dome on a concrete paved base.	Conduct regular inspections of the salt storage dome and the paved base to ensure structural integrity.	2
Housekeeping required to sweep up salt outside of the salt dome	Maintain housekeeping. Conduct regular inspections of areas where salt tracking may occur to ensure housekeeping is maintained.	1
Brine tank located on Site. Staff report that the tank is inspected and maintained. Floor drains were not observed adjacent to brine tank.	Conduct periodic inspections of the brine tank to ensure its integrity	1
Winter maintenance material are stored adjacent to a wetland area	Monitor wetland for signs of vegetative stress	2
Site drainage is southwards towards wetland area within the Ramsey Lake ICA	Install and maintain sediment control and review Source Water Protection Plan Policy requirements. Implement stormwater management at the Site.	1, 2

Activity levels referenced above are defined as follows:

1. Requires minimal effort/cost to implement.
2. Requires minimal to moderate additional cost/effort to implement and will require short term planning and potential changes to department operations.
3. Requires significant cost/effort to implement and may require long term planning.

[13] GHD, May 2016. 2016 Salt Management Plan, City of Greater Sudbury.

Other BMPs for road salt storage and handling as provided in the Transportation Association of Canada's (TAC's), Synthesis of Best Management Practices, Road Salt Management[14] were included within the assessment of continuous improvement practices and strategies provided as Appendix C to the 2016 SMP. These strategies and BMP and their implementation status as of the 2016 SMP are included as Table 2.

The Ontario Ministry of the Environment and Climate Change (MOECC) provides guidance regarding storage of winter maintenance materials[15]. Specifically, MOECC recommends that winter maintenance materials (i.e. road salt and other de-icing materials) be stored within permanent structures underlain by an impermeable base and surrounded by a berm/dyke to prevent seepage and runoff resulting in salt losses to the environment.

4.1.1 Recommended Actions

Based on the recommendations made in the 2016 SMP, TAC's Synthesis of Road Salt BMPS and MOECC Guidance, CGS should ensure that the following BMPs are implemented within the Ramsey Lake ICA:

- Salt and pickled sand storage should be conducted under cover on impermeable surfaces
- Enforce and document housekeeping practices
- Ensure that wash water used to clean winter maintenance vehicles and equipment is collected and directed to the sanitary sewer, if possible
- Monitor surface water runoff and groundwater seepage quality to ensure that groundwater and surface water are not impacted by salt losses at the Site

4.1.2 Monitoring

The results of surface water monitoring conducted as part of this RMP assessment (further discussed in Section 3.6) indicated that surface water at the Site and downgradient of the Site is impacted with sodium and chloride, as compared to background surface water sample. Surface water samples collected within the Site and prior to the on-Site swamp/wetland were significantly elevated, which is a result of the lack of BMPs as described previously (i.e., exposed pickled sand operations, outdoor mixing operations). A visual observation did not observe any significant or moderate evidence of vegetation stress or deterioration as a result of salt loadings from the Site.

To ensure the salt management operations and BMPs remain effective, GHD recommends both surface water and groundwater monitoring on a scheduled frequency.

Surface water can be monitored on a bi-annual (spring and fall) frequency to monitor the effectiveness of BMPs in improving surface water quality. Sample locations could be reduced to four locations, which includes an upgradient/background sample, an on-Site sample located immediately downstream of the winter maintenance material storage, at the Site boundary adjacent

[14] Transportation Association of Canada, September 2003. Synthesis of Best Management Practices, Road Salt Management.

[15] Ministry of the Environment, February 2011. Guidelines on Snow Disposal and De-icing Operation in Ontario. PIBS8271e.

to Highway 55, and further downstream at Korpela Park, which is 300 metres prior to discharge to Ramsey Lake.

As there are no monitoring wells installed at the Site, GHD proposes the installation of three monitoring wells at the Site. One monitoring well would be installed upgradient of the salt operations with two downgradient monitoring wells (one immediately south and one further south). These wells would be used to establish sodium and chloride levels within the shallow overburden aquifers and determine the potential for impacted groundwater, if any, to migrate into the SGRA and HVA south of the Site. Given the tight soil formation within the wetlands, the frequency of sampling could commence on an annual basis with a reduction to bi-annual (every two years) should the levels not fluctuate considerably.

For budget purposes, the only capital cost associated with this monitoring would be the installation of four monitoring wells at an approximate cost of $15,000. Annual surface water and groundwater sampling would be approximately $5,000.

Figure 6 provides the proposed monitoring well and surface water sample locations for monitoring the Site conditions and BMPs.

4.2 Relocate Winter Maintenance Material Storage Outside of the Ramsey Lake ICA

The Ramsey Lake ICA covers the majority of the Site. There is no on-Site location where a new storage facility could be constructed outside of the ICA. As such, moving winter maintenance materials outside of the Ramsey Lake ICA will require relocating to a new property or to an existing CGS facility that is appropriately situated.

A new or significantly re-designed winter maintenance depot must consider the entire salt handling cycle including delivery, stockpiling, loading and off-loading, access routes, as well as equipment washing and wash water management. Variables to consider in selecting a new or existing Site for use as a winter maintenance operations facility include:

- Strategic location and existing site services
- Current and potential future surrounding property uses (minimize nuisance effects)
- Salt vulnerable areas on or near the Site (i.e., drinking water sources, groundwater recharge zones, salt sensitive species, and agricultural operations, etc.)
- Space requirements for material storage and handling as well as complimentary operations (i.e., vehicle washing, storage, fueling, maintenance, and repair; brine production and loading; wash water management)
- Availability or constructability of an indoor space for winter materials storage
- Site drainage and stormwater management requirement
- Potential contaminant transport pathways

A proposed new winter maintenance depot must be specifically designed and engineered for salt storage and management including:

- Site operation and management
  - Materials storage and handling practices
  - Stormwater management
  - Vehicle wash water management
  - Access routes
  - Housekeeping
- Security
- Equipment and vehicle management
- Fueling
- Training and record keeping
- Environmental monitoring

Design considerations include the establishment of an area where activities that may result in the creation of salt-laden runoff can be isolated (winter maintenance area) and all runoff from this area should be contained on Site through stormwater management features (e.g., vegetated filter strips, swales, retention pond). The winter maintenance area, swales, and wet pond must be lined with a low permeability layer, and sweeping undertaken surfaces where winter maintenance materials are handled to remove accumulated solids, debris and salt precipitate.

Compared to redeveloping the existing site, relocating the winter maintenance depot will involve significant additional cost and time, including:

- Identifying an appropriate location through the applicable planning process, which must consider the above-noted variables (i.e., potential for creating nuisance noise and traffic or impacting drinking water sources, groundwater recharge zones, species at risk, and agricultural operations, etc.)
- Property purchase and redevelopment (i.e., design and construction)
- Demolition of the existing winter maintenance depot

Should the decision between alternatives be based on cost, relocating the existing depot is considerably more expensive and not recommended.

4.3 Required Plans for Redevelopment or New Reconstruction

With either the reconstruction of the existing Site or a development of any new site, best management practices and plans anticipated include the following:

Operations, Maintenance and Monitoring (OMM) Plan

An Operations, Maintenance and Monitoring Plan should be prepared for any redeveloped or new Site, which would include routine inspection of material storage facilities (structures and asphalt

pads). Potential cracks or damaged areas of asphalt paving will be repaired on an ongoing basis, as required, to minimize the downward migration of surface water.

Storm Water Management (SWM) Plan

A Storm Water Management (SWM) plan should developed for any redeveloped or new Site, which would include sediment removal consisting of vegetated filter strips, vegetated swales, an oil/water separator, wet pond and an engineered outlet structure. These features should be constructed with a low permeability liner to optimize the containment and collection of salt precipitate. The vegetated filter strips and swales will promote particulate removal and plant uptake, the oil/water separator will remove sediments and hydrocarbons, and the wet pond will settle out fine particulates and provide a mixing volume to normalize chloride concentrations and dampen peak concentration discharge.

Operation and maintenance will include the following, as a minimum:

- Inspection of the asphalt deck for cracks, etc. and sealing as required to ensure minimal infiltration.
- Routine sweeping of the asphalt deck to remove deposited salt precipitate and sediments, and disposal off-Site at an approved location.
- Removal of debris and sediments from the level spreader, vegetated filter strip, and vegetated swales and management on Site or disposal at an approved off-site location.
- Regular inspection and cleaning of the oil/water separator at the beginning and end of the snow removal season to maintain optimal removal efficiency.
- Removal and disposal of sediments from the SWM Pond when sediment accumulation levels exceed the designed sediment capture volume/capacity. Plantings that are potentially disturbed during sediment removal activities will be restored where necessary.
- Monitoring of discharge water quality.

This installation will require an environmental compliance approval (ECA). An OMM Plan for all stormwater management controls will be required, which will become part of the stormwater ECA.

Spill Prevention and Contingency (SPC) Plan

If it is anticipated that fuels (petroleum hydrocarbons) and brine may be handled or stored on Site, and that vehicle servicing may also be conducted, a Spill Prevention and Contingency (SPC) Plan should be developed to prevent or reduce the risk of spills of pollutants; and prevent, eliminate, or ameliorate any adverse effects that result from spills of pollutants. The Plan will be developed after the completion of construction activities and prior to site being operational.

Site-Specific Health and Safety Plan (HASP)

A Site Specific Health and Safety Plan (HASP) should be also developed with instruction on maintaining security and site maintenance. This Plan will also be developed and implemented upon completion of the construction activities and prior to the site being operational.

5. Summary

GHD completed a Risk Management Plan Assessment (Assessment) for the Frobisher Depot located at 1800 Frobisher Street in Sudbury, Ontario (Site). The Site is an active winter maintenance depot operated by the City of Greater Sudbury (CGS). Winter maintenance activities conducted at the Site include: salt and sand storage and handling; brine manufacturing; vehicle/equipment storage, maintenance, and repair; and administrative functions.

Under the Clean Water Act (CWA), road salt handling and storage is a prescribed drinking water quality threat, which may contribute to the issue of rising sodium levels within Ramsey Lake. Based on the specific characteristics of road salt storage and handling at the Site (i.e., greater than 0.5 tonnes of road salt stored/handled) and the intersection of the Site with the Ramsey Lake Issues Contributing Area (ICA), the threat is deemed significant. As such, in accordance with the Greater Sudbury Source Protection Area Source Protection Plan Policy Sa-4E RMP, the Site requires a Source Water Risk Management Plan (RMP) for road salt handling and storage activities.

Surface water samples collected for sodium and chlorides, as part of the RMP Assessment, identified:

- Upgradient/background total sodium concentration of 152 milligrams per litre (mg/L) and chloride concentration of 117 mg/L.
- On-Site total sodium concentrations of 4,010 and 4,170 mg/L, and chloride concentrations of 6,220 and 6,430 mg/L.
- Downstream total sodium concentrations ranging from 181 to 313 mg/L, and chloride concentrations ranging from 322 to 558 mg/L. While total sodium concentrations generally remained the same downstream of Highway 55/Kingsway, chloride concentration generally slowly decreased with travel from 558 to 374/367 mg/L.

As expected, the highest sodium concentrations were observed immediately downstream of the salt depot where the pickled sand and mixing practices remain uncovered and exposed to the elements. Sodium concentrations were lower downstream. The on-Site (downgradient) low-lying swamp provides an excellent salt attenuation and buffer in minimizing the transport of salt from the Site towards the creek and eventually Ramsey Lake. No visual evidence of vegetative stress or deterioration was observed as a result of salt loadings from the Site.

As such, two measures available to CGS to manage the significant threat of road salt storage and handling within the Ramsey Lake ICA include:

- Maintain Site operations and implement BMPs with monitoring to evaluate the effectiveness of BMPs.
- Relocate the winter maintenance material storage to a new site, located outside of any area where road salt storage and handling is deemed a significant threat, preferably within an area of low salt vulnerability as identified in the CGS Salt Optimization Plan.

Considering the additional cost and time associated with relocating the depot, in association with the benefits provided by the low-lying downgradient swamp which provides salt attenuation and a

buffer from salt travel, redeveloping the existing Site using BMPs (i.e., build a dome for the pickled sand, install a monitoring network) would be the most economical and practical option.

All of Which is Respectfully Submitted,

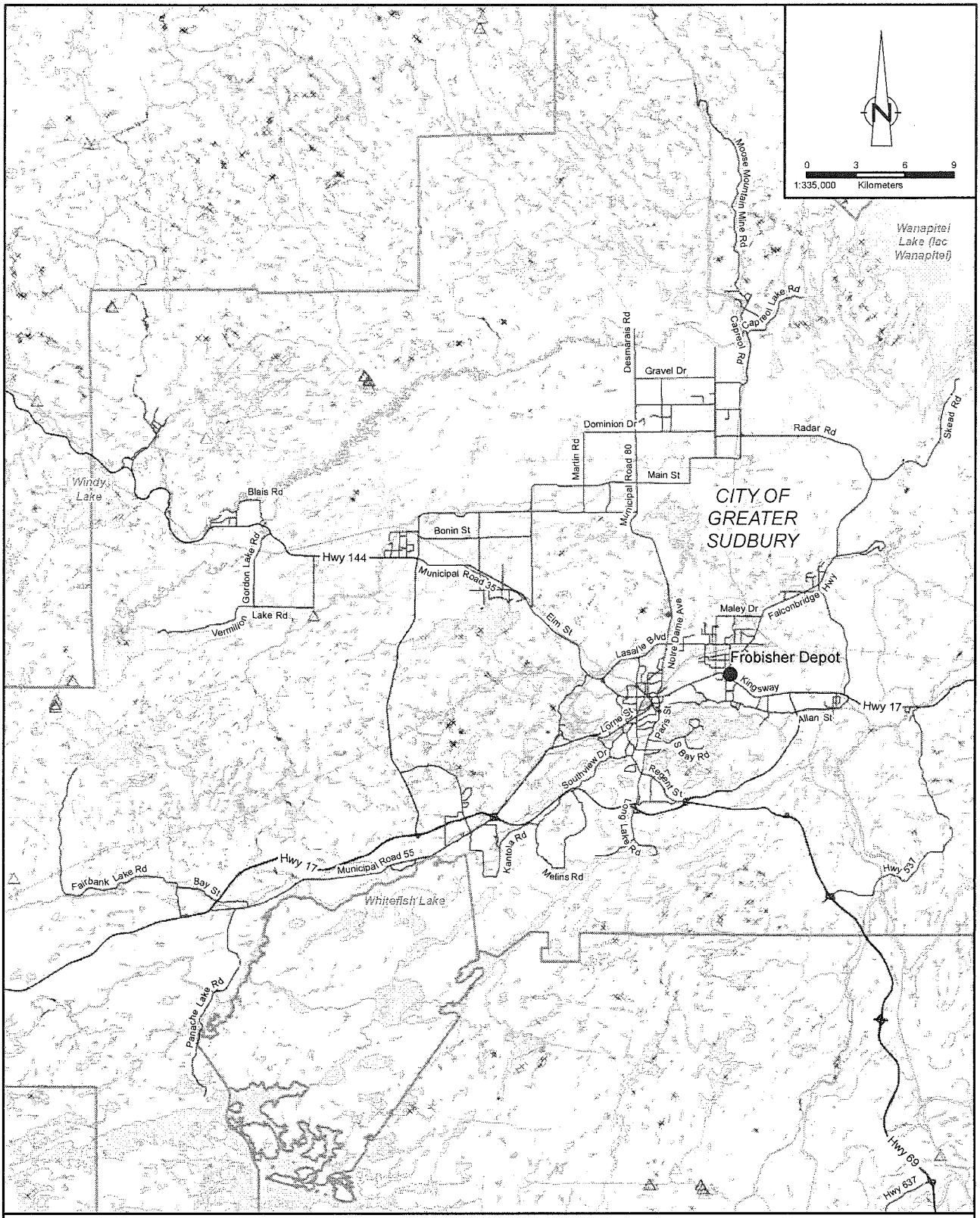
GHD

Robert Bressan, P.Eng., FEC

Sarah Ackert Ferguson, P.Eng.

Andrew Betts, M.A.Sc., P.Eng.

Figures



Source: MNRF NRVIS, 2014. Produced by GHD under licence from Ontario Ministry of Natural Resources and Forestry, © Queen's Printer 2017;
Coordinate System: NAD 1983 UTM Zone 17N

figure 1

SITE LOCATION MAP
RISK MANAGEMENT PLAN ASSESSMENT – FROBISHER DEPOT
CITY OF GREATER SUDBURY
Sudbury, Ontario

039382-42(008)GIS-OT001 Nov 09/2017

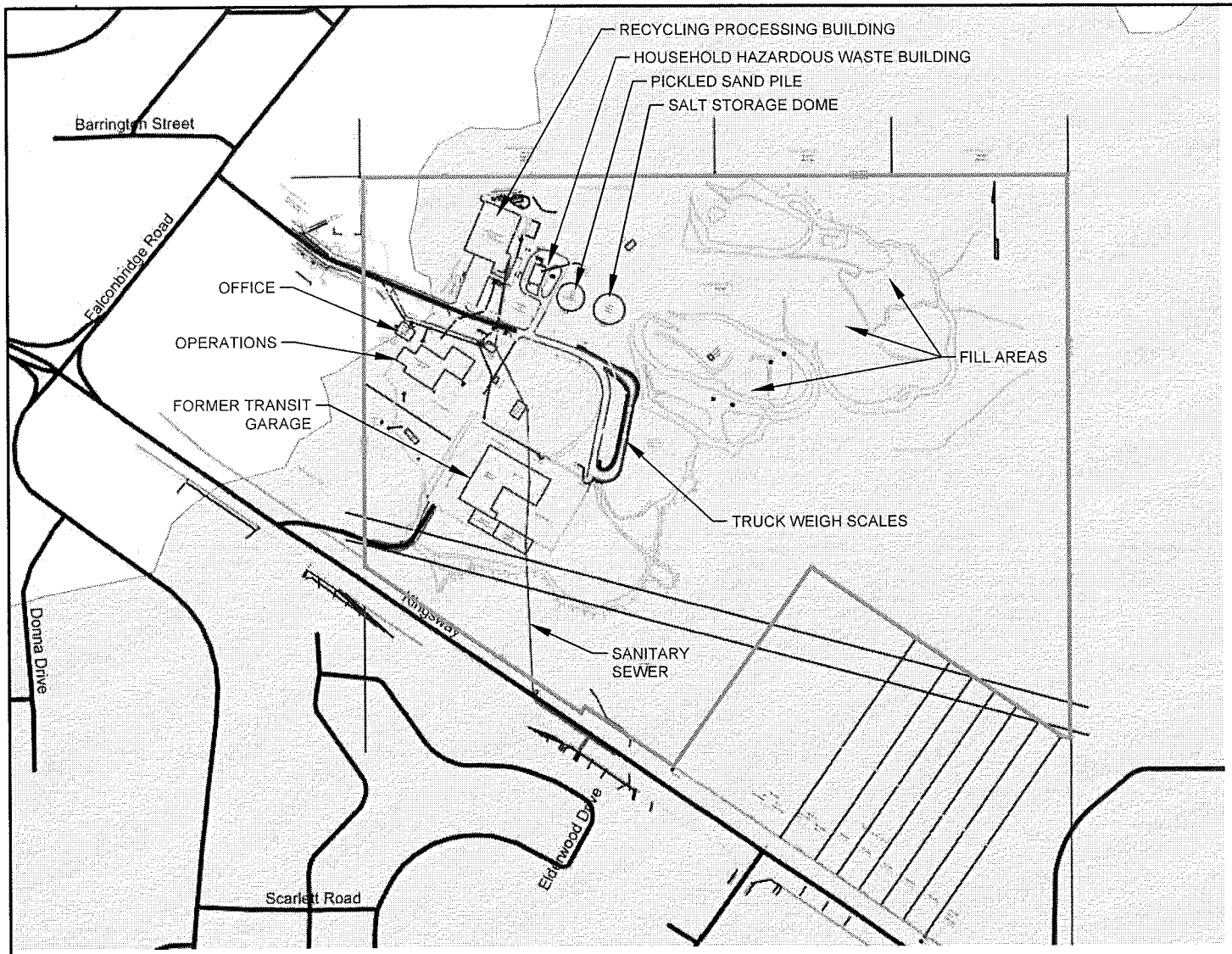


figure 2

SITE LAYOUT
RISK MANAGEMENT PLAN ASSESSMENT - FROBISHER DEPOT
CITY OF GREATER SUDBURY
Sudbury, Ontario

GHD

39382-42(008)GN-WA002 NOV 10, 2017

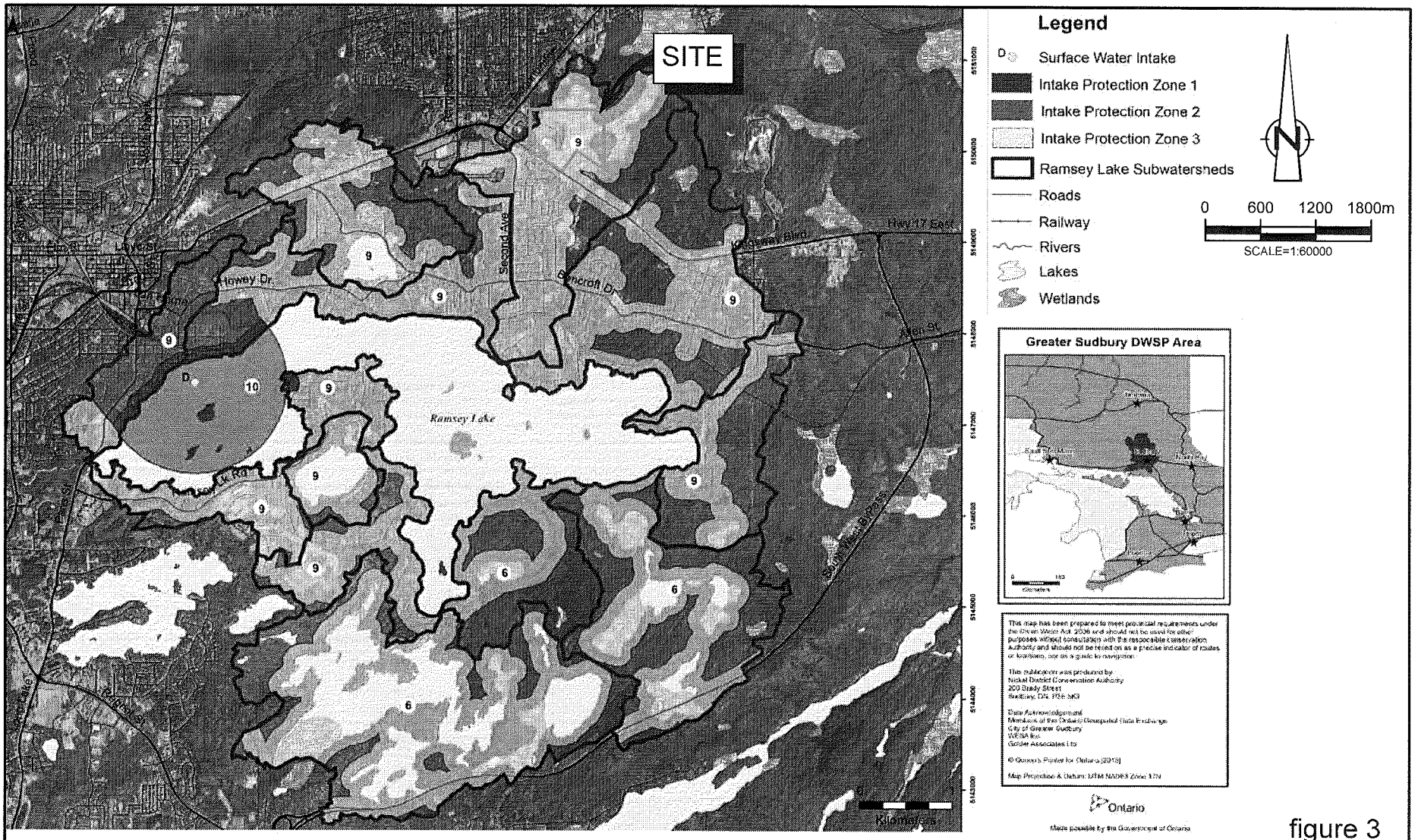
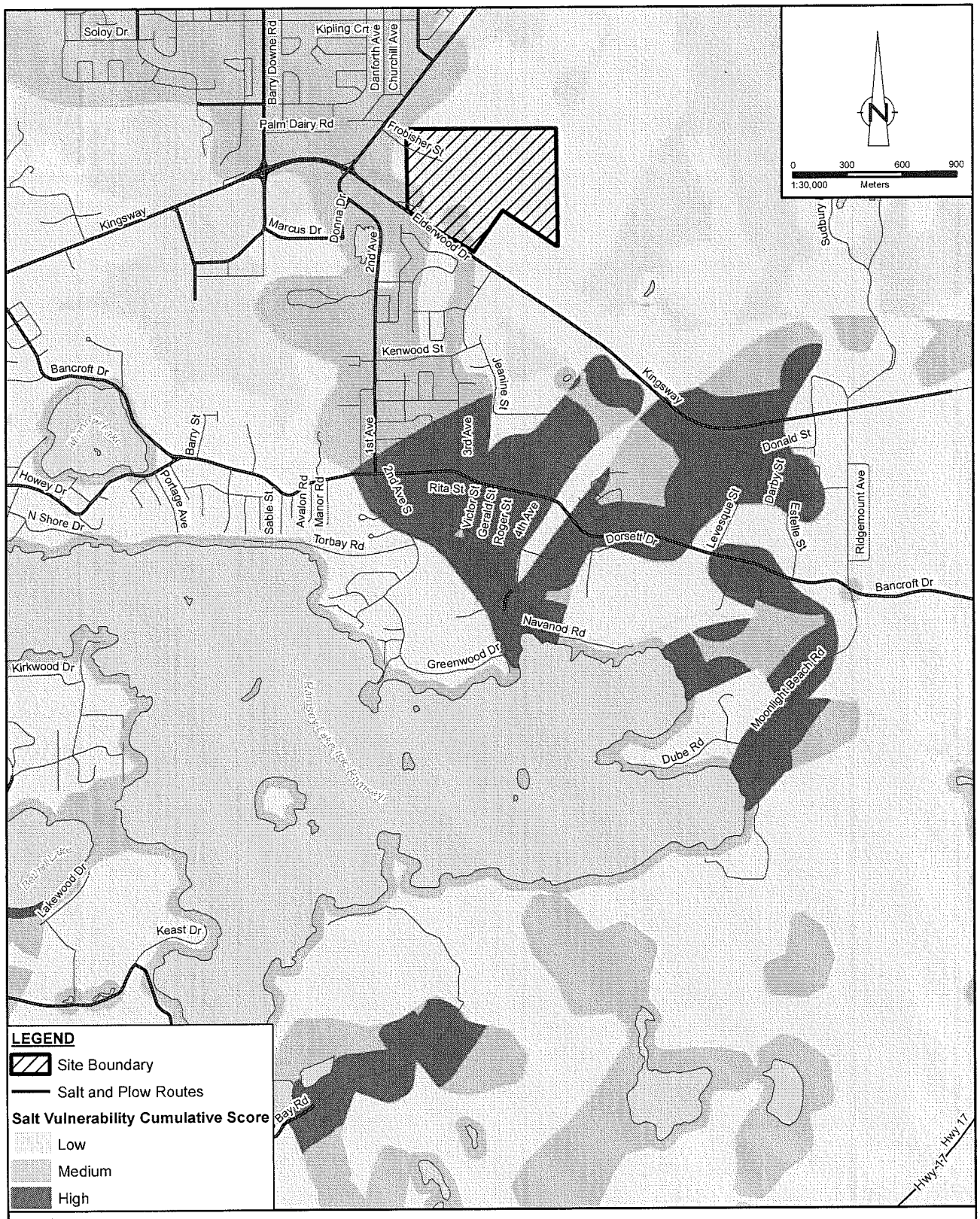


figure 3

RAMSEY LAKE INTAKE PROTECTION ZONES WITH VULNERABILITY SCORING
RISK MANAGEMENT PLAN ASSESSMENT - FROBISHER DEPOT
CITY OF GREATER SUDBURY
Sudbury, Ontario

39382-42(008)GN-WA003 NOV 9, 2017

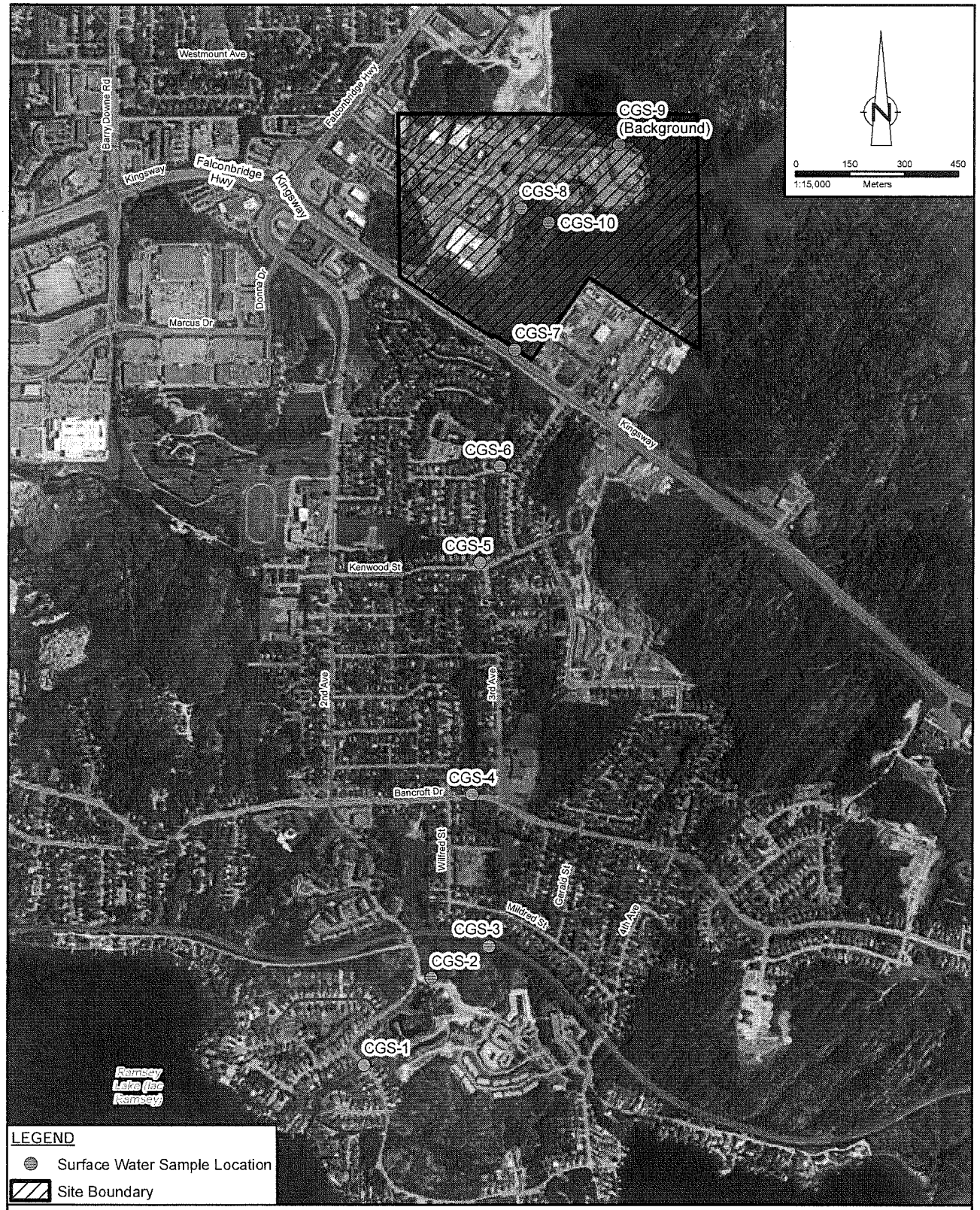


Source: Image ©2017 Google, Imagery date: 08/05/2016
Coordinate System: NAD 1983 UTM Zone 17N

figure 4

SALT VULNERABILITY INDEX
RISK MANAGEMENT PLAN ASSESSMENT – FROBISHER DEPOT
CITY OF GREATER SUDBURY
Sudbury, Ontario

039382-42(008)GIS-OT004 Nov 10/2017

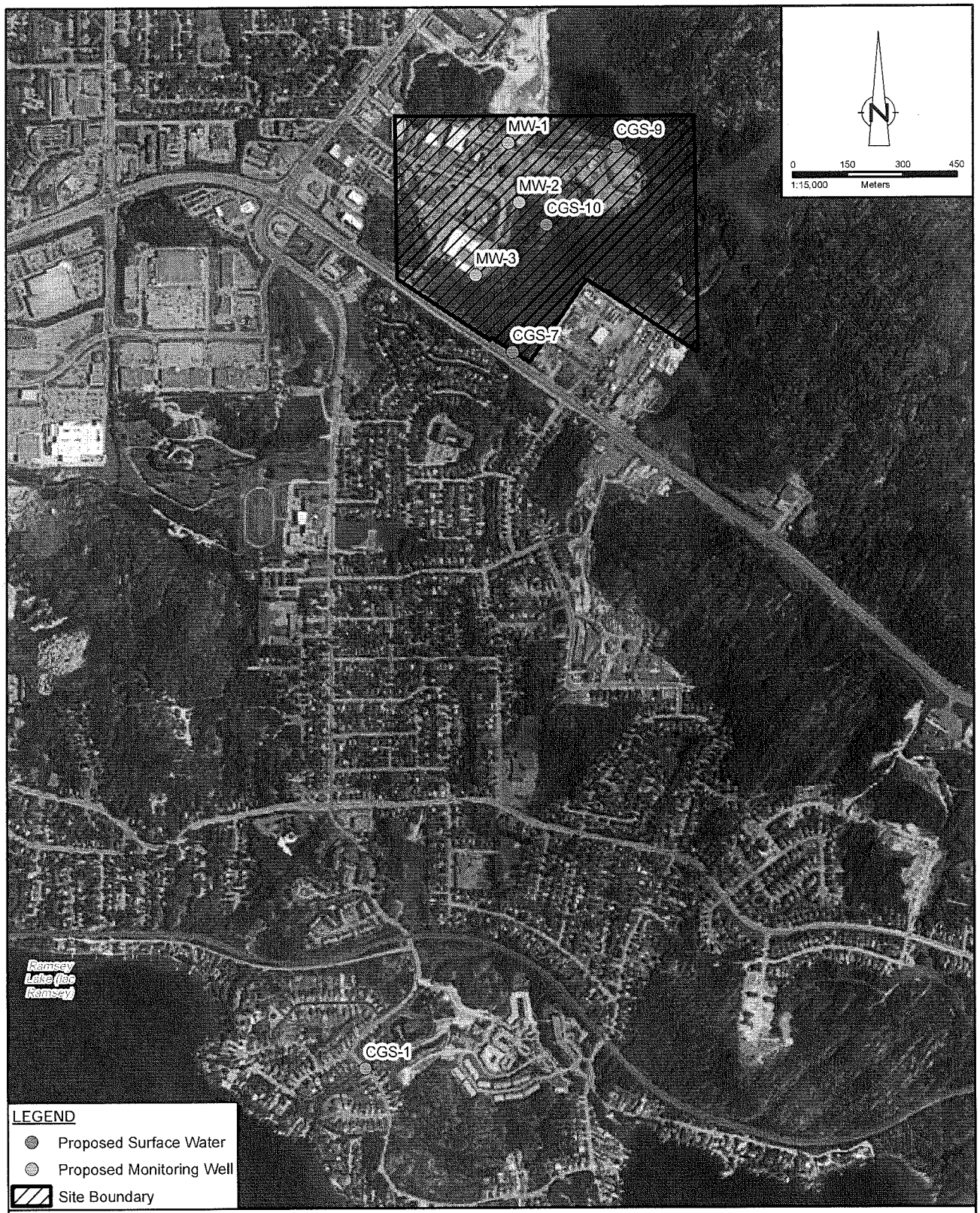


Source: Image ©2017 Google, Imagery date: 08/05/2016
Coordinate System: NAD 1983 UTM Zone 17N

figure 5

SURFACE WATER SAMPLES – OCTOBER 4 & 5, 2017
RISK MANAGEMENT PLAN ASSESSMENT – FROBISHER DEPOT
CITY OF GREATER SUDBURY
Sudbury, Ontario

039382-42(008)GIS-OT002 Nov 10/2017



Source: Image ©2017 Google, Imagery date: 08/05/2016
Coordinate System: NAD 1983 UTM Zone 17N

figure 6

PROPOSED MONITORING PROGRAM
RISK MANAGEMENT PLAN ASSESSMENT – FROBISHER DEPOT
CITY OF GREATER SUDBURY
Sudbury, Ontario

039382-42(008)GIS-OT003 Nov 10/2017

Tables

Table 1

Surface Water Sampling - Analytical Results
Frobisher Depot - Surface Water Sampling
City of Greater Sudbury, Ontario

					Chemical Analysis			
	Location ID	Location Description	Sample Date	Sample Identification	Chloride	Total Suspended Solids	Sodium-dissolved	Sodium - total
Surface Water Samples	CGS-1	Korpela Park (north of Kormak St.)	4-Oct-17	SW-39382-171004-RB-01	374	<10	200	218
	CGS-1	Korpela Park (duplicate)	4-Oct-17	SW-39382-171004-RB-02(1)	367	<10	202	203
	CGS-2	Finlandia Bridge (beneath)	4-Oct-17	SW-39382-171004-RB-03	322	<10	173	181
	CGS-3	CPR Concrete Culvert (south side)	4-Oct-17	SW-39382-171004-RB-04	414	<10	207	210
	CGS-4	Bancroft Drive (north side)	4-Oct-17	SW-39382-171004-RB-05	426	<10	224	225
	CGS-5	Kenwood Street (north side)	4-Oct-17	SW-39382-171004-RB-06	430	<10	238	248
	CGS-6	Highgate Road (north side)	4-Oct-17	SW-39382-171004-RB-07	451	<10	238	247
	CGS-7	Highway 17 Kingsway (north side)	4-Oct-17	SW-39382-171004-RB-08	558	10	282	313
	CGS-8	Depot (standing water)	4-Oct-17	SW-39382-171004-RB-09	6,220	27	3,790	4,010
	CGS-9	Background (north of fill material)	4-Oct-17	SW-39382-171004-RB-10	117	<10	81	152
	CGS-10	Downstream of Depot (stream into swamp)	5-Oct-17	SW-39382-171004-RB-11	6,430	<10	3,680	4,170

Notes:

All units are in milligrams per Litre (mg/L)

(1) Field duplicate sample

Na Sodium

TSS Total Suspended Solids

Table 2

Best Management Practices - Continuous Improvement
Risk Managment Plan Assessment - Frobisher Depot
City of Greater Sudbury, Ontario

Best Management Practices	Currently Reviewed and Updated As Needed	Need for Review and Updating	Requires periodic review to maintain continuous improvement	Currently Implemented or Completed	Not Currently Considered	NOTES
Material Delivery and Handling						
Defined winter maintenance material storage and handling area				✓		
Low permeability pad		✓				
Berm or curb to prevent runoff into surrounding area					✓	
Salt-laden runoff directed to catch basins					✓	There are no stormwater catchbasins on Site
Salt stored inside a permanent, roofed structure				✓		Salt is stored in a dome
Impermeable Floor		✓				Floor is relatively impermeable
Periodic Roof/wall Inspections			✓	✓		Regular inspection are conducted
Periodic Floor Inspections for cracks and leaks		✓				
Indoor Loading Salt into spreaders				✓		
Practices to minimize spillage during loading	✓		✓			
Practices for quick salt spill clean up/housekeeping	✓		✓			
Excess salt returned to storage			✓	✓		
Salt deliveries covered while in transport and delivered in good weather	✓			✓		
Clean loading pads following transfer of material indoors					✓	
Records kept: Weigh tickets with truck number for each delivery				✓		
Timing of transfer of material indoors		✓				
Cleaning of loading pad after material transfer					✓	
Pickled Sand stored inside a permanent, roofed structure					✓	Pickled sand is stored outside
Indoor Pickled sand mixing					✓	
Outdoor mixing in good weather	✓		✓			
Discontinue summer storage of pickled sand		✓			✓	
Equipment Washing						
Wash all vehicles indoors		✓				
Salt water retention/treatment area		✓			✓	
Oil/water separator installed		✓				
Liquid Brine Production, Storage, and Handling						
Are water wells located up-gradient						There are no drinking water wells on Site. The Site and surrounding area are servcies by municipal water supply
Sufficient water supply for brine production				✓		
Seondary Containment					✓	There are no floor drains in the area of the brine tank
Vehicle Impact Protection				✓		The brine tank is located inside a building
Brine transfer from tank to truck conducted on solid impermeable surface		✓			✓	
Periodic Inspections of tank and piping	✓		✓			
Consideration to use washwater or salt impacted drainage for brine production					✓	

Table 2

Best Management Practices - Continuous Improvement
Risk Managment Plan Assessment - Frobisher Depot
City of Greater Sudbury, Ontario

Best Management Practices	Currently Reviewed and Updated As Needed	Need for Review and Updating	Requires periodic review to maintain continuous improvement	Currently Implemented or Completed	Not Currently Considered	NOTES
Records of Material Usage						
Use material tracking system to rationalize amount of materials used with the amount ordered and the residual amount at the end of the season		✓	✓			CGS Fleet has previously experimented with various sensors on its' trucks without a reliable solution to date (comp spread, plow sensores, etc.)
Training						
Sufficient training for equipment operators on controls and operating procedures	✓		✓	✓		
Health and safety requirements for use of equipment and materials			✓	✓		
Environmentally Sensitive/Vulnerable Areas						
Identify vulnerable areas and areas of natural and scientific interest			✓	✓		
Liaise with local potable water supply agencies				✓		
Monitor ground water and recharge areas					✓	
Locate stockpiles and snow disposal sites outside of vulnerable areas		✓				
Communication Strategy						
Prepare an internal handbook for employees that communicates the Council approved winter maintenance policies and procedures and other important information such as, contact lists, shift assignments, etc.		✓	✓	✓		

Appendices

Appendix A
Surface Water Sampling Standard Operating Procedures (SOP)

Technical Memorandum

To:	Tony DeSilva, CGS Road Operations	Ref. No.:	39382-42
From:	Robert Bressan/lb/1	Tel:	705-254-2438
CC:			

Subject: **Surface Water Sampling Procedure - City of Greater Sudbury**

1. Field Procedure for Surface Water Sampling

The purpose of the surface water sampling program is to obtain samples of the creek that are representative of existing surface water conditions. The parameters to be sampled and analyzed include:

- Chloride
- Sodium
- Total Suspended Solids (TSS)

Physical water quality parameters to be recorded in the field at each sampling location as samples are being collected include:

- Conductivity in mS/cm or µS/cm (i.e., specific conductance, conductivity normalized to 25°C)
- Temperature in °C
- pH [unitless]
- Turbidity as NTU
- Dissolved Oxygen (DO) in mg/L
- Total Dissolved Solids (TDS) in mg/L
- Oxidation Reduction Potential (ORP) in mV

Prior Planning and Preparation

The following should be considered prior to conducting surface water sampling:

- Check the weather prior to the sampling date to ensure the appropriate conditions are being sampled. To capture base flow (i.e., dry) conditions, ensure the sample location has not received precipitation within the past three days (72 hours). To capture run-off (i.e., wet) conditions, ensure the sample location has received at least ten millimeters of precipitation within 24 hours of sampling.

- If sample locations are located on private lands, coordinate with the owner for property access prior to the sample event.
- Make proper arrangements with the laboratory with regard to sample containers and sample date.
- Make proper arrangements with field equipment supplier with regard to water quality meter and sample date for equipment pick-up and drop-off (i.e., Maxim Environmental and Safety Inc.). Ensure calibration certificates are provided to ensure equipment is functioning properly. Also, ask to ensure equipment is set to read-out specific conductance for conductivity. Conductivity is a temperature dependent parameter; therefore, the same body of water can have a different conductivity as the temperature increases or decreases. For data comparative purposes, specific conductance is preferred as it is the conductivity of the water body at 25°C. If using a Horiba U-50 series water quality meter, the unit uses an automatic temperature conversion function to calculate conductivity at 25°C at a temperature coefficient of 2 %/°C based on the measured value of the temperature (see section 6.5 of the manual for more information). Ask the supplier for a demonstration on how to use the unit if you are unsure.
- Assemble equipment and supplies prior to sample event (i.e., water quality meter, sample containers, sample coolers, ice, metre stick, waders/overboots, protective gloves, field book/worksheet, pencils/pens, camera/phone for photographs, sample location map/figure, sample work plan, additional equipment if required such as peristaltic pump or t-bars)
- Pre-plan the sampling sequence (i.e., downstream to upstream)
- Working in water presents hazards not encountered in on-land operations. Complete a hazard analysis prior to the first sample event to mitigate risks to the sampler and review with the sampler prior to each sampling event.

Sample Location Selection

Surface water samples should be collected in areas of the creek that have a uniform cross section and flow rate. Mixing is influenced by turbulence and water velocity, therefore surface water samples should be collected in locations immediately downstream of a riffle area (i.e., fast flow zone) to ensure good vertical mixing. To ensure continuity within the sampling program, all surface water samples should be collected at the same location during each sampling event (i.e., install a t-bar at each sampling location) and documented in field notes, including photographs. Wading into the creek increases the chances of disturbance of sediments from the creek bed and therefore should be performed with caution. Surface water samples must be collected with no suspended sediments and should be collected starting at the furthest downstream location to avoid sediment interference with upstream locations. The site should also be clear of immediate point sources (i.e., tributaries and industrial and municipal effects) unless the sampling is being performed to assess these sources.

Sampling Technique

Surface water samples will be collected using the "direct dipping" technique, which involves directly dipping the sample container into the creek, unless the sample container contains preservatives. If a sample container contains preservatives, a pre-cleaned unpreserved sample container should be used to collect the

surface water sample. The surface water sample can then be decanted into the appropriate preserved sample container.

To collect a surface water sample, wade into the water and stand downstream of the sample location, submerse the inverted bottle to the deserved sample depth (typically 15 centimetres below the water surface with the sample container being completely submerged to eliminate the collection of floating debris), and tilt the opening of the sample container upstream to fill. Avoid moving around which could increase the chances of sediment disturbance. If the sample is to be collected in an area where the flow depth is less than one inch, special equipment is required to eliminate sediment disturbance. Surface water samples may be collected using a pre-cleaned shallow container then decanted to the appropriate sample container, or sampling could be performed using a peristaltic pump. A small excavation in the creek bed to create a sump for sample collection can also be considered however, it should be prepared in advance to allow all the sediments to settle prior to surface water sampling.

Once the sample bottle has been filled, secure the lid and place into the appropriate sample bag (if provided) and then into a cooler. After all samples have been collected, the cooler should be filled with ice prior to delivery to the laboratory. If samples will be shipped by via courier to the laboratory, double bag the ice, and line the cooler with a garbage bag sealing ice and samples within the cooler to prevent the occurrence of leaking during shipping. If glass containers are shipped, special attention should be paid to protecting them during shipping. The cooler should be tapped closed with a custody seal in place to maintain chain-of-custody until delivered to the laboratory.

Sample Container Labeling

It is important to ensure all surface water samples are labeled correctly to reflect the sample identification number (i.e., sample ID) associated with the sample location on all sample containers. The laboratory supplying the sample containers will typically provide blank sample labels which can be filled out in the field however, if possible, sample containers/labels can be filled out the day before to save time. Typically, the following information is recorded on each sample container:

- Unique sample ID number
- Sample date and time
- Sampler name or initials
- Analysis requested (i.e., chloride/sodium/TSS)
- Any identifier that can reveal the location to the lab (e.g. WR1 [White River 1]) should be avoided to prevent lab bias in reviewing the sample analysis.

Labels should be written in permanent ink and affixed to the sample container. An example of a unique sample ID would be:

SW-MMDDYY-XXX-001

where:

SW = sample matrix is surface water

MMDDYY = month/day/year

XXX = sampler's first, middle, and last initials

001 = sequential number for the sample event

Chain-of-Custody (COC) is the sequence of possession of an item. A sample is considered to be in custody if it is in the actual possession of a person, in the view of the person after being in his/her actual possession, or was placed in a secure area by that person. The integrity of analytical data is dependent in part on the legally defensible chain of custody of the samples collected. Therefore, COC records must be completed in permanent ink for all samples collected as it documents the transfer of samples for the specified analysis. The COC record must be signed and dated by the sampler when transferring samples. Ask the laboratory how to properly fill out the COC if you are unsure. When shipping samples, the chain of custody is maintained by applying a seal across the cooler lid that must be broken to open the cooler. The receiving laboratory will break the seal and accept the chain of custody has been maintained in transit.

Field Notes for Surface Water Sampling

Use a field book or worksheet to document all surface water sampling activities and record the following at least once per day:

- Name/type of equipment in use for measuring field parameters, date of calibration certificate
- Results of on-site daily calibration test. Note post test-results, and any sensors that fail calibration
- Weather conditions (i.e., dry, raining, overcast) – indicate changes throughout the day

Record the following at each monitoring location:

- Description of surface water sampling location (i.e., location name and surrounding)
- Sampling technique (i.e., direct dipping, peristaltic pump)
- Description of photographs taken
- Physical field parameter values and associated parameter units (i.e., conductivity, pH, temperature, TDS, DO, turbidity, ORP)
- Air temperature and any changes to weather conditions (i.e. starts raining)
- Stream flow directions (i.e., north to south, east to west)
- Creek physical conditions (i.e., width, depth, etc.)
- Visual observations (i.e., presence of tributaries, impoundments, bridges, railway trestles, oil sheen, odours, buried debris, vegetation and canopy cover, algae, fish and other aquatic species, surrounding industrial area, creek and creek bank erosion)
- Unique sample ID including time sample was collected and location

Post Sampling Activities

The following should be performed once sampling has been completed:

- Equipment should be cleaned, allowed to dry completely, and stored
- Sample coolers dropped off at the laboratory with the COC record filled out and attached (check with laboratory for sample drop-off times and after hours procedure)
- File field notes and download photographs
- Compile laboratory results into location specific summaries

Appendix B
Analytical Data – Surface Water Sampling Event (October 4 & 5, 2017)

AGAT Laboratories

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

CLIENT NAME: GHD LIMITED
651 COLBY DRIVE
WATERLOO, ON N2V1C2
(519) 884-0510

ATTENTION TO: Airesse MacPhee

PROJECT: 039382-42 - City of Greater Sudbury (PO# 73509263)

AGAT WORK ORDER: 17U268416

WATER ANALYSIS REVIEWED BY: Mike Muneswar, BSc (Chem), Senior Inorganic Analyst

DATE REPORTED: Oct 13, 2017

PAGES (INCLUDING COVER): 5

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

*NOTES

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.

AGAT Laboratories

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

Certificate of Analysis

AGAT WORK ORDER: 17U268416

PROJECT: 039382-42 - City of Greater Sudbury (PO# 73509263)

CLIENT NAME: GHD LIMITED

ATTENTION TO: Airesse MacPhee

SAMPLING SITE:

SAMPLED BY:

Inorganic Chemistry - Surface Water Samples

DATE RECEIVED: 2017-10-05

DATE REPORTED: 2017-10-12

Parameter	Unit	G / S	RDL	Date Prepared	Date Analyzed	SW-39382-171004-RB-01 Water 2017-10-04 8793582	SW-39382-171004-RB-02 Water 2017-10-04 8793584	SW-39382-171004-RB-03 Water 2017-10-04 8793589	RDL	SW-39382-171004-RB-04 Water 2017-10-04 8793594	SW-39382-171004-RB-05 Water 2017-10-04 8793603
Chloride	mg/L		0.50	2017-10-12	2017-10-12	374	367	322	1.0	414	426
Total Suspended Solids	mg/L		10	2017-10-11	2017-10-11	<10	<10	<10	10	<10	<10
Sodium-dissolved	mg/L		0.10	2017-10-12	2017-10-12	200	202	173	0.10	207	224
Total Sodium	mg/L		1.0	2017-10-12	2017-10-12	218	203	181	1.0	210	225

Parameter	Unit	G / S	RDL	Date Prepared	Date Analyzed	SW-39382-171004-RB-06 Water 2017-10-04 8793608	SW-39382-171004-RB-07 Water 2017-10-04 8793613	SW-39382-171004-RB-08 Water 2017-10-04 8793618	RDL	SW-39382-171004-RB-09 Water 2017-10-04 8793623
Chloride	mg/L		1.0	2017-10-12	2017-10-12	430	451	558	10	6220
Total Suspended Solids	mg/L		10	2017-10-11	2017-10-11	<10	<10	10	10	27
Sodium-dissolved	mg/L		0.10	2017-10-12	2017-10-12	238	238	282	2.5	3790
Total Sodium	mg/L		1.0	2017-10-12	2017-10-12	248	247	313	25	4010

Parameter	Unit	G / S	RDL	Date Prepared	Date Analyzed	SW-39382-171004-RB-10 Water 2017-10-04 8793628	RDL	SW-39382-171005-RB-11 Water 2017-10-05 8793634
Chloride	mg/L		0.20	2017-10-12	2017-10-12	117	10	6430
Total Suspended Solids	mg/L		10	2017-10-11	2017-10-11	<10	10	<10
Sodium-dissolved	mg/L		0.05	2017-10-12	2017-10-12	80.8	2.5	3680
Total Sodium	mg/L		1.0	2017-10-12	2017-10-12	152	25	4170

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to PWQO (mg/L)
Guideline values are for general reference only. The guidelines provided may or may not be relevant for the intended use. Refer directly to the applicable standard for regulatory interpretation.

8793582-8793634 Elevated RDLs indicate the degree of sample dilutions prior to analysis in order to keep the analytes within the calibration range of the instruments and to reduce matrix interferences.

Certified By:

AGAT Laboratories

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

Quality Assurance

CLIENT NAME: GHD LIMITED

PROJECT: 039382-42 - City of Greater Sudbury (PO# 73509263)

SAMPLING SITE:

AGAT WORK ORDER: 17U268416

ATTENTION TO: Airesse MacPhee

SAMPLED BY:

Water Analysis

RPT Date:			DUPLICATE				REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Method Blank	Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
Inorganic Chemistry - Surface Water Samples															
Chloride	8793589	8793589	322	321	0.3%	< 0.10	101%	90%	110%	108%	90%	110%	85%	80%	120%
Total Suspended Solids	8793582	8793582	< 10	<10	NA	< 10	98%	80%	120%	NA			NA		
Sodium-dissolved	8793582	8793582	200	191	4.6%	< 0.05	99%	90%	110%	99%	90%	110%	98%	70%	130%
Total Sodium	8793582	8793582	218	209	4.2%	< 0.5	99%	90%	110%	88%	80%	120%	95%	70%	130%

Comments: NA signifies Not Applicable.
Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Certified By:

AGAT Laboratories

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

Method Summary

CLIENT NAME: GHD LIMITED

AGAT WORK ORDER: 17U268416

PROJECT: 039382-42 - City of Greater Sudbury (PO# 73509263)

ATTENTION TO: Airesse MacPhee

SAMPLING SITE:

SAMPLED BY:

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Water Analysis			
Chloride	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Total Suspended Solids	INOR-93-6028	SM 2540 D	BALANCE
Sodium-dissolved	MET-93-6105	EPA SW-846 6010C & 200.7	ICP/OES
Total Sodium	MET-93-6105	EPA SW 846 3010A & 6010C	ICP/OES

1742684916

AGAT Laboratories

5835 Coopers Avenue
Mississauga, Ontario L4Z 1Y2
Ph: 905 712 5100 Fax: 905 712 5122
webearth.agatlabs.com

Chain of Custody Record

If this is a Drinking Water sample, please use Drinking Water Chain of Custody Form (potable water consumed by humans)

Report Information:

Company: GHD
Contact: ROBERT BRESSAN
Address: 96 WHITE OAK DRIVE EAST
SAULT STE. MARIE ON
Phone: 705-254-2438 Fax: 705-254-2430
Reports to be sent to:
1. Email: robert.bressan@ghd.com
2. Email: alyssa.maybee@ghd.com

Project Information:

Project: CITY OF GREATER SUDBURY
Site Location: FRUSHER CREEK
Sampled By: ROBERT BRESSAN
AGAT Quote #: PO:
Please note: If quotation number is not provided, client will be billed full price for analysis.

Invoice Information:

Bill To Same: Yes [X] No [ ]
Company:
Contact:
Address:
Email:

Regulatory Requirements:

[ ] No Regulatory Requirement
(Please check all applicable boxes)

[ ] Regulation 153/04
Table (Indicate One) [ ] Ind/Com [ ] Res/Park [ ] Agriculture
Soil Texture (Check One) [ ] Coarse [ ] Fine

[ ] Sewer Use
[ ] Sanitary [ ] Storm
Region (Indicate One) [ ] MISA

[ ] Regulation 558
[X] CCME
[X] Prov. Water Quality Objectives (PWQO)
[ ] Other
(Indicate One)

Is this submission for a Record of Site Condition? [ ] Yes [X] No

Report Guideline on Certificate of Analysis [ ] Yes [X] No

Laboratory Use Only

Work Order #: 735092 63
Cooler Quantity: 1
Arrival Temperatures: 7.9 | 8 | 8.2
Custody Seal Intact: [ ] Yes [ ] No [ ] N/A
Notes:

Turnaround Time (TAT) Required:

Regular TAT [X] 5 to 7 Business Days
Rush TAT (Rush Surcharges Apply)
[ ] 3 Business Days [ ] 2 Business Days [ ] Next Business Day
OR Date Required (Rush Surcharges May Apply):
Please provide prior notification for rush TAT
*TAT is exclusive of weekends and statutory holidays
For 'Same Day' analysis, please contact your AGAT CPM

Sample Matrix Legend

B Biota
GW Ground Water
O Oil
P Paint
S Soil
SD Sediment
SW Surface Water

Sample Identification	Date Sampled	Time Sampled	# of Containers	Sample Matrix	Comments/ Special Instructions	Field Filtered - Metals, Hg, CrVI (Y/N)	O. Reg 153: Metals and Inorganics; All Metals; 153 Metals (excl. Hydrides); Hydride Metals; 153 Metals (incl. Hydrides)	ORPs: B-HWS; CN; Cr6+; EC; Hg; pH; SAR	Full Metals Scan	Regulation/Custom Metals	Nutrients: TP; NH3; TKN; NO2; NO3+NO2	Volatiles: VOC; BTEX; THM	PHCs F1 - F4	ABNs	PAHs	PCBs: Total; Aroclors	Organochlorine Pesticides	TCLP: M&I; VOCs; ABNs; B(a)P; PCBs	Sewer Use	TSS	Total Sodium	Dissolved Sodium
SW-39382-171004-RB-01	004/17	15:25	4	SW	* ALL &	N		X												X	X
RB-02		15:38			SAMPLES			X												X	X
RB-03		15:56			WERE			X												X	X
RB-04		16:19			NOT			X												X	X
RB-05		16:49			FIELD			X												X	X
RB-06		17:19			& FILTERED &			X												X	X
RB-07		17:58						X												X	X
RB-08		18:18			PLS LAB			X												X	X
RB-09		18:41			FILTER			X												X	X
RB-10		18:58						X												X	X
SW-39382-171005-RB-11		13:06	4	SW				X												X	X

Samples Relinquished By (Print Name and Sign)	Date	Time	Samples Received By (Print Name and Sign)	Date	Time
Robert Bressan	Oct 5/17	14:30	HOLLY SGOUROS	5 OCT 17	1430
Samples Relinquished By (Print Name and Sign)	Date	Time	Samples Received By (Print Name and Sign)	Date	Time
				17/10/6	1532
Samples Relinquished By (Print Name and Sign)	Date	Time	Samples Received By (Print Name and Sign)	Date	Time

Page 1 of 1
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Pink Copy - Client | Yellow Copy - AGAT | White Copy- AGAT

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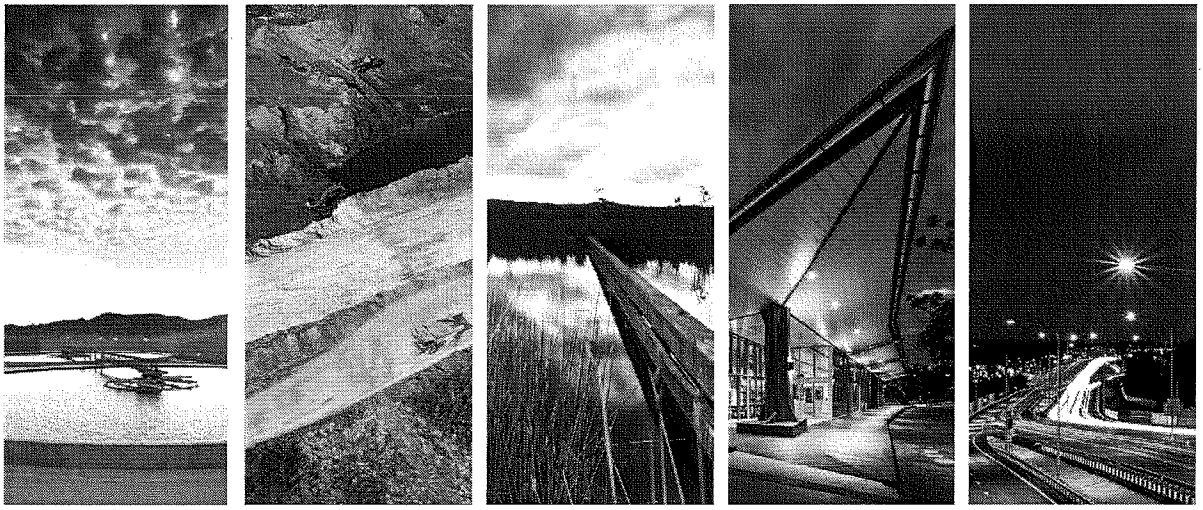

Salt Optimization Plan

City of Greater Sudbury

GHD | 96 White Oak Drive Sault Ste. Marie Ontario P6B 4J8 Canada

039382| 41| Report No 7 | January 18 2018

Executive Summary

This Salt Optimization Plan is a multi-departmental collaborative effort that is striving to optimize the use of road salt within the City of Greater Sudbury (CGS/City) to maintain safe surfaces for pedestrian and vehicular traffic while minimizing the environmental impacts related to the storage, handling, and application of road salt. The Salt Optimization Plan was initially launched as part of a source water protection initiative to protect sources of drinking water from rising sodium and chloride concentrations as per policy number Sa2EF-SA within the Greater Sudbury Source Protection Area Source Protection Plan[1] and in response to a Ministry of Environment and Climate Change (MOECC) request.

The Salt Optimization Plan assesses the potential risk to environmental receptors within vulnerable areas associated with the application of salt within the CGS. Vulnerable areas incorporated within the Salt Optimization Plan include the following: source water protection (SWP), wellhead protection areas (WHPAs), intake protection zones (IPZs), highly vulnerable aquifers, significant/sensitive groundwater recharge areas, lake trout and fish spawning areas, wetlands, and provincially tracked species sensitive to salt application. By combining and weighing each environmental receptor/vulnerable area cumulatively, areas and roadways within the CGS were rated as low to high receptor risk related to salt exposure (see Figure 11). Based on the identification of intersections of salt vulnerable areas and roadways within the CGS, recommendations are provided to minimize the impact of salt on these environmental receptors (see Table 1) and provide direction to the Working Group to maintain a safe road network while protecting the environment.

CGS developed this Salt Optimization Plan in an effort to remain proactive with its Salt Management Plan initiatives and as a requirement of the Ministry of the Environment and Climate Change (MOECC). By doing so, the City is demonstrating to the community that safe and environmentally conscious road salt management and winter maintenance practices are a priority for the municipality.

1 "*Greater Sudbury Source Protection Area Source Protection Plan*", Prepared on Behalf of the Greater Sudbury Source Protection Committee Under the Clean Water Act, 2016 (Ontario Regulation 287/07). Approved September 19, 2014.

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Figure Index

Table Index

1. Introduction

This Salt Optimization Plan is a multi-departmental collaborative effort that is striving to optimize the use of road salt within the City of Greater Sudbury (CGS/City) to maintain safe surfaces for pedestrian and vehicular traffic while minimizing the environmental impacts related to the storage, handling, and application of road salt. The Salt Optimization Plan was initially launched as part of a source water protection initiative to protect sources of drinking water from rising sodium and chloride concentrations as per policy number Sa2EF-SA within the Greater Sudbury Source Protection Area Source Protection Plan.[2] and in response to a Ministry of Environment and Climate Change (MOECC) request.

The Salt Optimization Plan assesses the potential risk/vulnerability to environmental receptors associated with the application of salt within the CGS road network. Environmental receptors incorporated within the Salt Optimization Plan include the following geographical information system (GIS) databases: source water protection (SWP), wellhead protection areas (WHPAs), intake protection zones (IPZs), highly vulnerable aquifers, significant/sensitive groundwater recharge areas, lake trout and fish spawning areas, wetlands, and provincially tracked species sensitive to salt application. By combining and weighing each environmental receptor/vulnerable area cumulatively, areas and roadways within the CGS can be rated as low to high receptor risk related to salt exposure. Based on the identification of the salt vulnerable areas and their intersection with roadways, recommendations are provided to minimize the impact of salt onto these environmental receptors and provide direction to the CGS Road Operations staff and Source water Protection Group (Working Group) to maintain a safe road network while protecting the environment.

CGS has developed this Salt Optimization Plan in an effort to remain proactive with its Salt Management Plan initiatives and as a requirement of the Ministry of the Environment and Climate Change (MOECC). By doing so, the City is demonstrating to the community that safe and environmentally conscious road salt management and winter maintenance practices are a priority for the municipality.

2. Project Overview

2.1 Vision

To minimize the environmental impact of road salt application, while maintaining safe surfaces for pedestrian and vehicular traffic.

2.2 Goals/Objectives

The City strives to minimize the impacts of road salt to the environment by encouraging reductions in the use of road salt in areas where this reduction will not impact pedestrian and vehicular safety.

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2 "*Greater Sudbury Source Protection Area Source Protection Plan*", Prepared on Behalf of the Greater Sudbury Source Protection Committee Under the Clean Water Act, 2016 (Ontario Regulation 287/07). Approved September 19, 2014.

It also strives to optimize current winter maintenance practices to achieve an overall reduction in the application of road salt while delivering the expected level of service to its customers. To achieve these goals, best management practices, education and outreach initiatives, and improvements to current technology are considered within this Salt Optimization Plan.

3. Background

3.1 Source Water Protection

Source water protection is a concept that gained status as a result of the Walkerton tragedy and the ensuing inquiry into the related events by Justice O'Connor. Following the inquiry, recommendations were made, and it was determined that the best way to manage our drinking water resources is through a multi-barrier approach; the first of these barriers being protection at the source. The Clean Water Act (2006)[3] was instated to provide legislative guidance and authority to establish this barrier to protect drinking water sources from potential significant threats for current and future generations.

The City has six drinking water systems (listed below) including three surface water intakes and associated water treatment plants and 24 municipal groundwater water wells. Together these sources supply drinking water to 148,000 residents. An additional 12,000 residents are serviced by private drinking water systems. The City's drinking water systems (DWSs) are as follows:

1) Sudbury DWS:
   - Ramsey Lake (surface water intake)
   - Wanapitei River (surface water intake)
   - Garson (three wells)
2) Vermilion River DWS (surface water intake)
3) Valley DWS (13 wells)
4) Falconbridge DWS (three wells)
5) Onaping DWS (three wells)
6) Dowling DWS (two wells)

As a requirement under the Clean Water Act, an evaluation of existing water quality issues and potential water quality threats was conducted as part of the source water protection program as well as a delineation of vulnerable areas (i.e. protected zones around groundwater wells and surface water intakes where pollutants can reach the well or intake within a specific length of time). During the issues evaluation, review of the MOECC's Drinking Water Surveillance Program (DWSP) water quality data for 1991 to 2013 revealed elevated and rising sodium and chloride concentrations within Ramsey Lake. As such, sodium (primarily attributed to the application of road salt, but also the handling and storage of road salt as well as snow storage) was identified as a drinking water

[3] *"Clean Water Act, 2006, S.O. 2006, C.22"*, MOECC, Amendments June 20, 2012.

quality issue within Ramsey Lake vulnerable areas[4]. The application of road salt was also identified as a significant threat for the Wanapitei River DWS. Snow storage was identified as a significant threat to the Valley DWS.

Elevated sodium levels were also identified within the Dowling, Valley, and Garson DWSs, however sodium was not identified as a drinking water quality issue for these DWS due to insufficient available data to determine the presence of a significant increasing trend.

To start addressing the increasing sodium trend and the treats associated with the application, handling, and storage of road salt as well as snow storage, three specified actions are prescribed within the policies of the Greater Sudbury Source Protection Area Source Protection Plan, including:

1) **Policy Sa-6F SA**: Prohibit the establishment of large municipal or commercial snow melt (snow dump) facilities within vulnerable areas where they would be a significant threat.

2) **Policy Sa-5F s57**: Prohibit the handling and storage of road salt within vulnerable areas where this activity would be a significant threat. Within the Ramsey Lake Issues Contributing Area (ICA), this policy applies to road salt storage quantities of 0.5 tonnes and greater.

3) **Policy Sa-2EF-SA**:
   - Identify vulnerable areas where winter maintenance activities could be a significant threat.
   - Optimize the use and management of road salts.
   - Implement practices to minimize salt loss into the environment and impacts to drinking water sources.
   - Prioritize snow removal and street sweeping/cleaning on primary, arterial, and collector roads within vulnerable areas as soon as possible during/after snow melt.

As previously noted, this Salt Optimization Plan was initiated to meet the requirements of Policy Sa-2EF-SA and satisfy the MOECC.

3.2 Salt Management Plan

The Salt Optimization Plan is being established to complement the City's Salt Management Plan (SMP)[5], which was developed in response to Environment Canada's Code of Practice on the Environmental Management of Road Salt. The Code of Practice outlines policies and a procedural framework that ensures the City's continuous improvement of an effective winter maintenance service.

The Salt Management Plan summarizes and provides an overview of the City's current road salt management practices. It speaks to all of the major activities related to winter maintenance,

4 *"Greater Sudbury Source Protection Area Assessment Report"*, Prepared on Behalf of the Greater Sudbury Source Protection Committee Under the Clean Water Act, 2016 (Ontario Regulation 287/07). Approved September 2, 2014.

5 *"2016 Salt Management Plan, City of Greater Sudbury"*, Prepared by GHD, May 19, 2017.

operational practices and strategies as well as monitoring and updating requirements stipulated within the plan.

The Salt Optimization Plan fits within the continual improvement framework of the SMP. By offering recommendations on new and innovative ways of best managing the handling, storing and applying road salt, the Salt Optimization Plan keeps in line with the policy statements within the SMP.

3.3 Frobisher Depot Risk Management Plan

The Greater Sudbury Source Protection Area Source Protection Plan prescribes the establishment of risk management plans (RMPs) for activities related to the handling, storage, and application of road salt as well as snow storage within the following areas:

1) **Policy Sa-4E RMP**: Existing road salt handling and storage areas where the activity is a significant threat. Within the Ramsey Lake ICA, this policy applies to road salt storage quantities of 0.5 tonnes and greater.

2) **Policy Sa-3EF RMP**: Existing and future road salt application and existing snow storage for properties with exterior parking lots that are equal to or greater than one hectare, where the activities could be a significant threat and where Policy SA6F-SA does not apply.

As such, significant drinking water threat activities related to the City's winter maintenance program, including those of salt handling and storage occurring at the Frobisher Depot, will be addressed through RMPs.

The Frobisher Depot has a covered salt storage dome with a relatively impermeable base that stores the salt needed for the winter maintenance season. Pickled sand (i.e. sand mixed with salt at approximately five percent by volume) is currently stored outside at the site within the footprint of the former pickled sand dome located beside the salt storage dome. Brine is prepared and stored in a separate building at the site. Application equipment used during the winter maintenance season is loaded at the site prior to deployment to respond to winter events. Portions of the site used for salt and pickled sand storage and handling are located within the Ramsey Lake vulnerable area further discussed in Section 4.3.

The Frobisher Depot RMP, which ensures that all best management practices related to the significant drinking water threat activities are or will be employed on site, is provided under separate cover.

4. Vulnerable Areas

This section of the report is dedicated to a presentation of mapped areas having a known high vulnerability to groundwater and surface water contamination. An understanding of these vulnerable areas and their spatial association will provide further insight into salt vulnerable areas and enable us to make targeted and informed decisions regarding salt reduction strategies.

The Assessment Report produced in response to legislative requirements under the Clean Water Act[6] identified and mapped five (5) primary vulnerable areas for the Source Protection Region:

1) Well Head Protection Areas (WHPAs)
2) Intake Protection Zones (IPZs)
3) Issues Contributing Areas (ICAs)
4) Highly Vulnerable Aquifers (HVAs)
5) Significant/Sensitive Groundwater Recharge Areas (SGRAs)

Mapping for these areas was obtained from Conservation Sudbury.

Three additional vulnerable areas also considered within this document are as follows:

1) Fish Spawning Areas and Lake Trout Lakes/Proposed Lake Trout Lakes
2) Wetlands
3) Provincially Tracked Species

Mapping for these areas was obtained from the CGS GIS Department.

The CGS' boundary and road inventory/network are shown on Figures 1 and 2. CGS Surficial Drainage Areas, which show the tertiary watershed areas within the City limits (i.e. Vermillion, Upper and Lower Wanapitei, Killarney, as well as small portions of the Sturgeon, Spanish, and French watersheds), are shown on Figure 3.

4.1 Well Head Protection Areas (WHPAs)

Well Head Protection Areas (WHPAs) represent vulnerable areas that were delineated as part of the source water protection program, based on the presence of a municipal DWS. WHPAs are areas surrounding a municipal supply well where activities occurring at the surface may have the most impact on the quantity and quality of drinking water obtained from groundwater sources.

The WHPAs delineated for the City's wells include four areas: WHPA-A, WHPA-B, WHPA-C and WHPA-D. WHPA-A is the same for all wells and consists of a 100 meter radius, whereas WHPA-B, WHPA-C and WHPA-D are based on groundwater travel times to the wells and include two, five and 25 year categories. In addition, two of the wells within the Valley DWS (Wells M and J) in addition to both wells in the Dowling DWS are considered to be groundwater under the direct influence of surface water (GUDI) and as such a WHPA-E was established for these wells. The WHPA-E is delineated as an Intake Protection Zone-2 (IPZ-2) with the intake location at the point of interaction between groundwater supply and surface water or, if that is unknown, at the point in surface water that is closest to the well.

The WHPAs for the municipal wells are shown on Figure 4.

6 *"Greater Sudbury Source Protection Area Assessment Report"*, Prepared on Behalf of the Greater Sudbury Source Protection Committee Under the Clean Water Act, 2016 (Ontario Regulation 287/07). Approved September 2, 2014.

4.2 Intake Protection Zones (IPZs)

Intake Protection Zones (IPZs), similarly to the WHPAs, were also delineated around each surfacewater supply source as part of the source water protection program, in this case around the surface water intake structures located within the Wanapitei River, the Vermilion River, and Ramsey Lake. There are three different zones outlined as part of the IPZ delineation process: IPZ-1, IPZ-2, and IPZ-3.

The **Wanapitei River** intake structure is located in the southeast section of the City and is classified as a Type C intake (i.e. located within in a river and flow direction and velocity are unaffected by a water impoundment structure). The Wanapitei River IPZ-1 consists of a 200 metre (m) semi-circle, with the intake at the center point of the semi-circle and a 10 m extension downstream of the intake. Where the zone abuts land, a 120 m setback from the high water mark is included.

The **Vermilion River** intake structure is located within the southwest section of the City and is classified as a Type C intake. The Vermilion River intake is located within a natural basin where water circulates before continuing downstream. The Vermilion River IPZ-1 was modified to reflect local hydrodynamic conditions and consists of a 400 m radius around the intake. Where the zone abuts land, a 120 m setback from the high water mark is included.

The **Ramsey Lake** intake structure is located within the south section of the City and is classified as a Type D intake (i.e. it does not fit into the description of a Type A, B or C intake). The Ramsey Lake IPZ-1 consists of a one kilometer (km) radius around the intake structure, and where the zone abuts land, a 120 m setback from the high water mark is included.

All three IPZ-1 (Wanapitei River, the Vermilion River, and Ramsey Lake) are shown on Figure 5.

The delineation of IPZ- 2 for each surface water intake was conducted based on a two-hour travel time, which is equal to or less than the amount of time it would take a surface water plant operator to shut down the surface water treatment plant in response to a spill event (see Figure 5).

The delineation of IPZ-3 includes the area within the surface water body that may contribute water to the intake and also includes a 120 metre (m) setback from the high water mark. Transport pathways may also be included. The IPZ-3 for Ramsey Lake includes a 120 m setback applied to all contributing tributaries and storm sewers within the watershed. In areas where road side ditches serve as storm drains the protection zone includes a 120 m setback from the road network. IPZ-3 for the Wanapitei and Vermilion Rivers include contributing tributaries extending northwards over 100 km each, to the Arctic Divide.

4.3 Issues Contributing Area (ICA)

As a result of elevated and rising sodium and chloride levels identified within Ramsey Lake, the Clean Water Act required that an additional vulnerable area be identified. This area is called the Issues Contributing Area (ICA). The ICA is outlined by including the total surface area where activities occurring within its boundaries may contribute to the issues identified, in this case the increasing sodium and chloride levels. Given that the application of road salt is a non-point source, the Ramsey Lake ICA was considered as being the entire Ramsey Lake IPZ-3 (Figure 5). No other ICAs were identified within the Greater Sudbury Source Protection Area Source Protection Plan.

4.4 Highly Vulnerable Aquifers

Highly Vulnerable Aquifers (HVAs) were delineated as part of source water protection program by considering characteristics that have an impact on increasing the aquifer's susceptibility to threat activities. According to these characteristics, HVAs are typically those consisting of materials that have high permeability (such as sands and gravels), have a water table level near the surface, and have little to no overlying confining layers. HVAs are found dispersed throughout the City as shown on Figure 6.

4.5 Significant/Sensitive Groundwater Recharge Areas

Significant/sensitive groundwater recharge areas (SGRAs) are those where water falling as precipitation can infiltrate easily into the ground, and become part of an aquifer system. The map of SGRAs was developed as part of the source water protection program using a model and includes areas where the annual recharge volume accounts for 55 percent or more of annual precipitation minus evapotranspiration over the entire recharge area. SGRAs are found dispersed throughout the central portion of the City mainly within Valley East, Dowling, and Onaping areas as shown on Figure 7.

4.6 Fish Spawning Areas

Fish Spawning Areas (FSA) for sensitive species (i.e. Brook Trout, Lake Trout and Walleye) are identified within the City's Official Plan, Natural Heritage Background Study.[7] and were delineated based on information gathered from the Ministry of Natural Resources and Forestry's (MNRF's) Natural Resources and Values Information System (NRVIS) and the Laurentian University Cooperative Freshwater Ecology Unit (CFEU). As shown on Figure 8, there are no FSAs within the City limits.

4.7 Lake Trout Lakes/Proposed Lake Trout Lakes

Lake Trout Lakes (Existing and Proposed) are identified in the City's Official Plan and were identified based on information gathered from the MNRF's NRVIS and the Laurentian University CFEU. Various Lake Trout Lakes/Proposed Lake Trout Lakes are located throughout the City as shown on Figure 8.

4.8 Wetlands

Wetland area are identified within the City's Official Plan and were delineated based on information provided in the MNRF's NRVIS, as well as mapping prepared by City staff based on aerial photo review. There are multiple wetlands located throughout the City, as shown on Figure 9, including the provincially significant Vermilion River Wetland Complex.

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7 *"City of Greater Sudbury Official Plan, Natural Heritage Background Study"*, February 2005

4.9 Provincially Tracked Species Sensitive to Salt

Provincially tracked species areas were delineated based on information provided by the MNRF's Natural Heritage Information Centre (NHIC) under the City's MNRF Sensitive Data Use Licence Agreement. The NHIC manages data regarding the locations of species at risk (SAR), other tracked species, and natural areas within Ontario. The dataset for the City includes over 1,000 recorded observations of various birds, fish, snakes, turtles, insects, and plants, which were narrowed down by the application of the following criteria:

- Observations made prior to the year 2000 were excluded
- Observations with no information regarding the observer were excluded
- Species that were not directly affected by salt (i.e. do not live in aquatic or semi-aquatic habitat, or feed primarily on benthic species) were excluded
- Species that are not salt sensitive (i.e. they migrate to/live in salt water during part of the year)

The remaining species observations were mapped using the NHIC data. Figure 10 shows areas where provincially tracked species of interest were identified and is presented in one kilometer grid squares in compliance with the NHIC guidelines relating to data sensitivity.

5. Salt Vulnerability Index

The intent of the index is to provide a relative vulnerability to activities involving road salt application, storage and handling. It can be used to target specific salt reduction initiatives in areas of high salt vulnerability to help address surface and groundwater migration of sodium and chloride.

A multi-criteria analysis was performed on CGS managed plow routes proximate to various sodium-chloride sensitive receptor datasets provided by the MNRF, Conservation Sudbury, CFEU, and CGS. These receptor datasets were assigned weights to reflect their relative sensitivity to sodium-chloride exposure. CGS managed plow routes were buffered by 50 metres in all directions, then intersections were generated between the plow route buffered areas and the weighted receptors. These intersections were aggregated and their weights summed for spatially-common areas. These sums were subjected to a vulnerability classification ranging from negligible to highly vulnerable with the results from the entire CGS presented on an overview figure.

The index was calculated by assigning weighted values to each vulnerable area as follows:

Vulnerability Area/Criteria	Weight
WHPA-A	10
WHPA-B	8
WHPA-C	6
WHPA-D	4
WHPA-E	2
IPZ-1	10
IPZ-2	6

Vulnerability Area/Criteria	Weight
IPZ-3	2
Highly Vulnerable Aquifer	7
Significant/Sensitive Groundwater Recharge Areas	7
Fish Spawning/Lake Trout	2
Provincially Significant Wetlands	4
Non-Provincially Significant Wetlands	1
Salt Sensitive Provincially Tracked Species	5

By overlapping each of the mapped vulnerable areas along with their weighted values, we obtain a map covering the extent of the City by area and road which show a salt vulnerability index ranging from low to high risk (Figures 11a and 11b).

6. Recommendations

To achieve the project's vision of minimizing the environmental impact of road salt application while maintaining safe surfaces for pedestrian and vehicular traffic, recommendations are provided to improve the efficiency of winter maintenance practices. The recommendations are listed in Table 1 and divided into the following categories:

- Baseline understanding
- Level of Service
- Material Tracking and Monitoring
- Technology & Control Techniques
- Pilot Projects
- Education and Outreach
- Future Objectives

Each recommendation is categorized as either a short or long term goal, has an associated priority level (low, medium or high) and includes the group/department responsible for implementation. The implementation status of each recommendation is to be taken as its status at the time of the Salt Optimization Plan publication.

It is anticipated that a working group consisting of various City departments including members of the Source Water Protection Group, Road Operations and Traffic & Transportation staff, will continually review and assess these recommendations on an recurring basis, typically once every five years.

7. Monitoring and Updating

The purpose of monitoring and updating is to provide a basis for continuous improvement and to ensure efforts toward the implementation of the City's Salt Optimization Plan recommendations are ongoing. A review/revision of the status of the recommendations' implementation will therefore be completed at the end of each 5-year period by the working group, at which time, suggestions for new recommendations to be implemented can be added to the plan.

All of Which is Respectfully Submitted,

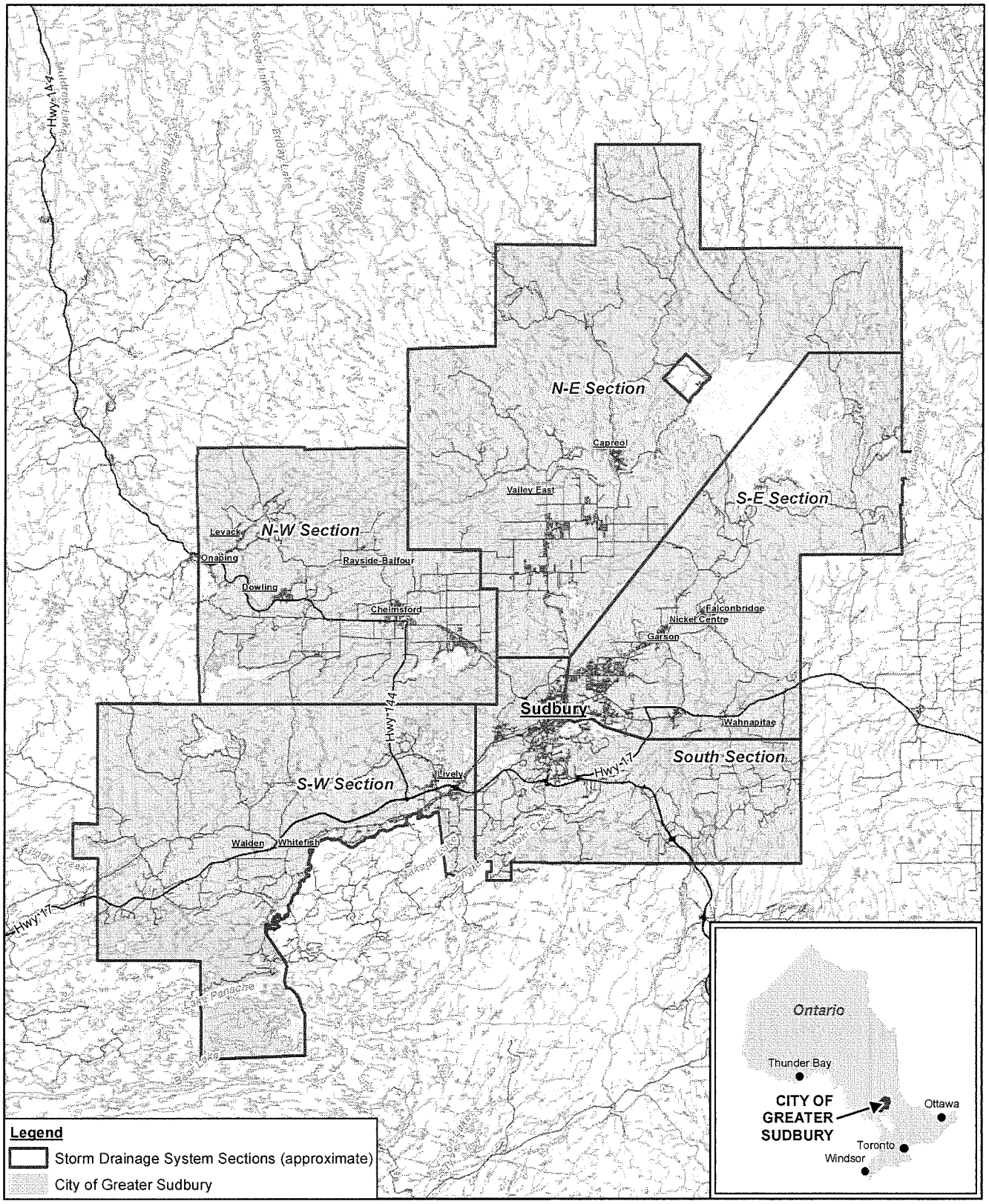
GHD

Robert Bressan, P.Eng., FEC

Sarah Ackert Ferguson, P.Eng.

Andrew Betts, M.A.Sc., P.Eng.

Figures



Source: MNRF NRVIS, 2017. Produced by GHD under licence from Ontario Ministry of Natural Resources and Forestry, © Queen's Printer 2017.
City of Greater Sudbury - Infrastructure - Needs Assessment - Storm Drainage System.

0 5 10 15
Kilometers

Coordinate System:
NAD 1983 UTM Zone 17N

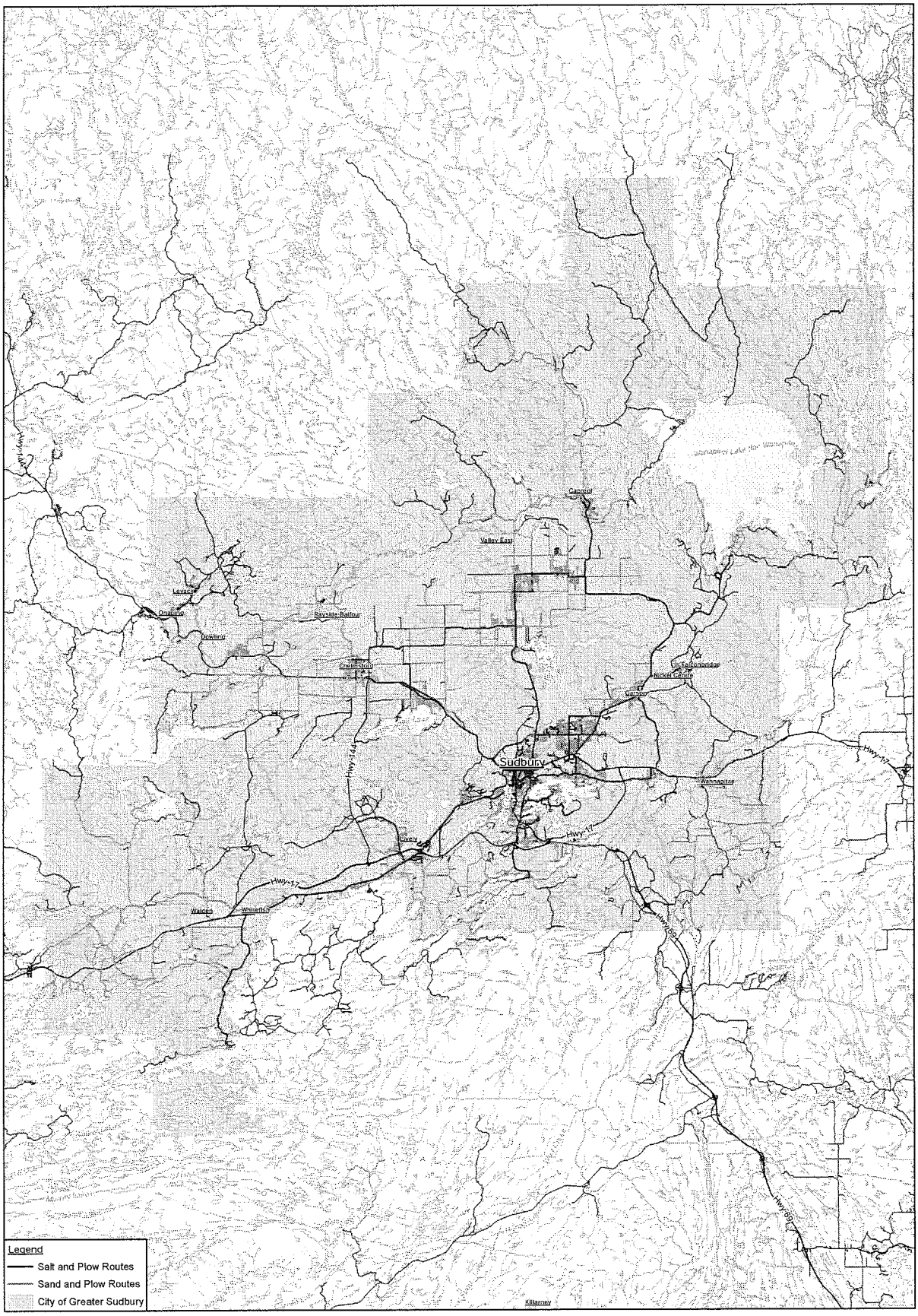
CITY OF GREATER SUDBURY
SALT OPTIMIZATION PLAN

39382-41
Oct 13, 2017

CITY OF GREATER SUDBURY LIMITS

FIGURE 1

GIS File: Q:\GIS\PROJECTS\39000s\39382\Layouts\007\39382-41(007)GIS-WA001.mxd



Source: MNRF NRVIS, 2017. Produced by GHD under licence from Ontario Ministry of Natural Resources and Forestry, © Queen's Printer 2017, City of Greater Sudbury, 2017.

0 3 6 9
Kilometers

Coordinate System:
NAD 1983 UTM Zone 17N

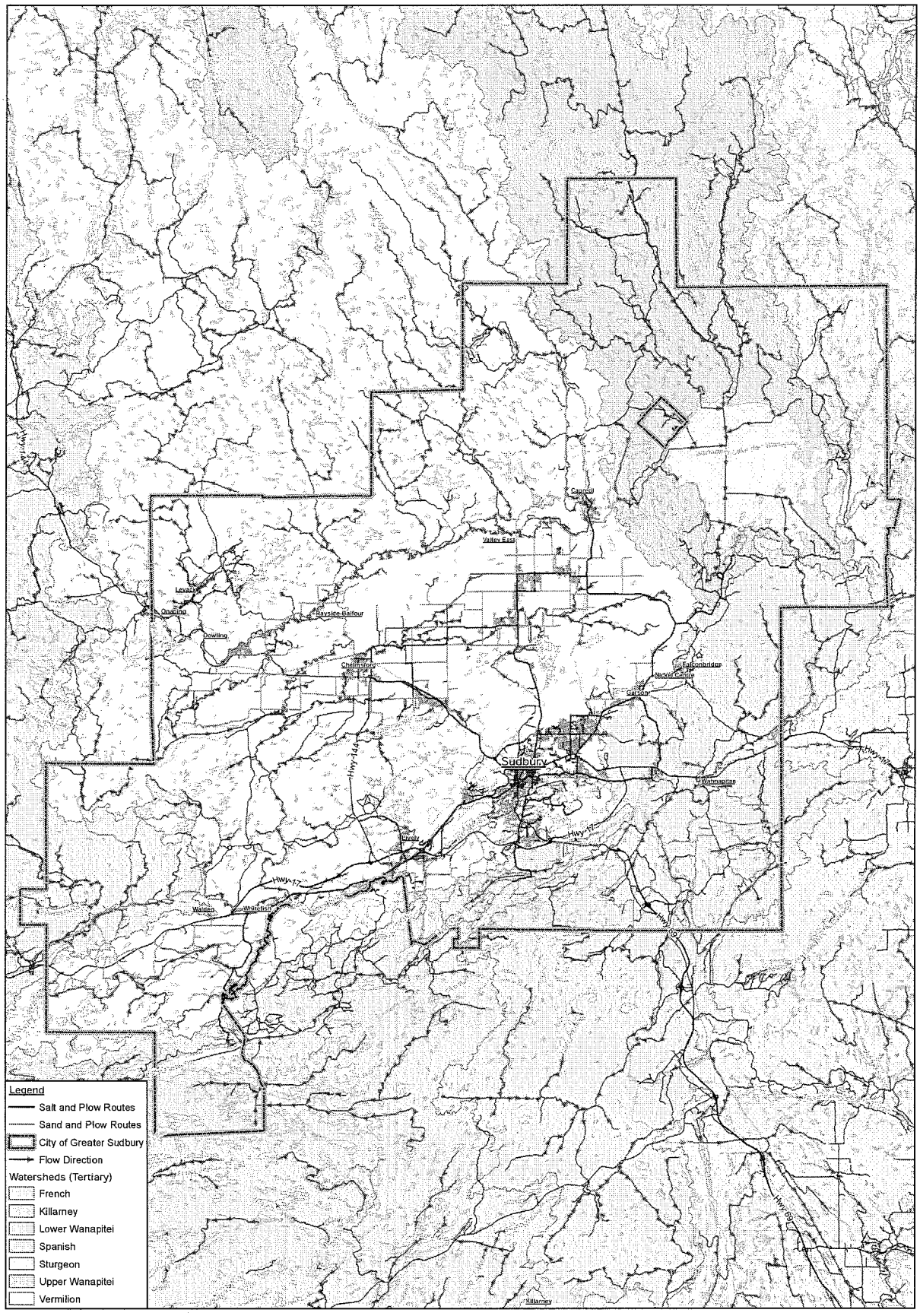
CITY OF GREATER SUDBURY
SALT OPTIMIZATION PLAN

39382-41
Oct 13, 2017

ROAD INVENTORY

FIGURE 2

GIS File: Q:\GIS\PROJECTS\39000s\39382\Layouts\007\39382-41(007)GIS-WA002.mxd



Source: MNRF NRVIS, 2017. Produced by GHD under licence from Ontario Ministry of Natural Resources and Forestry, © Queen's Printer 2017. City of Greater Sudbury, 2017.

0 3 6 9
Kilometers

Coordinate System:
NAD 1983 UTM Zone 17N

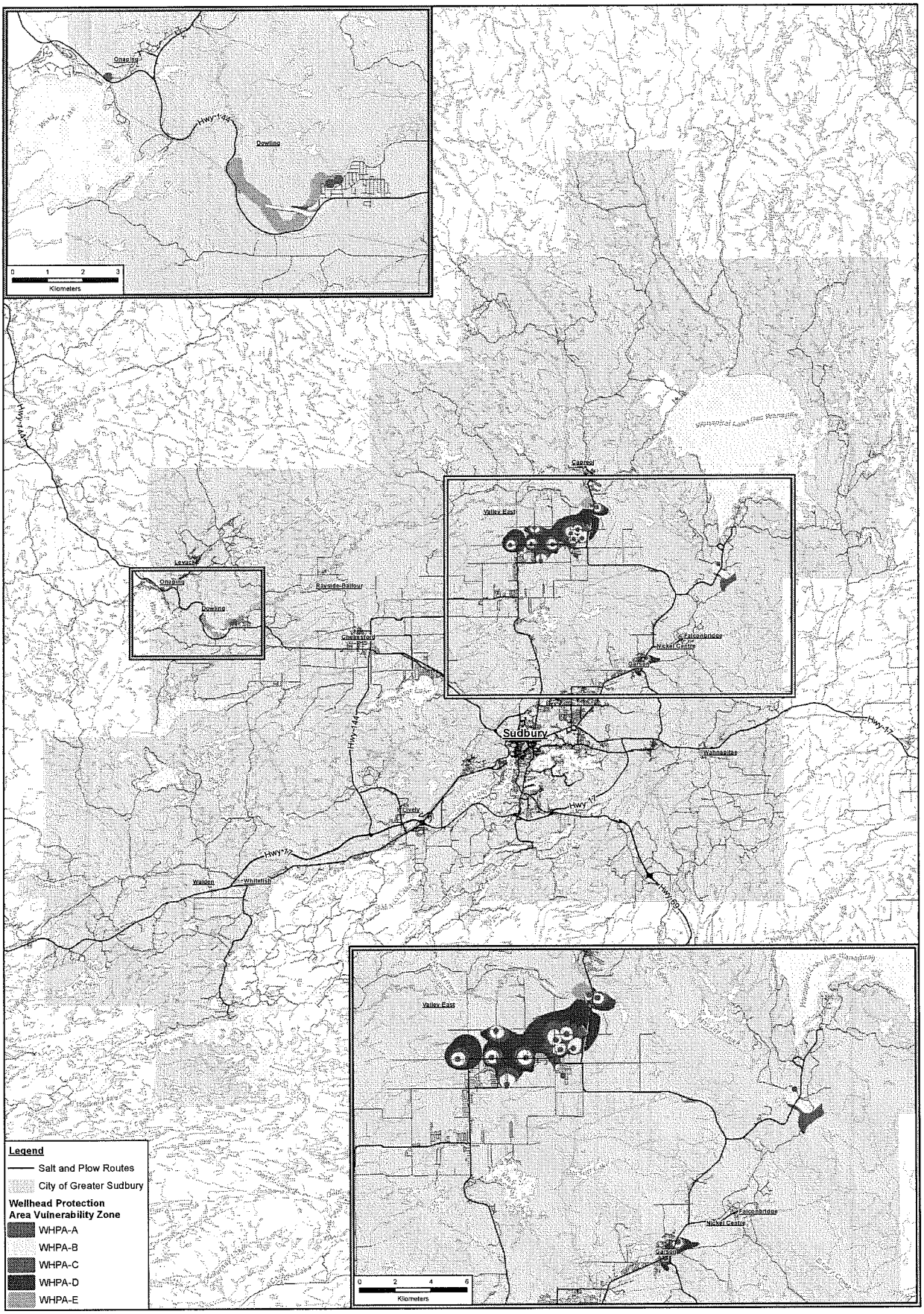
CITY OF GREATER SUDBURY
SALT OPTIMIZATION PLAN

39382-41
Oct 13, 2017

SURFICIAL DRAINAGE

FIGURE 3

GIS File: G:\GIS\PROJECTS\39000s\39382\Layouts\007\39382-41(007)GIS-WA003.mxd



Source: MNRF NRVIS, 2017. Produced by GHD under licence from Ontario Ministry of Natural Resources and Forestry, © Queen's Printer 2017. City of Greater Sudbury, 2017.

0 3 6 9
Kilometers

Coordinate System:
NAD 1983 UTM Zone 17N

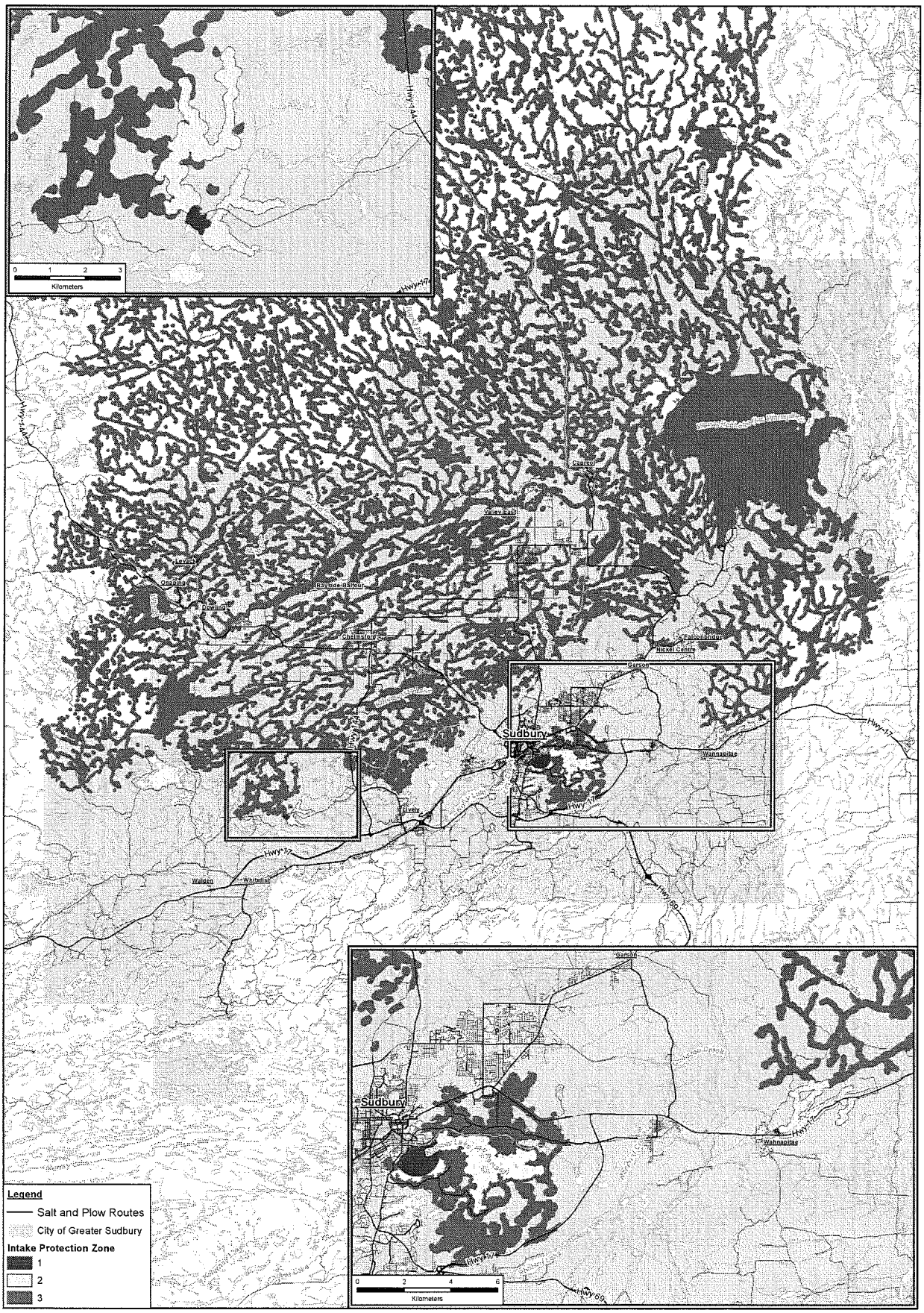
CITY OF GREATER SUDBURY
SALT OPTIMIZATION PLAN

39382-41
Oct 16, 2017

WELLHEAD PROTECTION AREAS

FIGURE 4

GIS File: Q:\GIS\PROJECTS\39000s\39382\Layouts\007\39382-41(007)GIS-WA004.mxd



Source: MNRF NRVIS, 2017. Produced by GHD under licence from Ontario Ministry of Natural Resources and Forestry, © Queen's Printer 2017. City of Greater Sudbury, 2017.

0 3 6 9
Kilometers
Coordinate System:
NAD 1983 UTM Zone 17N

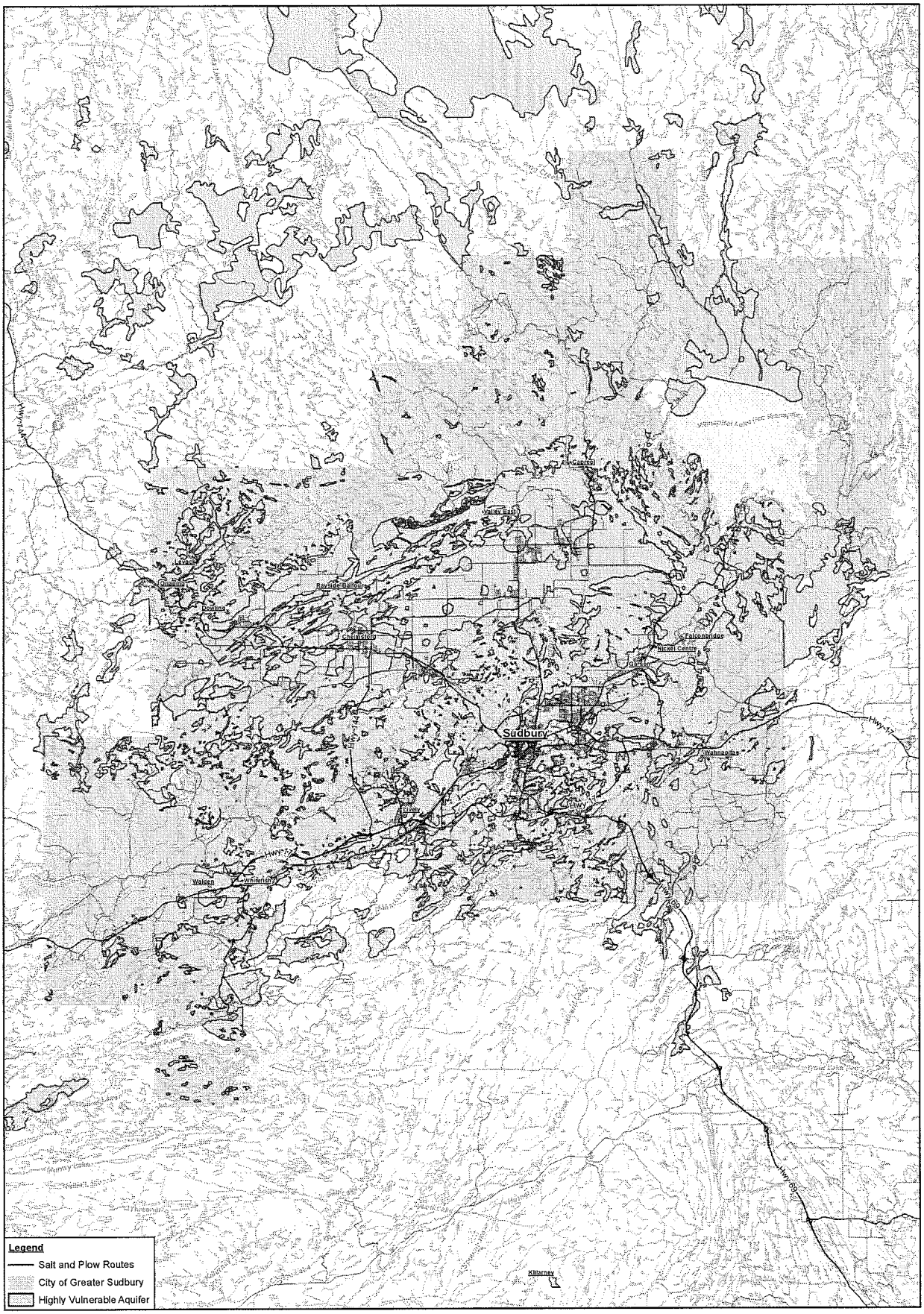
CITY OF GREATER SUDBURY
SALT OPTIMIZATION PLAN

39382-41
Oct 16, 2017

INTAKE PROTECTION ZONES

FIGURE 5

GIS File: Q:\GIS\PROJECTS\39000s\39382\Layouts\007\39382-41(007)GIS-WA005.mxd



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0 3 6 9
Kilometers

Coordinate System:
NAD 1983 UTM Zone 17N

CITY OF GREATER SUDBURY
SALT OPTIMIZATION PLAN

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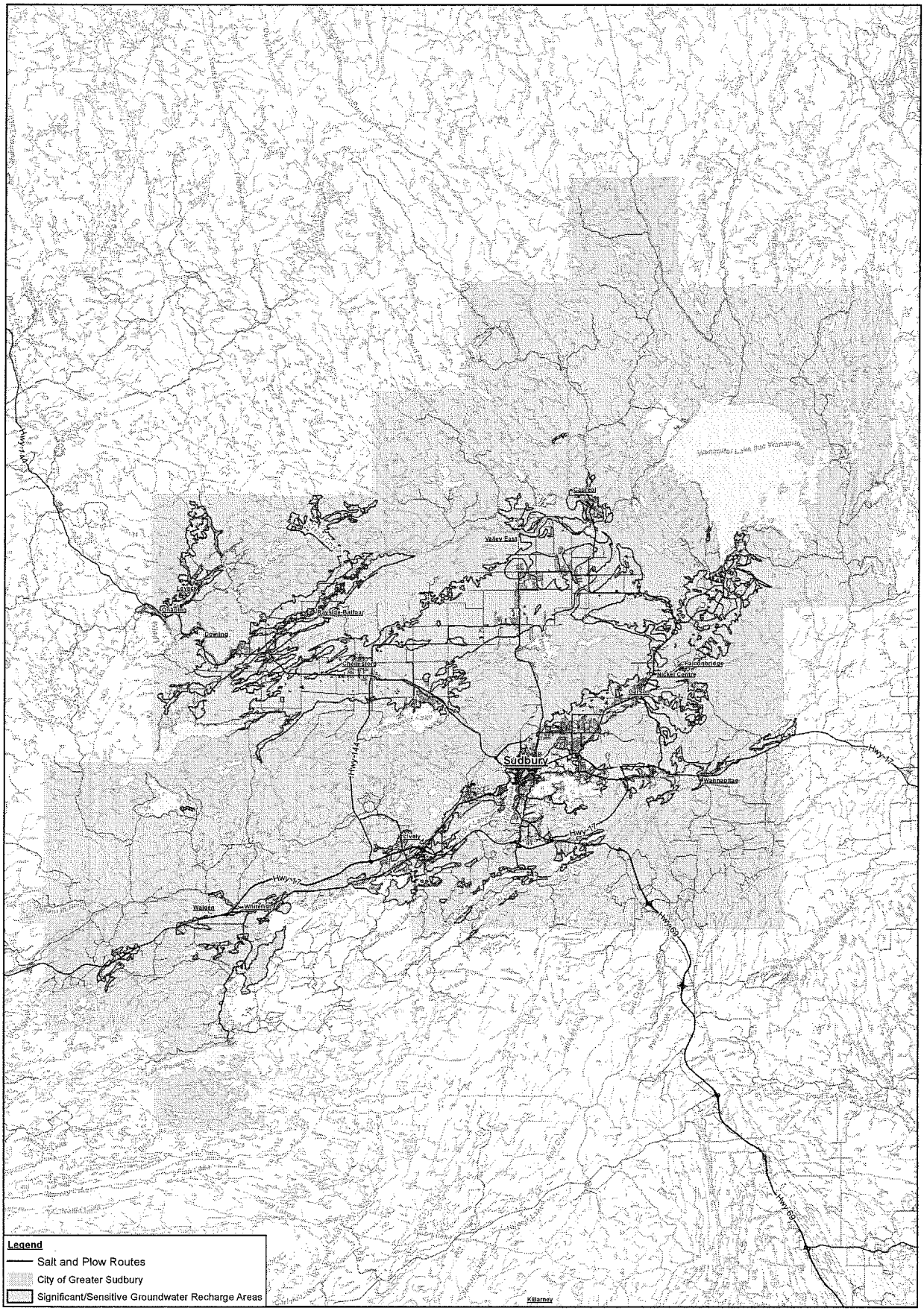
Oct 16, 2017

HIGHLY VULNERABLE AQUIFERS

FIGURE 6

GIS File: Q:\GIS\PROJECTS\39000s\39382\Layouts\007\39382-41(007)GIS-WA006.mxd



Source: MNRF NRVIS, 2017. Produced by GHD under licence from Ontario Ministry of Natural Resources and Forestry, © Queen's Printer 2017. City of Greater Sudbury, 2017.

0 3 6 9
Kilometers

Coordinate System:
NAD 1983 UTM Zone 17N

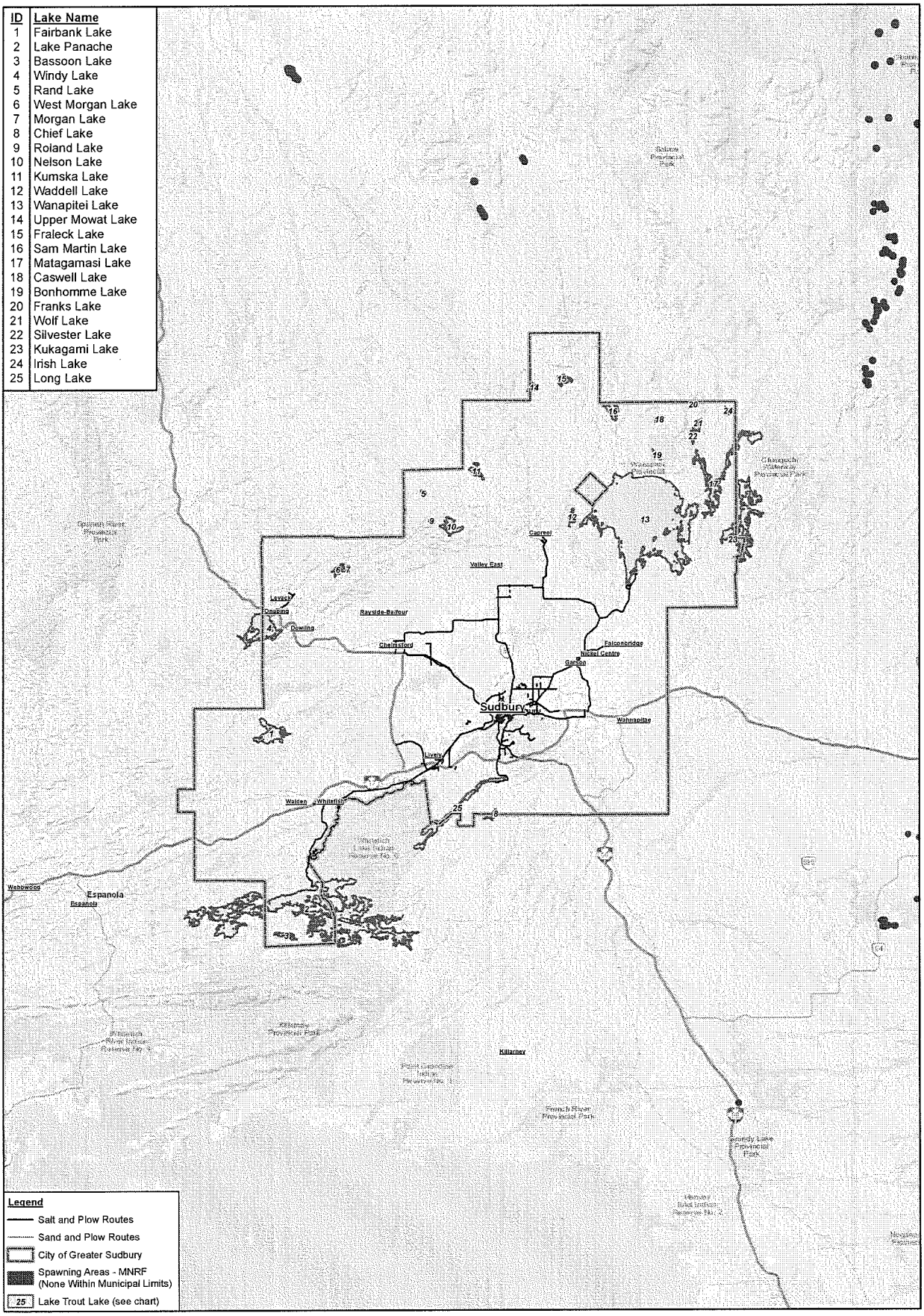
CITY OF GREATER SUDBURY
SALT OPTIMIZATION PLAN

39382-41
Oct 16, 2017

SIGNIFICANT / SENSITIVE
GROUNDWATER RECHARGE AREAS

FIGURE 7

GIS File: Q:\GIS\PROJECTS\39000s\39382\Layouts\007\39382-41(007)GIS-WA007.mxd



Source: MNRF NRVIS, 2017. Produced by GHD under licence from Ontario Ministry of Natural Resources and Forestry, © Queen's Printer 2017. ESRI Streets Basemap.

0 5 10 15
Kilometers
Coordinate System:
NAD 1983 UTM Zone 17N

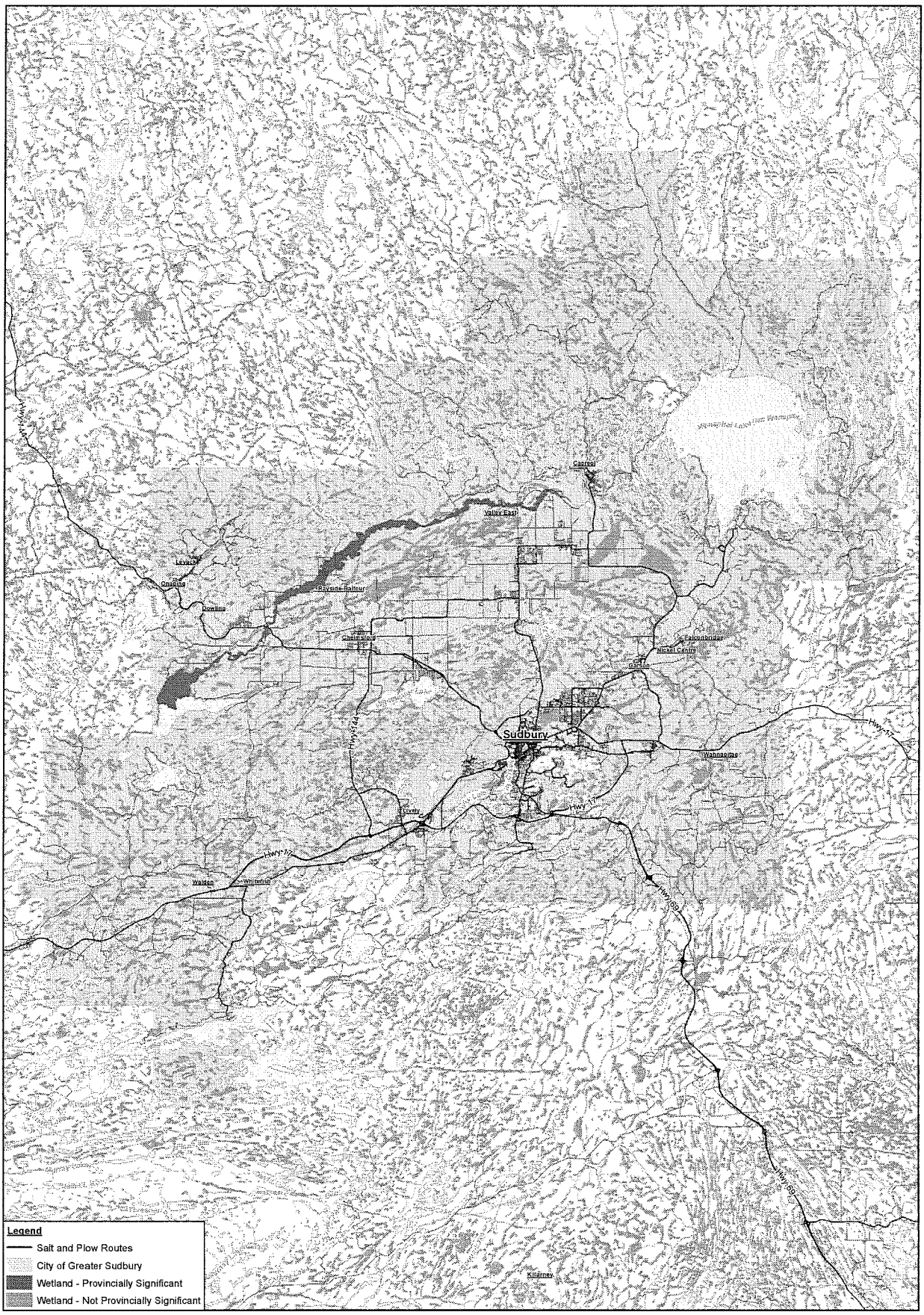
CITY OF GREATER SUDBURY
SALT OPTIMIZATION PLAN

LAKE TROUT LAKES AND
FISH SPAWNING AREAS

39382-41
Oct 17, 2017

FIGURE 8

GIS File: Q:\GIS\PROJECTS\39000s\39382\Layouts\007\39382-41(007)GIS-WA006.mxd



Source: MNRF NRVIS, 2017. Produced by GHD under licence from Ontario Ministry of Natural Resources and Forestry. © Queen's Printer 2017. City of Greater Sudbury, 2017.

0 3 6 9
Kilometers

Coordinate System:
NAD 1983 UTM Zone 17N

CITY OF GREATER SUDBURY
SALT OPTIMIZATION PLAN

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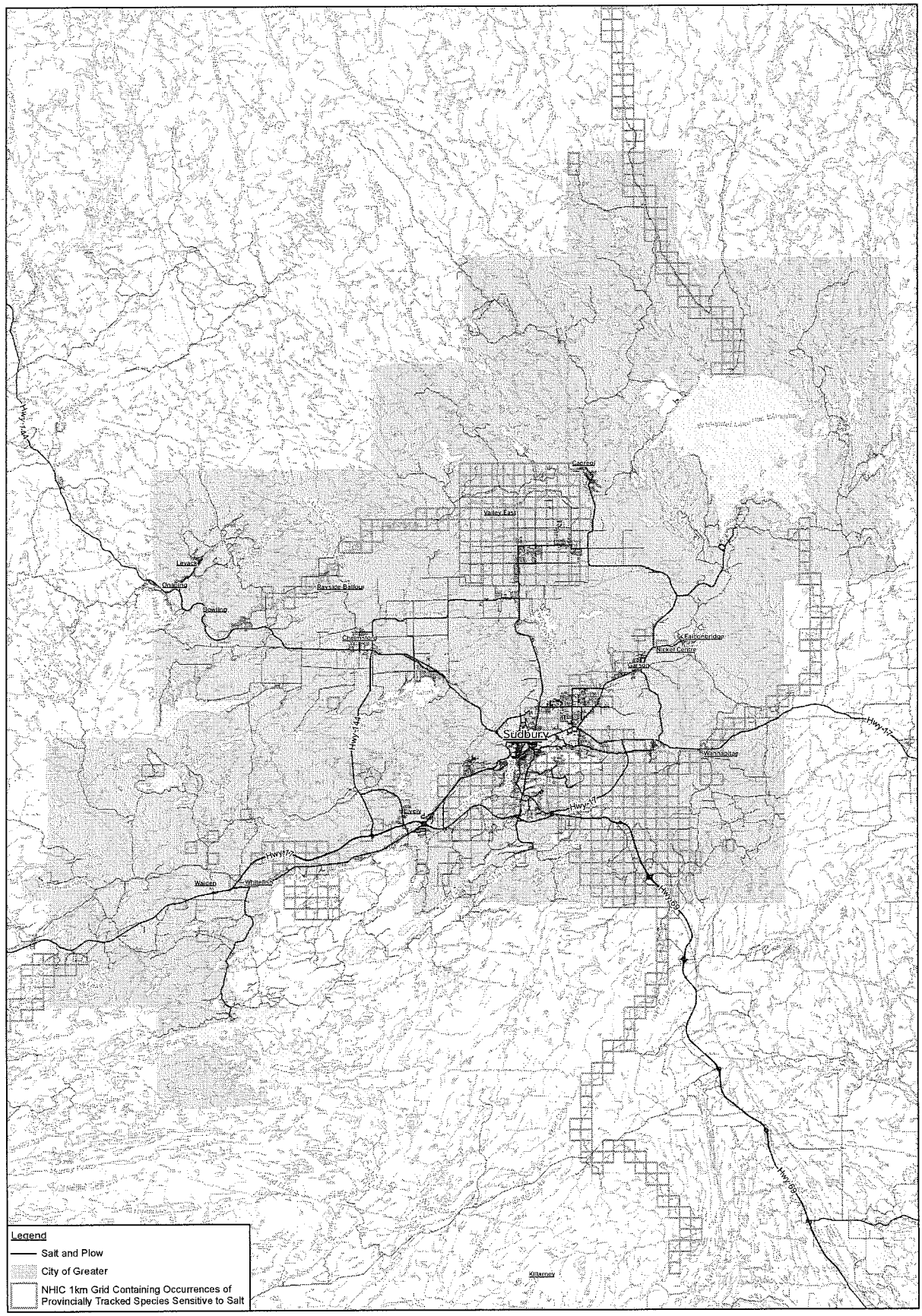
Oct 17, 2017

WETLANDS

FIGURE 9

GIS File: Q:\GIS\PROJECTS\39000s\39382\Layouts\007\39382-41(007)GIS-WA009.mxd



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0 3 6 9
Kilometers

Coordinate System:
NAD 1983 UTM Zone 17N

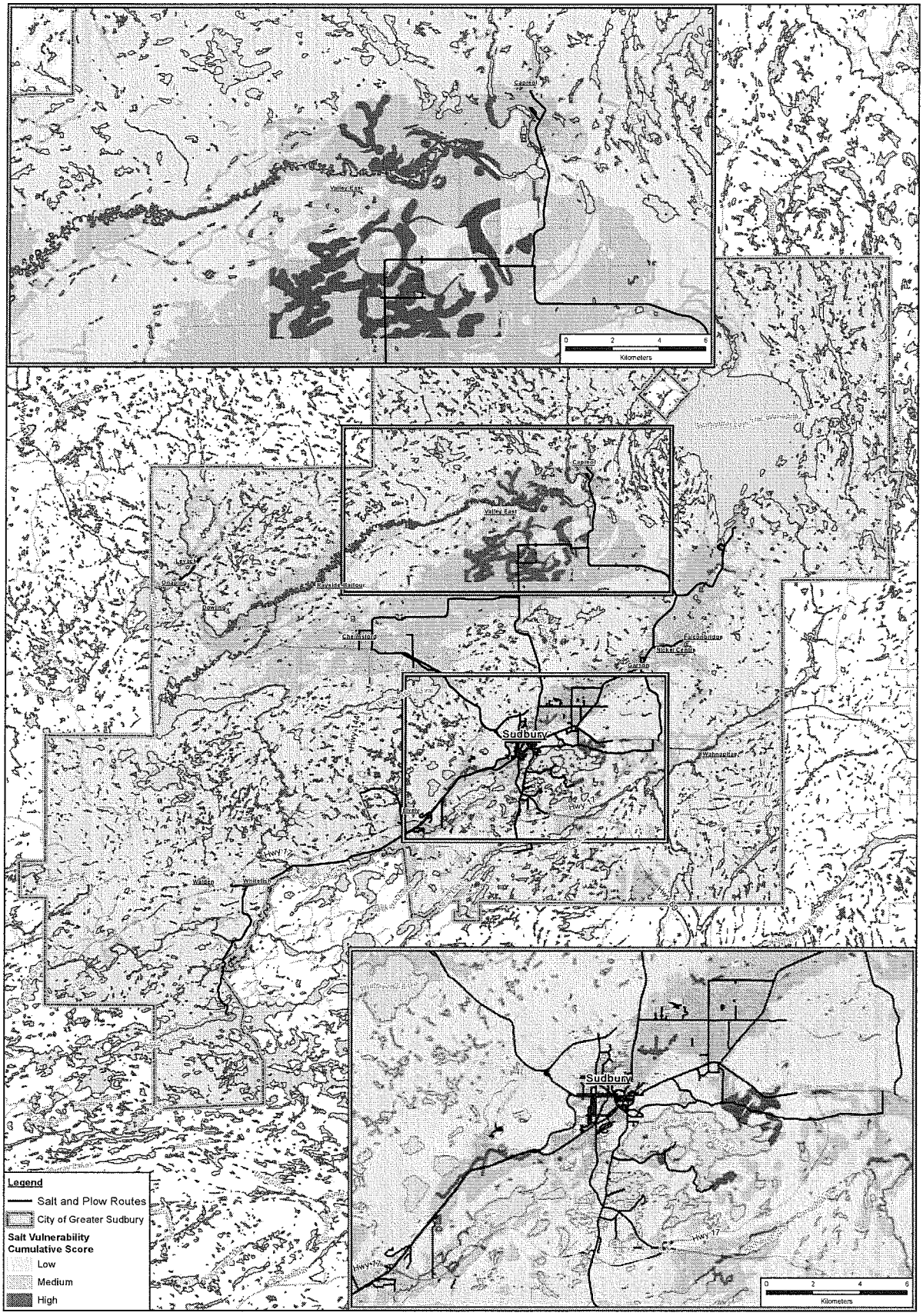
CITY OF GREATER SUDBURY
SALT OPTIMIZATION PLAN

39382-41
Oct 20, 2017

DISTRIBUTION OF PROVINCIALLY TRACKED SPECIES SENSITIVE TO SALT APPLICATION

FIGURE 10

GIS File: Q:\GIS\PROJECTS\39000s\39382\Layouts\007\39382-41(007)GIS-WA010.mxd



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0 3 6 9
Kilometers

Coordinate System:
NAD 1983 UTM Zone 17N

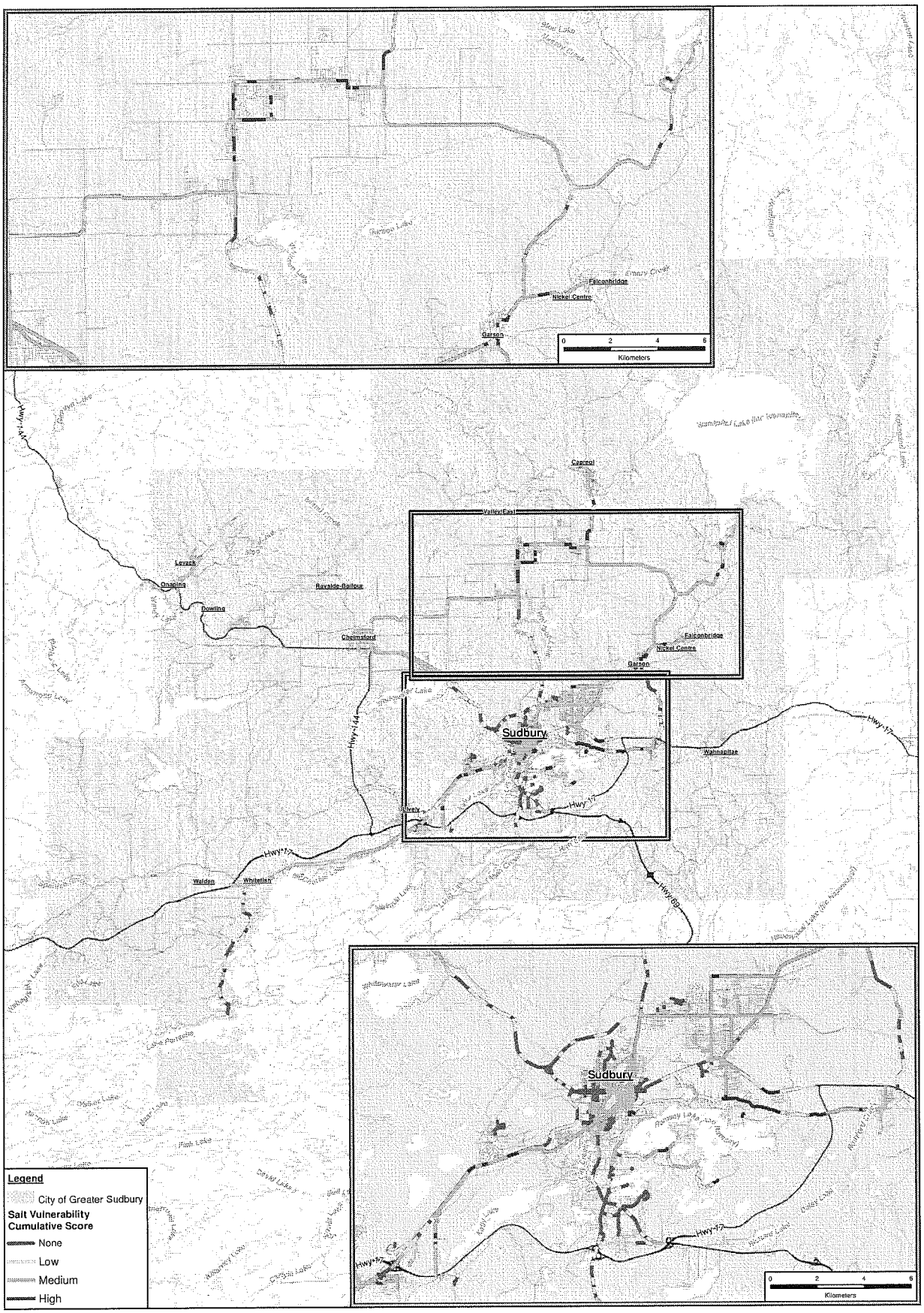
CITY OF GREATER SUDBURY
SALT OPTIMIZATION PLAN

39382-41
Nov 7, 2017

SALT VULNERABILITY INDEX

FIGURE 11a

GIS File: Q:\GIS\PROJECTS\39000s\39382\Layouts\007\39382-41(007)GIS-WA011.mxd



Source: MNRF NRVIS, 2017. Produced by GHD under licence from Ontario Ministry of Natural Resources and Forestry, © Queen's Printer 2017. City of Greater Sudbury, 2017.

CITY OF GREATER SUDBURY
SALT OPTIMIZATION PLAN

39382-41
Oct 31, 2017

SALT VULNERABILITY INDEX – ROAD NETWORK

FIGURE 11b

GIS File: O:\GIS\PROJECTS\39000s\39382\Layouts\007\39382-41(007)GIS-WA012.mxd

Tables

Table 1

Salt Optimization Plan - Recommendations
City of Greater Sudbury

	Recommendation	Timeframe	Recurrence	Priority	Responsible	Status
Baseline Understanding	Establish a salt vulnerability index based on existing surface and groundwater vulnerable areas including WHPAs, IPZs, SGRAs, HVAs and ESGRAs. Create a salt vulnerability index map with the results to better understand salt sensitive areas to help in better decision-making.	Short Term	Initial with updates when major developments are planned	High	Road Operations with assistance from NDCA/SWPC/GIS	Complete
	Review transportation infrastructure that receives winter maintenance services to better identify system users (i.e., vehicles, bicycles, e-bikes, pedestrians, etc.) and incorporate user data and winter maintenance considerations into the Transportation Master Plan (i.e., sidewalk priority index).	Short Term / Long Term	5 years	Medium	Road Operations and Traffic & Transportation	Future
	Update available traffic count data, and posted speed limits.	Short Term	Annually	High	Traffic	Ongoing
	Update Ontario Minimum Maintenance Standards road classification mapping.	Short Term	Annually	High	Traffic	Ongoing
Level of Service	Establish a level of service for municipal parking facilities that will be included within the Winter Maintenance Operations Plan.	Short Term	Annually	High	Building / Planning	Complete
	Annually review transportation infrastructure that receives winter maintenance services, specifically priority plow (and salt/sand) routes to identify opportunities for improvement. Proposed changes in service will consider all road segments' planning classification (arterial, collector, and local), OMMS class, gradient, zoning and proximity to points of interest (schools, vulnerable sector community, churches and community buildings). Environmental vulnerability of the surrounding area must also be considered.	Short Term	Annually	High	Road Operations	Ongoing
	Establish or look for areas to expand direct liquid application routes with the use of additives.	Long Term	Annually	High	Road Operations	Ongoing
Material Tracking & Monitoring	Create a City-wide map of all surface water sampling locations for chloride/sodium concentrations including historic data where available. Track any changes in chloride/sodium loadings into receiving waters during the spring freshet and use this as a KPI.	Long Term	Annually	Medium/Low	Water/Wastewater Division / GIS / Environmental	Ongoing data collection
	Create a City-wide map of all groundwater sampling locations for chloride/sodium concentrations including historic data where available.	Long Term	Annually	Medium/Low	Water/Wastewater Division / GIS / Environmental	Ongoing data collection
	Develop an institutional partnership with post-secondary institutions to perform ongoing analytics of data captured relating to transportation infrastructure winter maintenance services.	Long Term	As required	Low	Road Operations	Future Ongoing
	Track the volume of anti-icing/de-icing materials used by CGS Fleet.	Short Term	Annually	High	Road Operations	Ongoing data collection
	Develop a snow removal contract template for future Traffic & Transportation Services snow removal contractors.	Long Term	As required	High	Road Operations	Complete
	Update Global Positioning System (GPS) devices used by City plows, sanders and contractor vehicles to incorporate Salt Vulnerable Area maps and track salt application within these areas.	Short Term	As required	High	Road Operations	Future
Technology & Control Techniques	Establish a corporate policy to have all corporate vehicles, including transit vehicles, use snow tires during the winter maintenance season.	Long Term	As required	Low	Fleet	Future
	Obtain additional Road Weather Information System (RWIS) within the City of Sudbury to better understand and respond to weather events.	Long Term	As required	Medium	Road Operations	Complete
	Obtain anti-icing/de-icing material application equipment for City Fleet that is capable of being calibrated.	Long Term	As required	Medium	Road Operations / Fleet	Ongoing
	Calibrate all equipment used for winter maintenance services as per manufacturer recommendations.	Short Term	Annually	High	Fleet	Ongoing
	Obtain multi-purpose types of equipment that can be utilized to better perform winter maintenance services (e.g. sanders with plowing ability, rear- mounted spreader with GPS unit).	Long Term	As required	Medium	Road Operations / Fleet	Ongoing: Fleet Renewal
	Establish a corporate standard to have cameras installed at strategic street signal installation locations to obtain better insight into weather conditions and traffic flow	Long Term	As required	Low	Traffic and Transportation Services	Future
	Develop storm water management plans at maintenance yards and snow disposal facilities that would also help to capture and control salt laden runoff.	Long Term	As required	High	Road Operations	Future

Table 1

Salt Optimization Plan - Recommendations
City of Greater Sudbury

	Recommendation	Timeframe	Recurrence	Priority	Responsible	Status
Pilot Projects	Engage with post-secondary institutions that are currently performing research on winter maintenance practices. Contribute and participate in these research opportunities when able.	Short Term	As required	High / Medium	Communications and Community Engagement / Traffic and Transportation Services	Ongoing
Education & Outreach	Have the Source Water Protection Group present annually at the Snow School held for operators at the beginning of each winter maintenance season.	Short Term	Annually	High	NDCA/SWPC	Future
	Require Smart About Salt Training for all City contractor hires	Short Term	As required	Medium	Road Operations	Future
	Continue encouraging and offering learning opportunities for City staff involved in winter maintenance activities through professional development opportunities and knowledge sharing sessions.	Short Term	As required	High	All departments	Winter debriefs occurring annually
	Hold a promotional campaign to begin at the start of every winter maintenance season and continue throughout the season that will help educate the general public about salt application best management practices and the City's winter maintenance program. May include promotional materials in the local newspaper, informational pamphlets, ads through City run social media outlets, etc.	Short Term	Annually	Medium	Road Operations / Communications and Community Engagement	Future
Future Objectives	Review and assess permissible truck routes through the City for potential changes to optimize the winter maintenance strategy.	Long Term	Annually	High	Road Operations	Ongoing
	Have future updates to the Transportation Master Plan consider ways to optimize winter maintenance activities of proposed road network changes.	Short Term	As required	Medium	Road Operations	Future
	Employ plowing as the primary technique to reduce amount of material applied to the surface.	Short Term / Long Term	Annually	High / Medium	Road Operations	Ongoing
	Review material application rates to identify successes and areas for improvement.	Short Term	Annually	High	Road Operations	Ongoing
	Establish definitions of hills, curves, intersections as ranges (ex. steep hill, very steep hill) within the Winter Operations Plan. Include a clause that winter maintenance within these areas is to be based on operator judgement.	Short Term	Initially	Low	Road Operations / Engineering	Future
	Provide recommendations and guidance to Planning and Engineering Policy and Standards on how winter maintenance can be better considered in site designs.	Long Term	As required	High	Road Operations / Traffic & Transportation / Engineering / Planning	Ongoing
	The City of Greater Sudbury to continue as an active member of Ontario's Road Salt Management Group (ORSMG). The ORSMG has municipal and Environment Canada membership and investigates/pilots state-of-the-art salt management practices and explores new technologies to further enhance road salt management.	Short Term	Annually	Medium	Road Operations	Ongoing

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SODIUM CHLORIDE (NaCl)

Description

Sodium chloride (also known as rock salt) is a naturally occurring mineral.

Health and Environmental Effects

The use of sodium chloride for de-icing can have adverse effects on vegetation, soil and water quality under specific conditions.

Vegetation

Roadside vegetation injury by salt spray and salt laden runoff has been documented and where widespread damage occurs can be a significant problem.

Soil

Infiltration of salt-laden runoff can cause some soil types to be less fertile, less permeable, have higher alkalinity and be more prone to erosion [Gales 1992 pg.141].

Water And Aquatic Life

Chloride ions are highly mobile and can contaminate surface water and groundwater under certain conditions. High chloride concentrations can, under specific conditions, affect water density thereby inhibiting seasonal mixing of lake water. Salt ions may liberate mercury and other heavy metals from lake sediments, although this hypothesis needs further evaluation. The impacts of de-icing salt on aquatic life are not usually significant but very high salt levels can stress aquatic environments.

Human And Terrestrial Wildlife Health

Sodium chloride, in high enough concentrations, can impart an unpleasant taste and odor to drinking water. Elevated salt levels in drinking water can be of concern to those individuals of the sensitive sub-population on sodium-restricted diets for hypertension treatment. On the issue of the health benefits of salt intake reduction, scientific data are becoming increasingly consistent in suggesting at most a small benefit from salt reduction. In many cases reviewed by Taubes [1998], little or no blood pressure benefit (lowering) was achieved by lowering dietary sodium.

The major documented wildlife impact related to road salting is the attraction of larger wildlife (particularly moose) to roadside pools of salt-laden water. Reported cases of ingested salt poisoning of smaller wildlife species are limited in extent and related to a combination of exceptional conditions. Researchers have concluded that saline drinking water for farm animals from road de-icing is not a water quality concern [D'Itri 1992]. If high salt loadings in small roadside ponds result in changes in pond chemistry, stress on breeding amphibians is possible. This potential requires further research.

Compatibility with Automotive and Highway Materials

Road salt use has vehicle and infrastructure implications. Effects occur from corrosion (from salt and other environmental causes) and other damage to surfaces in contact with salt materials

(slush, spray, mist, saline water). Studies in Toronto show that 50% of corrosion occurring on auto body steel was due to salt use during the winter months [Fromm 1984]. De-icing salts also contribute to the corrosion of reinforcing steel in concrete bridge decks and substructures. Costs are incurred to repair damaged surfaces and to develop and install protective measures to reduce salt corrosion. Future maintenance and repair costs can be expected to decline as vehicles, bridges and other infrastructure are constructed with better corrosion resistant materials.

De-icing Performance

The practical working temperature of sodium chloride is down to -9.4°C and its eutectic temperature (the lowest temperature at which the de-icer can suppress the freezing point of water) is -21°C at a mixture of 23.3% rock salt in water. As sodium chloride goes into solution it requires 39 British Thermal Units [BTU] from its surroundings. Sodium chloride is generally considered ineffective below -17°C.

Storage, Handling and Spreading Characteristics

Salt is easy to store, handle and distribute.

Additional Information

A sodium chloride application rate of 113 to 142 kg per 2-lane km is usually sufficient [Jones 1986 pg.111]. Salt costs approximately $33.05 U.S./tonne [Moran 1992, pg.357] which would be $1.86 to $2.34 per lane kilometer.

Sodium chloride is the most popular de-icer as it is inexpensive and highly effective when applied under proper climatic conditions.

CALCIUM CHLORIDE ($CaCl_2$)

Description

Calcium chloride is synthetic liquid brine in its natural state, but it is also available in solid flake and pelletized form. Calcium chloride absorbs moisture from the atmosphere and gives off heat (290 BTU) when converted to liquid so it works in lower temperatures than NaCl.

Health and Environmental Effects

Some contradictory information regarding the environmental effects of calcium chloride was found in the literature. However, many sources report that calcium chloride can have a negative effect on the environment, similar to sodium chloride [Fromm 1984]. Excessive amounts of calcium chloride can produce an oily residue. When in solution calcium chloride has damaging effects on some (materials such as leather, rubber, metals, etc.).

Corrosion

Calcium chloride is more corrosive to metal than sodium chloride [Moran 1992, pg.346]. However, as calcium chloride is effective at lower temperatures it is less harmful to concrete.

De-icing Performance

Calcium chloride is a better de-icer than sodium chloride and it works at lower temperatures (-15°C or less). Its practical working temperature is -31.6°C and its eutectic temperature is -51.1°C at $CaCl_2$ concentration of 29.8% by weight [Kirchner 1998].

Storage, Handling and Spreading Characteristics

Calcium chloride is usually used as a pre-wetting agent, or mixed with sand to prevent freezing at low temperatures. It can also be used as an anti-icer. It is spread using the same technique and equipment as sodium chloride.

Additional Information

Calcium chloride is approximately $1811 per tonne [Moran 1992, pg. 357]. Suggested application rates for anti-icing range from are 28 to 55 kg of calcium chloride pellets per lane kilometer, and some estimates for de-icing range as high as 140 kg per lane kilometer [Kirchner 1998]. This would cost approximately $5 to $10 per lane kilometer for anti-icing or up to $25 per lane kilometer for de-icing.

POTASSIUM CHLORIDE (KCl)

Description

Potassium chloride is a common fertilizer and is often used as a low salt substitute in cooking. It is mined from sylvite deposits in New Mexico and Saskatchewan.

Health and Environmental Effects

Slightly less than sodium chloride. Corrosion similar to sodium chloride.

De-icing Performance

Potassium chloride is less active than NaCl and $CaCl_2$. It has a practical working temperature of -3.8°C and a eutectic temperature of -11.1°C at a concentration of 19.75% by weight in water. Potassium chloride requires 170 BTU's of heat (an endothermic reaction) as it goes into solution.

Storage, Handling and Spreading Characteristics

Potassium chloride is frequently packaged as an additive to other de-icers.

Additional Information

The cost is similar to NaCl.

MAGNESIUM CHORIDE ($MgCl_2$)

Description
Magnesium chloride is a hygroscopic chemical similar to calcium chloride. In its natural state it is a liquid but it is also sold as a solid flake de-icer.

Health and Environmental Effects
Similar to NaCl.

Corrosion
Similar to NaCl. Magnesium chloride is one of the only chemicals that can moderately deteriorate concrete but is listed as "slow to attack concrete" [Kirchner 1998].

De-icing Performance
Magnesium chloride has a practical working temperature of -15°C and its eutectic temperature is -33.6°C at a 21.6 weight percentage in water. Magnesium chloride has the ability to attract and retain moisture from its surroundings, but not as well as calcium chloride.

Storage, Handling and Spreading Characteristics
As a liquid magnesium chloride is used in the same way as calcium chloride to pre-wet road salt, sand and other de-icer mixes.

Additional Information
Magnesium chloride is only 48% active so it must be applied at twice the rate of $CaCl_2$.

CALCIUM MAGNESIUM ACETATE (CMA)

Description

CMA is calcium magnesium acetate, a synthetic powdered mixture of dolomite lime and acetic acid. It was first identified as an alternative to road salt by the U.S. Federal Highway Administration in the late 1970's. Since then extensive research and testing has been conducted on the corrosion impacts, environmental impacts and de-icing efficiency of the substance.

A granulated dry formulation of CMA is typically used for roadway de-icing. However, CMA can also be used in liquid form or combined with salt or sand. Liquid CMA can be formulated in the field from dry CMA and is generally used for anti-icing [Cryotech 1998].

Health and Environmental Effects

CMA is a biodegradable substance and has not been proven to have adverse effect on soils, water or vegetation.

Soils

CMA has no effects on soil compaction or strength and may increase the fertility and permeability of some soils. CMA may contribute nutrients (calcium and magnesium) while displacing iron, aluminum, zinc and copper. [Gales 1992, pg.173].

Water

CMA is biodegradable and exhibits poor mobility in soils, so it is not likely to reach groundwater. It is more hygroscopic than NaCl (greater tendency to absorb moisture) so it is less susceptible to leaching action. Concern has been raised over the potential of CMA to extract heavy metals in soils and cause trace metal contamination of ground water. However, McFarland [1992, pg. 202] found that CMA was not found to mobilize preexisting heavy metals from a variety of roadside soils compared to water or NaCl.

Vegetation

No detrimental effects on roadside plants have been recorded when CMA was tested at concentrations likely to be generated by highway de-icing [NRC 1991, pg. 129].

Aquatic And Terrestrial Wildlife

No deleterious effects on aquatic organisms have been recorded when tested at concentrations likely to be generated by highway de-icing. CMA may reduce dissolved oxygen levels as it decomposes, hence heavy CMA treatments near small poorly flushed or poorly diluted ponds and streams may require special monitoring and further study. CMA smells like vinegar, so unlike salt it is not attractive to animals. It has been used in Scandinavia in deer management areas as a means of preventing vehicle/animal accidents.

Human Health

Some workers have complained of chemical irritation from CMA unless they wear protective clothing [Hanneman 1992, pg. 433]. CMA powder has a tendency to create nuisance dust that may require the use of dust masks and well-ventilated storage and handling areas. However, new pelletized versions are less prone to dusting and blowing, and are better able to penetrate packed snow than the early powdery CMA products.

Corrosion

CMA is less corrosive to metals found in automotive steels, aluminum alloys, stainless steels, combined metals, bridges, roadways, parking garages and other steel and concrete systems than NaCl. The corrosion rates of steel tested in tap water were equal to or slightly higher than those of steel tested in CMA solutions [NRC 1991, pg. 131]. CMA does not contribute to spalling and scalling on new reinforced concrete and does not accelerate corrosion of older chloride contaminated concrete. However, there is insufficient evidence that CMA reduces the rate of corrosion of steel in concrete that is already contaminated with chlorides.

De-icing Performance

Although CMA is effective at the same temperatures as salt it has different performance characteristics. CMA does not melt ice and snow but turns it into an oatmeal texture. It performs best when accompanied by plowing or traffic activity, and when it is applied at the outset of a storm before significant snow and ice accumulation. When applied early CMA is able to mix with the falling snow and inhibit the ability of snow particles to adhere to each other or to the pavement (NRC 1991, pg. 122). CMA does not produce a running brine and so it does not move off the surface like other de-icers, nor can its performance be measured in the same way (penetration, undercutting etc.).

CMA ions are larger than those of NaCl so the rate of diffusion into a liquid film surrounding ice is slower. When applied after the onset of a storm CMA takes longer to start working than NaCl (about 20 min) and is less successful in penetrating heavy snowpack and ice [NRC 1991, pg.114].

Practical Working Temperature is -6°C, and the eutectic Temperature is -27°C at a concentration of 32.5% CMA by weight in water [Kirchner 1998].

Storage, Handling and Spreading Characteristics

When CMA was used in powdered form it was dusty, difficult to handle and there were some reports of CMA spray adhering to windshields and body parts and causing skin irritation [NRC 1991 pg. 120 and 133]. When exposed to moisture CMA frequently cakes and clogs. Some inconvenience has occurred with CMA clogging and sticking to spreading equipment. New pelletized versions have alleviated most of these earlier problems.

CMA needs to be kept dry during storage, preferably in enclosed, well-ventilated shelters. Since CMA is less dense than salt it requires 60% more space [NRC 1991, pg. 123]. Regular salt spreading equipment is used for CMA.

Additional Information

Typical application rates of CMA are 20 to 40 grams per square meter or 70 to 113 kg per lane kilometer [Cryotech 1998]. CMA is lighter than salt. The theoretical amount of CMA relative to salt needed for comparable ice melting is 1.7 to 1 by weight. However Michigan reported having to use about 2.6 times as much CMA as salt to attain dry pavement conditions [Gales 1992, pg. 171].

Cost is approximately $716 U.S. per tonne (based on $650.00 per imperial ton [NRC 1991, pg. 135] which would be $50 to $80 U.S. per lane kilometer. Acetic acid represents about 80% of the cost (of CMA. It is synthesized from natural gas or through fermentation of feedstock (corn, dairy or whey).

To date the prohibitive cost of CMA has limited its principal uses to address particularly sensitive environmental or corrosion situations.

POTASIUM ACETATE

Description

Potassium acetate is a liquid formulation that is generally considered a better ice melter than CMA. It has been used primarily as a runway de-icer but products are also designed for roadway use. Potassium acetate can also be used to coat rail and truck beds, non-porous roofs and road signs to prevent the adhering of snow and ice. Potassium acetate has also been used to keep rail switched open, free manhole covers and truck scales and keep conveyors ice free and as an antifreeze in toilet water [Cryotech 1998].

Potassium acetate can be used as a pre-wetting agent for CMA, road salt, and other solid de-icers and sand. It has also been used as an anti-ice to keep bridge decks from freezing and as a roadway de-icer.

Health and Environmental Effects

Potassium acetate is biodegradable, and decomposes to potassium and acetate which exerts a slight BOD (Biological Oxygen Demand) as it is metabolized to carbon and water. The BOD of Potassium acetate at 2°C is 0.30 gram O_2 per gram. Potassium acetate is toxic to fish at elevated concentrations (LC50 at 1500 mg/L) [Cryotech 1998].

Corrosion

Potassium acetate is generally considered non-corrosive, however it is not recommended:

- for use on low quality or non-air entrained concrete;
- to be in contact with galvanized metals; or
- to be mixed with liquid chloride de-icers like $CaCl_2$ and $MgCl_2$.

De-icing Performance

Potassium acetate has a freezing point of -60°C and a practical working temperature of -26°C [Cryotech 1998].

Storage, Handling and Spreading Characteristics

If potassium acetate is not stored in a clean sealed container it can begin to prematurely biodegrade and exhibit biological growth.

Additional Information

On thin ice liquid potassium acetate can be applied at 50 g/m^2. On thicker ice (2.5 cm) the manufacturer recommends an application rate of 150 g/m^2 [Cryotech 1998].

SODIUM ACETATE (NaAc)

Description

Anhydrous sodium acetate has recently been introduced as an alternative de-icer. Successful trials were conducted over the 1997-98 winter season at Vancouver International Airport. Sodium acetate is a solid spherical pellet. It has been designed for airport runway use but it may also be applied to roads, parking garages and walkways.

Health and Environmental Effects

Sodium acetate readily degrades at low temperatures and has a relatively low biological oxygen demand [Cryotech 1998]. Contact with skin or eyes may cause irritation and inhalation of dust may irritate the upper respiratory tract.

Corrosion

Sodium acetate is not corrosive to metals like chlorides but it is more corrosive than CMA.

De-icing Performance

Anhydrous grade sodium acetate is exothermic so it gives off heat as it dissolves.

Storage, Handling and Spreading Characteristics

Sodium acetate may be spread with existing solid de-icer spreading equipment. It requires flat bulk storage and requires care to avoid caking caused by excessive moisture. Excessive handling may cause dustiness and suitable ventilation is required. It can be pre-wetted with liquid potassium acetate.

Additional Information

Sodium acetate can be applied at about two thirds the rate of urea to achieve similar effectiveness [Cryotech 1998].

Sodium acetate was successfully used at the Vancouver International Airport in 1997/98 on roads, bridges and parking surfaces.

UREA CO $(NH_2)_2$

Description

Urea is a common fertilizer (46% nitrogen) that comes as solid small white pellets or in liquid form. It is synthesized from ammonia and carbon dioxide.

Health and Environmental Effects

Soil

Moran (92) claims no negative effects on soil quality and being a form of nitrogen it may Actually Improve Soil Quality.

Vegetation

Urea is reported as having no negative effects on vegetation [Moran 92]. However, as urea is a common fertilizer overuse will cause vegetation burn.

Water And Aquatic Life

Urea degrades by hydrolysis to ammonia and is subsequently converted to nitrate by nitrifying soil organisms. Ammonia and nitrate are of high environmental concern [Sills 92, pg. 328]. Nitrates stimulate the eutrophication process and can contaminate drinking water. Ammonia is acutely toxic to aquatic life.

Human Health

Biodegradation of urea may result in objectionable odours due to the release of aldehydes.

Corrosion

Urea is less corrosive than the chlorides. For this reason it is a popular runway de-icer. However urea has a detrimental effect upon concrete as it causes severe scaling at 2% wt. concentration [Kirchner 1998].

De-icing Performance

Urea is less active than NaCl and $CaCl_2$. The practical working temperature of urea is -3.8°C and its eutectic temperature is -11.6°C [Kirchner 1998]. Urea requires heat to be effective (an endothermic reaction of 106 BTU).

Additional Information

Urea costs approximately $200/imp ton [Gales 1992]. It must be used in quantities twice as great as NaCl to be as effective (which would be approximately 113 to 142 kg per lane km). Urea costs approximately $22.60 to $28.40 per lane kilometer.

GLYCOLS

Description

Glycols are dihydroxy alcohols similar to the material used in anti-freeze. It is typically found as ethylene glycol or propylene glycol. It is commonly mixed with urea for use as a runway de-icer but it is not commonly used on roadways.

Health and Environmental Effects

Glycols are highly biodegradable under normal conditions and therefore do not persist in the environment.

Human And Terrestrial Wildlife Health

When ingested by humans and animals toxicity can be significant (has an attractive sweet taste). Propylene glycol is less poisonous than ethylene glycol but is a more potent skin irritant and sensitizer. Glycols do not bioaccumulate in organisms. Technical grade ethylene glycol contains the known carcinogen 1,4-dioxane. Biodegradation may result in objectionable odours due to the release of aldehydes.

Water And Aquatic Life

The acute and chronic aquatic toxicity of ethylene and propylene glycol is relatively low [Sills 1992 pg. 326]. Glycols biodegrade rapidly and exert extremely high BOD even in cold temperatures. This can deplete dissolved oxygen in water and negatively affect aquatic life. BOD of diluted ethylene glycol is 5000 mg/l (compared with domestic raw sewage which has a BOD of 200 mg/l) [Sills 1992, pg. 328].

Corrosion

Glycols are non-corrosive liquids.

De-icing Performance

Glycols are effective but short-lived de-icers.

Storage, Handling and Spreading Characteristics

Glycols are liquids and therefore require tanks and spray equipment for application.

Additional Information

Glycol is used in airport runway de-icing at a rate of 4.88 kg/100m^2.

Glycols are more effective when applied as an anti-icer in which case less can be used. Glycol is more expensive than salt.

METHANOL (CH_3OH)

Description
Methanol (or methyl alcohol) is sometimes used as an antifreeze. In its natural state it is a liquid and is commonly used as an important fuel source.

Health and Environmental Effects
Methanol is highly volatile, flammable and toxic [Bryan 1992 pg. 464]. It is lethal to humans and animals if ingested. The break down products of methanol contribute to ozone pollution in the lower atmosphere [Gales 1992 pg. 167]. Methanol is highly volatile so it evaporates before it can deplete oxygen from aquatic environments. However, methanol vapors are toxic and due to its high volatility ambient air quality can easily be degraded.

Corrosion
There is evidence of deleterious effects of methanol on asphalt concrete [Bryan 1992 pg. 464].

De-icing Performance
The eutectic point of methanol is -125°C at 83% concentration by weight in water. This makes methanol particularly effective at low temperatures. Methanol also works much more rapidly than salt.

Storage, Handling and Spreading Characteristics
Methanol's volatility, flammability and toxicity make it very difficult to handle.

Additional Information
Methanol is short lived (it evaporates quickly) and requires re-application within a few hours. It is approximately 5.5 times the cost of salt [Gales 1992, pg. 167].

SODIUM FORMATE (HCOONa)

Description

Sodium formate is produced as a by-product or waste product of other chemical processes. It is a solid de-icer. Very little information is available and much of the available information is contradictory.

Health and Environmental Effects

Both sodium formate and sodium chloride have similar environmental effects relating to sodium (can damage soil structure, and contributes to roadway vegetation burn). Sodium formate has a lower oxygen demand compared to other de-icing compounds.

Compatibility with Automotive and Highway Materials

Sodium formate does not contain chloride and so it is non-corrosive to steel. Some reports indicate that sodium formate has a neutral pH while others indicate a pH of 10 to 12 [Gales 1992, Old World 1998]. Sodium formate causes no more damage to concrete than salt.

De-icing Performance

Sodium formate is similar to salt in terms of de-icing speed, temperature range and endurance of de-icing effect [Gales 1992 pg. 167]. It has a eutectic point of -18°C.

Storage, Handling and Spreading Characteristics

Sodium formate can be applied with conventional equipment.

Additional Information

Sodium formate costs 13 times more than salt [Gales 1992, pg. 167].

ORGANIC COMPOUNDS (SUGAR BY-PRODUCTS)

Description

Sugar byproducts have been developed that may reduce the environmental issues connected with salts and may have longer residual effects when spread on roadways.

The organic compounds used for de-icing are typically byproducts of agricultural operations such as refining sugar beets or corn, or the ethanol distillation process. One of the most common is beet juice (left-over from the process of extracting sugar from sugar beets). Sugar byproducts are not de-icing material. While there is no consensus regarding to what degree beet juice and other sugar by-products depress freezing temperatures, sugar by-products alone are very poor ice melters. Instead, they are treated in alkali to increase the ionic strength of the liquid, which when mixed with brine lowers the freezing point of the de-icing solution. However, Fay [2007] found that, based on preliminary data, there was no significant difference in the ice-melting capacity of the tested chloride-based deicers, and the sugar by-product.

Most commonly, sugar byproducts are blended with brines of magnesium chloride, sodium chloride, calcium chloride and potassium chloride and the mixture is applied to dry roads as an anti-icing agent, or as pre-wetting agent.

Health and Environmental Effects

No long-term research yet exists, but Sugar by-products / brine liquid products are generally believed to be less harmful to infrastructure and the environment. Some commercially available products are recognized by the U.S. Environmental Protection Agency as being safe for human health and the environment. However, aesthetics may be a drawback. For example, beet juice can potentially stain carpets and exteriors.

Corrosion

While sugar by-products / brine liquid sugar by products have the potential to reduce corrosivity of deicers to metal, preliminary research by Fay [2007] indicated chloride-based deicers and the sugar byproduct-based deicer were similarly very corrosive to mild steel.

De-icing Performance

Sugar byproducts are not de-icing material. As such, the performance will depend on the brine with which the sugar byproducts are blended. Johnson [2005] reports that a commercially available sugar by-product / $MgCl_2$ brine liquid has the freezing point of -65° C.

Additional Information

Prices for the types of organic compounds described here are typically more than ordinary rock salt, although generally less is required. However, pilot programs (e.g., City of Montreal, Niagara Region and City of Barrie) are underway at the time of writing to determine if mixtures can reduce the number of applications by sticking longer to roadways, which it could offset its higher price point by reducing labor costs.

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