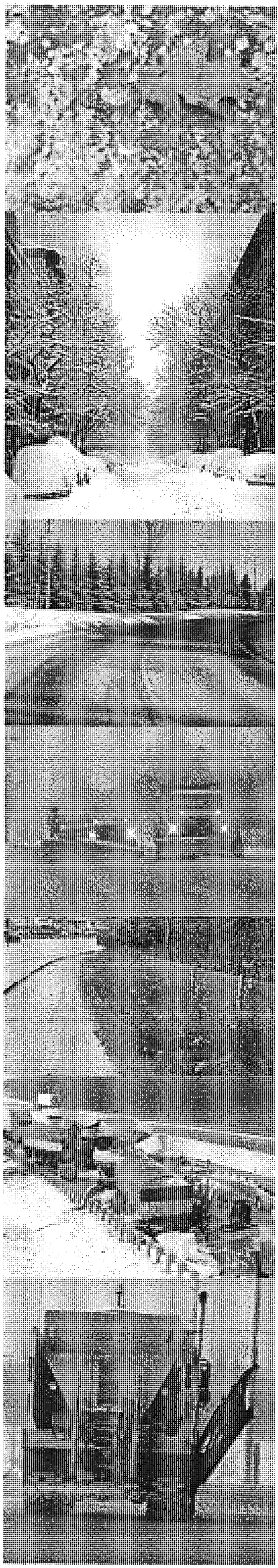
EXHIBIT 21



Assessing the Efficacy of Current Road Salt Management Programs

University of Waterloo

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July 26, 2010

Acknowledgments

Funding for this research was provided by the Ontario Ministry of the Environment and the Salt Institute. The research team wishes to acknowledge the important contribution to the study from the following groups and individuals: Regional Municipality of Waterloo Winter Maintenance Policy and Procedures Working Group (WMPPWG); Philip Hewitson (Director, Transportation Division, Public Works Services, City of Waterloo); Jim Robinson (Senior Hydrogeologist, Regional Municipality of Waterloo); Phil Deschene (Director of Public Works, City of Cambridge); Alex Piggott (Manager of Operations Support, City of Cambridge); Scott Berry (Manager of Operational Support CSD – Operations, City of Kitchener); Dave Lukezich (Winter Maintenance Specialist, Regional Municipality of Waterloo); Joe Tiernay, Executive Director, Ontario Good Roads Association (OGRA), Frank Hull (OGRA); Bob Hodgins; Aaron Todd, Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment; Mort Satin and Dick Hanneman (Salt Institute); Paul Johnson – Chair Ontario Road Salt Management Group; Phil James and Kyle Vander Linden Credit Valley Conservation Authority, Jeff Melchin, Quintin Rochfort, Shobanna Sivavaraman, Jamie Di Simone, Leanne Lobe.

The Pervious Concrete Pavement Study would not have been possible without support from the Cement Association of Canada (Rico Fung, Wayne Dawson), Ready Mixed Concrete Association (Sherry Sutherland Bart Kanters), Dufferin Concrete (Derek Lapierre, Ross Bain, Gord Cawker, Kelly Nix), University of Waterloo (Terry Ridgeway), the Centre for Pavement and Transportation Technology at the University of Waterloo (Vimy Henderson, Tracy Zhou, Rabiah Rizvi, Sam van Berkel, Cole Lamb, Renee Fung, Antonin du Tertre, Peter Chan, Riyad Ul-Islam, Mohab El-Hakim, Jodi Norris, Jennifer Yang and Shila Khanal).

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Executive Summary

An 18 month study was conducted by a University of Waterloo research team to assess whether adoption of the Code of Practice has effectively reduced chloride inputs to the environment in response to best management practices related to salt application and snow disposal. The study is intended to 1) provide data to support the Environment Canada 2010 review of the Code of Practice 2) evaluate the degree of implementation and effectiveness of selected best management practices to mitigate chloride transfer to the environment 3) identify barriers to implementation and 4) make recommendations to improve winter maintenance practices of roadways and parking lots. The report is divided into sections corresponding to research that was designed and conducted (surveys as well as field and laboratory studies) to evaluate the effectiveness of the Transportation Association of Canada's (TAC) *Syntheses of Best Management Practices (SOBPs)* to reduce chloride transfer to the environment. The *SOBPs* evaluated in this study include TAC 1 *Salt Plans*; TAC 2 *Training*; TAC 4 *Drainage and Stormwater*; TAC 5 *Pavements and Salt Management*; TAC 7 *Design of Road Maintenance Yards*; TAC 8 *Snow Storage and Disposal* and TAC 9 *Winter Maintenance Technologies.* The results and conclusions of each study component are summarized below in relation to specific TAC SOPBs evaluated.

ROAD SALT MANAGEMENT SURVEY (TAC 1, 2, 9)

To determine the degree to which voluntary road salt management plans programs have been implemented in Ontario, information was gathered through meetings with salt management working groups (RMOW Winter Maintenance Policy and Procedures Working Group, Ontario Road Salt Management Working Group, Toronto Conservation Authority, Credit Valley Conservation Authority and Regional Municipality of Waterloo), by convening a Salt Management workshop (May, 2008) and an International Conference on Road Salt Management (May 2009) at the University of Waterloo and by conducting a survey of Ontario Road Management Authorities.

An online tool (SurveyMonkey) was used to administer a survey that was sent to 432 public works officials in Ontario that included 40 cities, 6 Regional Municipalities, 25 Counties, 85 Towns, 1 District and over 260 Townships/Villages and Municipalities. Seventy out of 432 public works officials responded to the survey resulting in a response rate of 16.3%. The survey respondents included Regional Municipalities (20%), Cities (19%), Counties (13%), Townships (19%) and Towns (29%). Results of the survey are presented below.

Survey Results. The survey indicates that the Code has been adopted by a relatively high number of Ontario Municipalities (89% of the larger municipalities have Salt Management Plans). While the release of the Code in 2004 accelerated the rate of production of Salt management Plans, a number of municipalities required several years in preparing their plans. In some cases (43%), salt management plans are not reviewed as encouraged by the Code. Salt Management Plans cover principles of safety, environmental protection and accountability well but most have inadequate provision for continual improvement, measuring progress and communications. Many authorities have not updated their plans since initially prepared but some respondents intend to review plans in the near future. An increasing effort is required to encourage review and ongoing improvement of operations. Communication of the Salt management Plans and training to contractors and seasonal staff could be improved in many municipalities. The level of salt management training has been improved considerably through the efforts of the Ontario Good Roads Association and the Ontario Road Salt Management Group. According to the survey, 63% of the respondents have annual training programs. The learning goals set out in TAC's SOBP-Training are generally covered but some key areas – the more complicated learning goals – are not adequately covered. The Code has been effective in promoting the development of training packages but implementation is should be improved. Record-keeping has improved since the publication of the Code and the requirement for Annual Reporting. However some records that are necessary to measure effective monitoring and continuous improvement are lacking.

Since the release of the Code, mapping of salt vulnerable areas has increased with 51% of respondents indicating they have identified salt vulnerable areas and developed policies in proximity to these areas. Improved guidance in this area is strongly recommended. The Synthesis of Best Management Practices for maintenance yards has improved yard planning and design, upgrading and good housekeeping practices. Since the code was developed, the greatest improvement has been in the areas of salt storage and handling but the least improved areas are management of salt impacted water and environmental monitoring. There is a lack of awareness of this SOBP and more promotion is warranted. Approximately 61% of municipalities have snow disposal sites but most of these sites are not designed in accordance with the Code or the SOBP.

The authorities' responded positively about the benefits of the Code of Practice as a measure to advance salt management and environmental protection in Ontario. The key benefits of the Code are: 1) Increased awareness of the importance of salt management to protect the environment and of best management practices that are available 2) Provided validation for best practices and the need to improve winter control operations 3) Set a framework for salt management plans and benchmarks for salt management that lead to greater standardization 4) Accelerated the rate of introduction of best management practices and the adoption of new technologies 5) Reduced salt use and associated environmental impact 6) Reduced costs through salt reduction 7) Improved monitoring and recordkeeping.

The respondents identified several concerns and challenges regarding the Code that are primarily related to implementation challenges. Code-specific concerns were 1) There is a need to provide more detail, advice and direction regarding how to comply with the Code requirements 2) Municipalities require a simple and cost-effective way to map salt vulnerable areas and guidance on developing management practices for these areas. Implementation challenges include 1) Still difficult to change old practices and get Council and senior management commitment to change 2) The lack of resources, particularly money, is one of the main barriers to implementing the Code 3) Meeting public expectations and the challenge of changing levels of service is a challenge 4) Getting staff properly trained and getting best practice implemented in a consistent way continues to be a challenge 5) Coping with changing winters is a challenge. Other challenges include a lack of understanding or acceptance of the need for salt management and the environmental impacts of this practice. Changes in personnel at the staff, management and political levels since the Code was published underscore the importance of continual re-education.

DRAINAGE AND STORMWATER (TAC 4)

Three monitoring studies were conducted to evaluate the effectiveness of BMPs to manage chloride loss from drainage and stormwater. They include studies 1) to assess chloride in the shallow vadose zone and groundwater in response to reduced road salt applications in salt vulnerable areas 2) to measure the chloride concentration and loading in roadside snow pack of salt vulnerable areas and 3) to quantify chloride transfer in two Waterloo stormwater ponds.

Chloride in the shallow vadose zone and groundwater in response to reduced road salt applications in salt vulnerable areas. In response to progressively elevated concentrations of chloride (Cl^-) in some municipal well fields within the Regional Municipality of Waterloo (RMOW), several Best Management Practices (BMPs) were initiated in 2003-2004 in the vicinity of the impacted well fields in an attempt to reduce road salt leaching the water table which included a reduction in total road salt application of 25% in urban road network. The influence of salt reduction on groundwater quality in the Greenbrook Well Field, Kitchener was assessed by conducting a series of field monitoring activities designed to compare the quantity and mobility of chloride in the vadose zone for pre (2003) and post-BMP conditions (2009).

The groundwater monitoring data show that post-BMP chloride levels in the vadose zone at most of the field locations were ~50% lower than for pre-BMP conditions. However, chloride concentrations in groundwater remained fairly constant or increased slightly at two locations where specific safety concerns (sidewalks adjacent to public schools) resulted in the application of elevated levels of sidewalk deicing salts. The data indicate that substantial improvement in shallow groundwater quality (specifically Cl^- concentrations), resulted from the implementation of road salt BMPs. A detailed comparison of the soil core data collected from the unsaturated zone as measured in 2001 and 2008 indicates a significant reduction in average soil Cl^- concentration occurred following the implementation of the BMP activities. When these data are combined with estimates of groundwater recharge rates at each of the field monitoring stations, an average reduction of 60% in road salt mass loading to the water table was observed between the initial study (2003) and the 2008 study. The data support the overall conclusion that significant reductions in road salt loads to the subsurface resulted from the implementation of the BMP strategies in 2003. The study shows that a considerably lower percentage of the total applied road salt mass is entering the subsurface under the new salt management practices as compared to historical practices. The trends observed in the groundwater Cl^- data collected from the monitoring network correlates well with the observations made from a detailed assessment of chloride occurrence and distribution in the unsaturated zone. Accordingly, monitoring of changes in groundwater quality in shallow monitoring wells provide useful quantitative assessment of the performance of different BMPs in the urban environment. The actual time lag associated with the implementation of the BMPs and an observable influence at the water table, however, will depend on the thickness of the unsaturated zone and the vertical soil water velocity. The groundwater quality data clearly illustrate that the reduction in Cl^- concentration at the water table is a transient process that will take years to be fully realized.

Distribution and mass loading of chloride in snowpack of salt vulnerable zones. A field monitoring program was designed to quantify the spatial distribution and mass loading of chloride in roadside snowpack of salt vulnerable areas. The factorial design included measuring chloride concentrations and mass loading (kg m^{-2})in 3 well field capture zones (2, 5 and 10 year travel times) for 3 road classes (2, 3 and 4) within each capture zone, for 3 cities (Waterloo, Kitchener, and Cambridge). The data show that average chloride concentrations declined with distance from the road way. Variability in the data is related to several factors that influence both the redistribution of snow in urban environments and salt demand. Chloride concentrations in snow varied considerably as a function of road class, well field and sensitivity area (capture zone travel time).

Chloride transfer in two Waterloo stormwater ponds. A field study was conducted to examine the effect of landuse and road density/type on chloride concentrations in Laurel Creek and to evaluate the role of stormwater management ponds as a chloride source to receiving waters. Ten sampling stations in Laurel Creek (from its headwaters to the central part of Waterloo) as well as both the inflow and outflow of two stormwater management (SWM) ponds (conventional design– Pond 45 and hybrid extended detention design – Pond 33) were monitored in Waterloo, Ontario during the fall 2008 and winter/spring 2009. Chloride concentrations in Laurel Creek as well as the inflow and outflow of two stormwater ponds often exceeded the CCME chronic toxicity level (250 mg L^{-1}) and occasionally exceeded the CCME acute toxicity level (750 mg L^{-1}). Mean monthly chloride concentrations increased throughout the winter and spring at most sites but were typically lower in the less urbanized headwater sites than in areas with increasing impervious cover and road density/traffic volume. Mean monthly chloride levels at two monitoring sites (Keats and 5B) were often 10 to 20 times higher than background levels in Beaver Creek (site 17). The study found that inflow concentrations of chloride were similar for the two stormwater ponds of varying design but their outflow concentrations varied considerably over the study period. In the hybrid design (Pond 33), mean monthly outflow chloride levels peaked in December (~700 mg L^{-1}) but remained at $<$ 100 mg L^{-1} for the remainder of the winter. In contrast, chloride levels in the conventional design (Pond 45) were more variable and average monthly chloride concentrations increased steadily at the outflow from ~50 mg L^{-1} in October-08 to ~400 mg L^{-1} in April-09. The study suggests that the hybrid design pond (which consists of two settling ponds separated by a berm and a final vegetated area) was more effective at reducing chloride discharge at the outflow.

PAVEMENT AND SALT MANAGEMENT (TAC 5)

Performance of Pervious Concrete Pavement in an Accelerated Freeze-Thaw Climate: Transport and retention of water and salt within pervious concrete subjected to freezing and typical winter sanding. Pervious concrete has been shown to reduce stormwater volume and the concentration of many contaminants (with the exception of chloride) in urban runoff. In freeze/thaw environments, where the application of road salt is necessary, it is necessary to understand the impact of pervious concrete structures on the movement of water and hence, the transport of the Cl^- within the water. To accomplish this, a study was conducted to characterize the hydrologic performance of pervious concrete under frozen and thawed conditions, with varying additions of sand using both brine (23% salt solution) and fresh water. The overall impact of sand application to the surface of pervious concrete is a reduction in the speed of the movement of water through the pores, causing a delay in the peak flow received at the base of the concrete. In all experiments, the salt was transported through the pervious concrete very quickly. Salt underwent some dispersion with the application of sand and under frozen conditions, due to the more tortuous flow paths. Contrasting this is the impact of freezing water within the pores of the concrete. Although the overall impact of frozen water is similar to sand (i.e. slows water movement), the water is able to have this effect throughout the entire depth of the concrete, as water is able to freeze within the pores near to the base as well as at the surface of the concrete. This would also have consequences on the timing of salt transport, as it is a dissolved constituent within the water, and would also remain in the matrix of the concrete. However, these represent extreme conditions. Our observations indicate that the infiltration capacity of the pervious concrete structures, as tested, exceeds the probable maximum water loading rate that will be encountered in Southern Ontario, with or without sand; frozen or unfrozen.

The focus of the Ontario Clean Water Act is to reduce significant risks to drinking water by identifying vulnerable areas (wellhead protection areas, intake protection areas and other highly vulnerable areas) and developing plans to reduce significant risks to acceptable levels and prevent future significant risks. Chloride is listed as a potential threat to drinking water as indicated in Section 1.1 of Ontario Regulation 287/07. Implications of the Ontario Clean Water Act for road salt management include 1) Improved design and delivery of parking lot winter maintenance programs 2) Increased adoption of new technology 3) Improved delineation of salt vulnerable areas and refined winter maintenance procedures in intake protection zones (IPZs) 4) Increased level of training (certification) for road authorities and private contractors 5) Integration of salt management plans with source water protection committees (SPCs) objectives to delineate source waters, identify threats and develop and implement SWP Plan and 6) Improved stormwater management practices. While pervious pavement technologies can effectively reduce runoff, they can negatively impact groundwater quality when improperly located and poorly designed. To meet the future requirements of the Clean Water Act, better design guidance is required for the use of this material for parking lots located in salt vulnerable areas.

Clarkson Go Station Study. A study was conducted to measure and compare the chloride flux in runoff from two parking lots treated with different de-icing compounds (common road salt and a commercially available alternative de-icing material Mountain Organic Natural Icemelter) during the period October 2008 to April 2009. The data show that chloride losses from a parking lot treated with Mountain Organic Natural Icemelter were demonstrably higher than for a parking lot treated with road salt. More systematic study of the effectiveness (road safety) and associated environmental impacts of road salt and a range of alternative deicers are required to provide contractors with appropriate guidelines for optimal application rates and related spreading technology. Such information coupled with enhanced training, improved technology for salt application, better record keeping and reporting protocols would lead to significant reductions in the discharge of chloride from parking lots to the environment.

Parking Lot Management - Smart About Salt Program. In 2004, the Region of Waterloo developed and launched the *Smart About Salt (SAS)* Program. This locally initiated program incorporates a multi-faceted approach designed to reduce the application of salt on parking lots and sidewalks of both public and private properties by 1) working collaboratively with transportation operations staff from the municipally 2) developing guidelines and site plan design recommendations to minimize the need for de-icing on new developments 3) building public awareness through education programs and 4) implementing the *Smart About Salt* accreditation program for private snow contractors and clients to recognize and incorporate beneficial salt management practices on parking lots and sidewalks.

Given the increasing need to develop programs that further reduce the transmission of chloride to the environment, the *Smart About Salt* program is an example of a management model that can be effectively developed and administered by stakeholders to reduce the use of deicing chemicals by private contractors while achieving safe levels of service on parking lots and sidewalks. The program is based on developing partnerships and educational programs that promotes environmental leadership. If this or similar programs were widely implemented, it would likely promote optimal salt application and reduce winter maintenance costs while at the same time minimizing chloride discharge to the environment. There is some evidence to suggest that certification of contractors and improved record keeping practices may reduce liability and insurance costs.

There is a critical need to train and certify private contractors and to develop appropriate winter maintenance guidelines and practices for parking lots. The excessive addition of deicers to parking lots is in part related to the poor design of parking lots and related stormwater design of buildings. There is a real need to improve parking lot and building design standards to minimize the risk of water freezing on pavement which then necessitates additional applications of deicer.

SNOW STORAGE AND DISPOSAL (TAC 8)

Snow Storage Disposal Facilities (SSDFs) and Their Role in Urban Snow and Road Salt Management: Guidance for Design, Operation, and Maintenance. When snow is transported from urban areas to snow storage disposal facilities (SSDFs), it contains a range of particulate and dissolved constituents that can potentially be released into the environment during snowmelt. Snow removal, transport, storage and snowmelt and potential impacts of these processes on the environment are of concern in both urban and natural environments with transportation corridors. A review of recent literature on SSDFs is presented which describes current knowledge regarding 1) the basic characteristics of operation of SSDFs, 2) how such knowledge is used for developing guidance for planning, design and operation of SSDFs and 3) what is the potential role of SSDFs in the context of road salt management. Such information is necessary to improve guidance documents for the design of snow storage and disposal sites.

PCB 2016-029, Exhibit 21

Due to the volume of the exhibit, only the Executive Summary, Table of Contents, etc. is viewable; you may contact the Clerk's Office at 312/814-3629 if you are interested in all or part of the balance of the exhibit