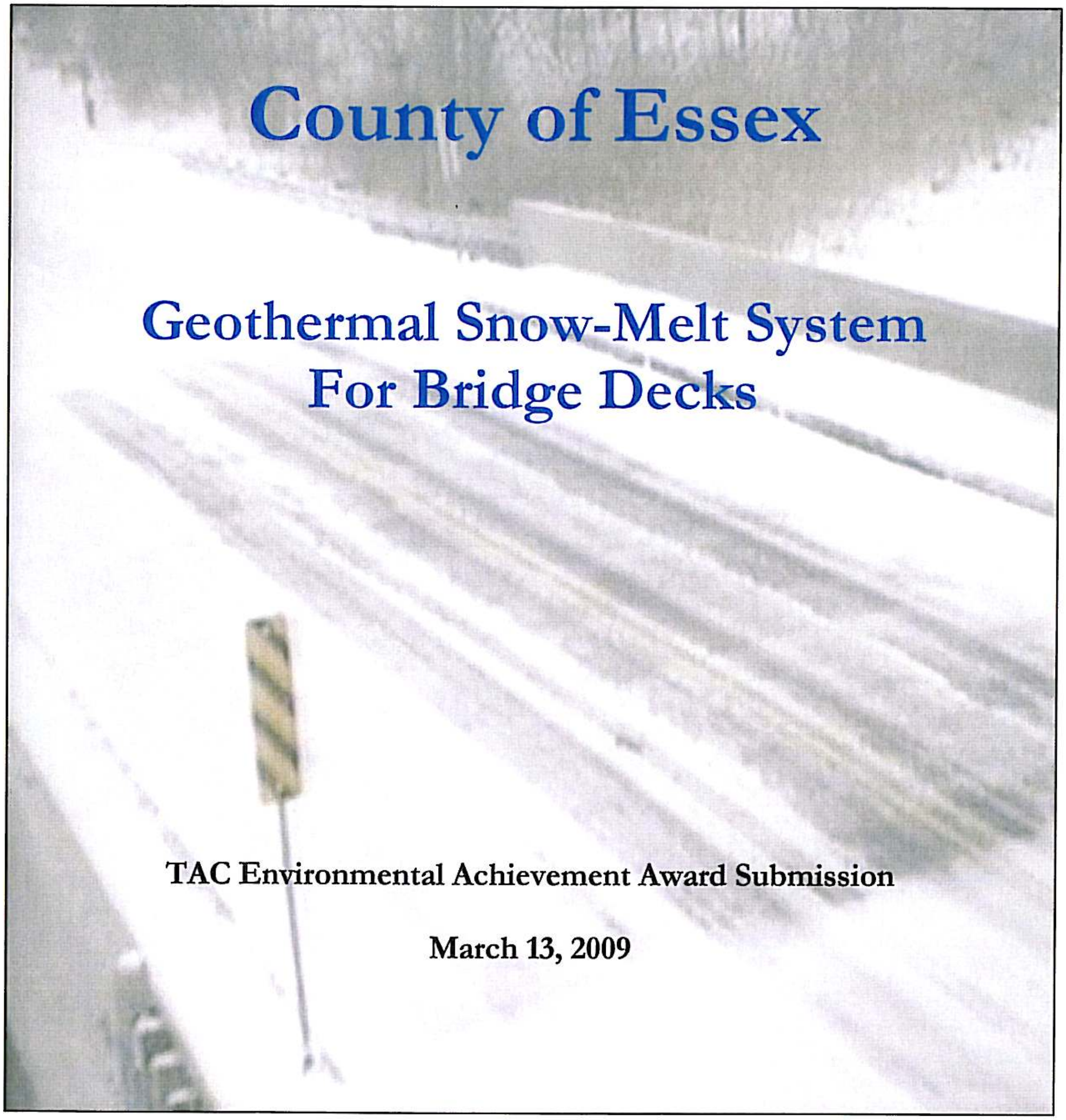

County of Essex

Geothermal Snow-Melt System For Bridge Decks

TAC Environmental Achievement Award Submission

March 13, 2009

I. Introduction

The County of Essex is responsible for the maintenance and construction of 87 bridges. Bridges and overpasses lose heat faster overnight than neighbouring roads because they are surrounded by air. Black ice forms in minutes when moisture in the air freezes into a thin, virtually invisible layer of ice on a bridge deck; this happens even though approach roads may be bare. As many freeze-thaw cycles are experienced in our area, Essex County highway bridges are prone to black ice and must be salted on a priority basis for the safety of motorists. However, the long-term effects of this established practice have become obvious. Our wetlands and farmlands are being damaged and our highway bridges require costly deck replacements. A geothermal snow melting or de-icing system is an environmentally-friendly alternative to the common mechanical and/or chemical winter maintenance and is available day and night without a costly stand-by emergency response. During heavy snow fall, the geothermal heating prevents the freezing of the surface even with low temperatures: mechanical clearing becomes very easy. Winter maintenance, snow melting and de-icing “from the bottom” using renewable and free geothermal heat is an obvious solution. The safety of pedestrians, as well as the security of the vehicle traffic may be increased with a reliable, sustainable and environmentally-friendly method.

The County of Essex is experiencing ‘first hand’ the effects of climate change. Out typical winter is transitioning to one in which we are seeing increased numbers of days where environmental conditions result in numerous freeze-thaw cycles which significantly impact the bridge decks. In addition, we are also recording record amounts of snowfall. The provision of the geothermal snow-melt system in the bridge deck affords the opportunity to control the amount of freeze thaw cycles this structure is allowed to experience.

A bridge structure which crosses the North Branch of the Cedar Creek within a provincially significant wetland provided an opportunity to be a testing facility to determine the feasibility of utilizing geothermal energy and to assist with the design for other renewable energy systems. The County of Essex used the opportunity provided by the reconstruction of this environmentally-sensitive bridge, to pro-actively implement a prototype into the bridge deck.

The County of Essex had the opportunity to partner with a private sector company. The company had devised the geothermal snow melt system technology prior to our requirement to replace the bridge through conventional design methods. The company was responsible for any additional costs above and beyond those quoted for the conventional bridge design, with no contributions by the County of Essex.

II. Goals/Objectives

Governance regimes have evolved in response to environmental challenges in that they are more flexible, collaborative and learning-based. Improvements are consistent with existing policies to provide safe and operational infrastructure and are better able to manage the challenges of integrating environment and development.

Geothermal systems increase safety & life cycle and lower long term cost of rehabilitations. The Species of flora & fauna in the local area benefit from reduced salt usage. The geothermal design reduces the need for road salts to be used on the concrete approaches and bridge deck. One of the most important economic aspects of geothermal energy is that it is generated using indigenous resources, which reduces our nation's dependence on imported energy, thereby reducing trade deficits. Once a bridge is designed and constructed, they are in service for a long time during which they must be maintained.

The County of Essex had both short-term and long-term goals with respect to the project. Its short-term goal was to protect the integrity of the conventional bridge design while using the opportunity to proactively consider new technology to set a benchmark for future projects. The long-term goal was to effectively use the geothermal energy to incorporate measures to reduce the need for snow and ice control & ultimately eliminate the need to salt the bridge deck. By reducing the amount of salt applied to bridges, maintenance routes can be optimized to provide a savings in time and thus contributing to a reduction in greenhouse gas emissions.

III. Benefits

- **Sustainability** - The County of Essex has developed policies to provide opportunities for the development of renewable energy systems and realize the wider public benefit of these systems in terms of establishing a more stable energy system, reducing greenhouse gas emissions and securing a sustainable energy earth supply. County Council adopted an Official Plan amendment (Renewable Energy System Policies) to introduce new policies including general policies for renewable energy systems (geothermal), wind and solar energy systems and biomass energy systems.

- **Innovative Technology** - innovative geothermal snow-melt system to combat the common freeze-thaw cycles (black-ice) and thermal expansion experienced in our area. The design also utilized prefabricated components for the foundation, columns, pier caps, bridge deck and parapet walls which shortened the length of construction.

- **Environmental Benefit** - The Bridge is located in one of Essex County's most biologically significant areas. The geothermal design reduces and ultimately eliminates the need for road salts to be used on the concrete approaches and bridge deck. The Species of flora & fauna in the local area benefit from reduced salt usage.

- **Social Benefit** - It is increasingly being recognized that the world has to replace fossil fuels with alternate fuels. Fortunately, renewable energies are accelerating into the forefront to replace fossil fuels. The most popular replacements are wind, solar & geothermal energy. It is available in our area and is being utilized today. Geothermal energy uses heat in the earth's crust to power turbines or to heat buildings, water or, in this case, bridge decks

- **Economic Benefit** - Operational costs saving are expected to be realized through reduced maintenance demands and less quantity of salt being required. Lower long term cost of rehabilitation is also anticipated. Future elimination of rehabilitation shortens road closures and eliminates detours.

- **Community Impacts** –Our local geography has the right features for geothermal facilities to be installed. The Cedar Creek Conversation Area is a popular recreational area & this project has increased safety for pedestrians and fishermen and has protected the nearby watercourse and wetlands as a result of reduced salt usage.

IV. Innovation

The County of Essex is continuously pursuing environmental initiatives in the rehabilitation projects linked to the highway infrastructure, in a cost-effective manner through private and public partnerships that restore and conserve Essex County's natural resources. Given its success, the snow-melt geothermal model can be adopted by municipalities to foster environmentally sustainable bridge rehabilitation projects where applicable.

The geothermal snow-melt bridge deck system is an innovative program that has helped the County of Essex bridge rehabilitation program to ensure partnerships with provincial and federal agencies, private stakeholders, First Nations and others are established to ensure environmental sensitive areas are protected and/or restored and function on a sustainable basis.

Currently, with the first days of winter approaching, road users have not normally adapted yet to the changing traffic conditions. Since bridges cool down faster than normal roads, freezing conditions, in particular, can occur on bridges even when normal roads do not hint of any issues. Traditional treatment includes salt blasting the area. Every improvement in the status quo has a positive effect on the capacity and performance of roads and bridges. Traffic and pedestrian safety is increased with a reliable, sustainable and environmentally friendly method.

V. Implementation

The concept of a geothermal bridge deck heating system that utilizes a ground source heat pump system that recovers energy stored in the earth and transfers it to heat fluid that is circulated through the bridge deck was explored. The main purpose of the geothermal design is to eliminate black ice, and small accumulations of snow, not necessarily to melt heavy snowfalls, and to reduce thermal expansion & contraction stresses. The functional design features include bridge drainage system directing rainwater & snowmelt away from wetlands, solar recharge, geothermal snowmelt system, geothermal caissons with closed loop piping systems to heat the bridge deck temp., eliminating black ice from forming and reducing winter maintenance activities.

Initially, the characteristics and availability of the geothermal resources at the site were confirmed as part of the investigation phase of the project. The bridge deck heating system design takes into consideration the structural integrity of the bridge: it will not impair the works or the roadway surface in the event of system leakage or failure. The system works to cool the bridge deck in the summer time and heat it during the winter, reducing the temperature extremes and associated thermal expansions and contractions that stress and cause wear to the bridge structure. A heated bridge deck not only eliminates 24/7 rapid response to treat black ice, but it also reduces snowplough damage to the bridge, reduces damaging thermal stresses, thereby reducing maintenance requirements.

Further, because salt is not required to make the bridge safe for driving, the bridge is expected to have a life span greater than the typical bridge life span. Sentinel strain gauges inserted throughout the deck also allow engineers to monitor the strain on the structure as vehicles drive over it. The system currently monitor many data points, including geothermal temperatures, air & pavement temperature and mechanical strains on the bridge deck heating system allowing municipal and contract engineers to log data, and remotely monitor bridge systems.

The system circulates fluid from the bridge deck directly to the ground loop heat exchanger in the summer in order to "recharge" the ground. This system makes use of hydronic heating in the bridge deck, with the heat source being a ground-source heat pump. In order to make the system economically feasible, it is necessary to operate it with "just-in-time" control strategy (i.e./only when needed). The heat demanded by the snow-melting system represents the thermal load. The pipe, 5/8 stainless steel, is embedded in a serpentine configuration. Pipe spacing is approximately 8 inch from center. Heat transfer within the slab itself is by conduction. Internal sources of heat are due to convection from flow of the heat transfer fluid through the pipes. Heat fluxes at the pavement surface are due to a number of environmental interactions and include convection, solar radiation, thermal (long-wave) radiation, sensible heat transfer from precipitation, and latent heat transfer from melting snow and evaporating water.

With respect to making the system economically feasible, the controller may eventually be the most important part of the system. At present, only very simple control strategies have been tested. The current control strategy is that it is manually "read ahead" in the weather file and, if there is to be snow or freezing rain, one or a combination of all parts of the heating system are turned on. The number of systems turned on is controlled by the bridge deck surface temperature. For recharging the ground in the summer, the controller bypasses the heat pump by sending control signals to the diverters and directs the flow to the ground loop heat exchanger.

The heating requirement of a snow-melting system is commonly described in terms of a heat flux. The heat flux required for successful operation of the system depends upon many factors including: environmental heat transfer mechanisms, bridge deck construction (materials, thickness, area, and orientation), hydronic tubing construction (material, diameter, spacing, and burial depth), system flow rates, heat transfer fluid properties (density and thermal properties), and the fluid supply temperature.

The objective of the design heat flux was to keep the average bridge surface temperature above freezing. The actual energy use of the system over the course of a heating season is still experimental at this time. Thermal recharge of the ground is necessary to effectively balance the thermal loading to the ground over the annual cycle, and hence reduce the size and therefore the cost of the system. Therefore, as with the heating load, thermal recharge loads are estimated on an hourly basis in order to design a reliable and cost-effective system.

Monitoring & Outreach

Provincial and other municipal road engineers are watching closely the performance of the bridge over the north branch of Cedar Creek. By using the various ground sources, in conjunction with the boilers at peak times, the bridge maintained a constant temperature throughout this past winter and experienced no ice formation.

Geothermal reduces energy usage, cuts operating costs, and offsets the burning of fossil fuels. In addition to energy savings, using geothermal heat reduces greenhouse gases (GHG) and air pollutants, helping to keep Essex County's air cleaner. If the geothermal bridge had to rely on electricity to generate the heat that geothermal water naturally contains, and they would also emit tons of carbon dioxide, nitrogen oxides & sulphur dioxides each year into the Essex County air shed.

The County of Essex and the private sector company have implemented a three (3) year-term monitoring program that will advance the body of knowledge of what environmental protection measures are most effective. This program includes monitoring of environmental heat transfer mechanisms, bridge deck construction, hydronic tubing construction, system flow rates, etc. The results of this work will benefit future bridge deck rehabilitation projects.

VI. Partnerships

Through tripartite initiatives such as the Infrastructure Canada Program and the Municipal Rural Infrastructure Fund, the Government of Canada has helped municipalities in all parts of Canada undertake thousands of infrastructure projects such as improvements to municipal roads and bridges. The Canada-Ontario Municipal Rural Infrastructure Fund agreement (COMRIF), targets the infrastructure needs of small urban centres and rural municipalities with populations of less than 250,000.

The County of Essex received funding for this project through Intake 3. The design build relationship with the consultant, NavCan, MOE and Essex Regional Conservation Authority all contributed to the R&D portion of the project.

VII. Cost Implications

A very important part of this project was aimed at optimizing the design and the control and operating strategies to minimize the first cost and the operating costs. The initial costs for the conventional or geothermal system replacement were equivalent for this project because of the proprietary nature of the technology and the risks inherent in such a forefront project. It was not tendered, but was implemented pursuant to a design-build/warranty/monitor fixed-price negotiated contract based on prevailing prices for a comparable but conventional bridge. Operational costs saving are expected to be realized through reduced winter maintenance demands and less quantity of salt being required.

The first year operating costs are based on testing the bridge system and maximizing the use of the system with no previous summer recharge. Several different tests are being performed with different scenarios on the system trying to optimize the use of the multiple heat sources. The annual operating cost will obviously fluctuate year to year depending on the varying weather conditions, the bridge systems being utilized, and the cost of electricity. These operating costs for a geothermal snow melting system without heat pumps is anticipated to be minimal once the system is optimized.

For subsequent projects, the cost for the installation of a system is estimated at approximately 20% greater than a conventional design. A value benefit analysis is recommended and normally shows a favourable result. Although initial costs are higher, such systems are not considered uneconomical given the social and macroeconomic benefits.

VIII. Communication

Bridges exist everywhere across Canada and safety remains a key issue. Based on the light snowfalls typical in our area, winter maintenance gradually transitioned from mechanical plowing operations to 'chemical plowing'. City and County departments slowly increased salt use, and because of the light snowfalls, salt worked best. They gradually relied more and more on salt to perform the snow clearing operation. Best management practices introduced in most salt management plans include plans to reduce salt usage. The geothermal snow-melt technology can be used on municipal bridges to ultimately eliminate salt usage and reduce greenhouse gas emissions by introducing more efficient winter maintenance methods.

Our initiative has been shared with County Council for endorsement of the project. The project was also presented to other municipalities through Ontario Good Roads Association (OGRA). Many municipal leaders were in attendance and expressed great interest in the heated bridge design. Local newspaper articles were written to share the information with the local public. In addition, a Public Information Centre meeting was held as part of the Environmental Assessment process.

IX. Leadership

An active bridge deck ice prevention system, taking full advantage of the current heating and control technologies available was highly desirable. Travel would be safer; resources would be used more efficiently; and damage to bridge, vehicles, and, the environment would be reduced. Utilizing local consultant talent and Council's support to undertake a learning-based, innovative technology, a cost-effective workable bridge deck heating system was built and is being operated today.

This project was structures around establishing the technical feasibility, optimizing the design to reach economically acceptable capital costs and operating costs, predicting the increase in bridge deck lifetime due to reduced application of salt, and quantifying the economic benefits due to increased bridge deck life, improved safety, and reduced maintenance. In addition, a substantial effort was made to transfer the technology throughout the region, and beyond.

X. Lessons Learned

ESTABLISH GOOD INTERNAL COMMUNICATION. The County owes much of its success to the strong support Council has given to sustainable planning and energy initiatives.

SOLICIT SUPPORT FROM THE PROVINCIAL GOVERNMENT. Provincial ministries provided advice and financial support throughout the planning process.

CAPITALIZE ON PUBLIC INTEREST. The project revealed a desire for change and a citizen demand for the municipality to take a leadership role in these areas. This interest has sparked a community-wide energy planning process, which will focus on the County as a whole, rather than just on municipal operations.

HAVE A CONTINGENCY PLAN. Geothermal energy is powerful and sometimes you have too little or too much. If your end-use demand isn't there, it'll be wasted. Or, on the contrary, back-up boilers were needed when we didn't have enough energy storage.

USE AN INTEGRATED DESIGN APPROACH. By planning the entire project at the beginning with conventional methods and keeping all stakeholders apprised of developments, the construction team was able to meet the project time line and keep the project on budget

XI. Appendix

Photo 1: Geothermal Snow-Melt Bridge

Photo 2: Mechanical Room

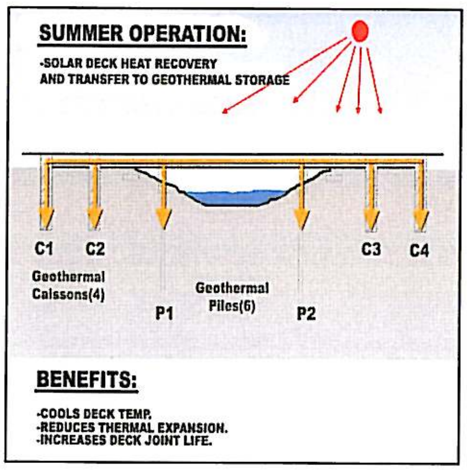

Photo 3: Solar Recharge – **Summer**

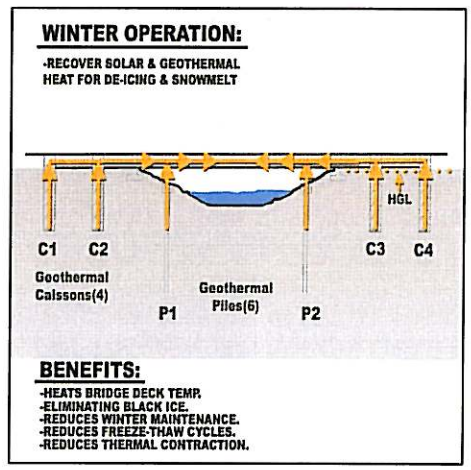

Photo 4: Solar Recovery – **Winter**

Photo 5: Caissons

Photo 6: Caissons

Photo 7: Caissons

Photo 8: Caissons

Photo 9: Deck Loops

Photo 10: Ground Loops

Photo 11: Pile Loops

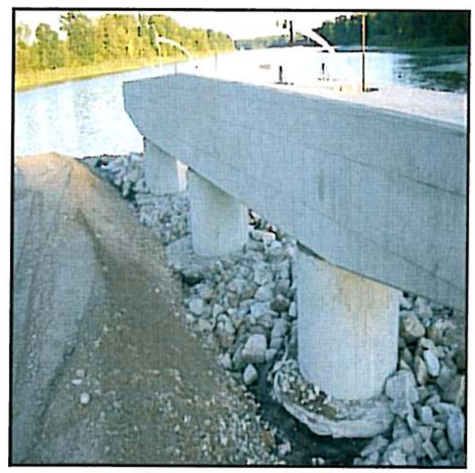

Photo 12: Pile Loops

Photo 13: Snow-Melt System

Photo 14: Snow-Melt System

Photo 15: Snow-Melt System

Photo 16: Snow-Melt System