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Heat-Seeking Sewer Model

Finding Waste Heat in Sewers and Matching it to Opportunities, Now...and in the Future

2014 Canadian Consulting Engineering Awards

SUBMITTED BY:

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Heat-Seeking Sewer Model

Finding the Heat in the Sewers and Matching it to Opportunities, Now...and in the Future

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Contact Name:	Ms Joan Carter
Project Title:	Heat-Seeking Sewer Model
Location of Project:	Vancouver, BC
Component being Submitted:	Sewage heat model
Category of Entry:	F – Special Projects
Joint Submitters:	N/A
Project Owner:	Metro Vancouver
Project Client:	Metro Vancouver
Prime Consultant:	Kerr Wood Leidal Associates Ltd.
Summary Description of Project:	A significant amount of renewable heat can be recovered from the sewer system and used to heat buildings. Metro Vancouver retained Kerr Wood Leidal Associates to examine the implications of implementing sewage heat recovery projects. The resulting Heat-Seeking Sewer Model finds waste heat, matches it to recovery opportunities, and answers the question: How much heat can you safely recover without endangering sewage treatment processes?
Names of Other Consultants Involved:	N/A
Names of Contractors Involved:	N/A

Executive Summary

A significant amount of renewable heat flows through Metro Vancouver's sanitary sewers each day as warm sewage. This excess energy can be recovered and used to heat buildings and is an economical means of displacing natural gas and reducing greenhouse gas emissions. Because of increasing interest in recovering sewage heat for space heating and cooling, Metro Vancouver retained Kerr Wood Leidal Associates to examine the viability and implications of implementing sewage heat recovery projects.

The question was: How much heat can you safely recover without endangering sewage treatment processes, both now and in the future? To answer this question, KWL developed the Heat-Seeking Sewer Model. The Model calculates the sewage flow rate and associated sewage temperature at nodes within the sanitary sewer network. The sewage heat capacity throughout the system is calculated by tracking the flows and temperatures of each sewage component separately. Until the Model was developed, no model existed that could calculate these discrete changes for a large sewage network with multiple sewage heat recovery projects, and no model could provide a GIS interface and mapping capabilities.

The Model results show that there is plenty of heat in the sewer system to heat homes. Up to 100 MW of recoverable heat is available across the region, enough to heat about 650 to 1,000 high-rise buildings. Although this Model was applied to Metro Vancouver, it can be deployed in any sewer collection system, enabling widespread implementation of sewage heat recovery projects *and* effective management of the underlying sewage systems.

Background and Project Overview

A significant amount of renewable heat flows through Metro Vancouver's sanitary sewer network each day in the form of warm sewage. This excess energy can be recovered and used to heat buildings. This is an economical means of displacing natural gas and reducing greenhouse gas emissions, as demonstrated by the Southeast False Creek Neighbourhood Energy Utility in Vancouver, which uses recovered sewage heat. "According to the City of Vancouver, the sewage heat recovery will supply approximately 70% of the [Southeast False Creek] neighbourhood's annual heating and hot water energy demand, and will produce 50% less greenhouse gas emissions compared to conventional energy sources."[1]

Metro Vancouver manages sewerage, drainage, and treatment of liquid waste for most municipalities in the Greater Vancouver area, some of which have aggressive targets for reducing greenhouse gas emissions. For example, the City of Vancouver's is to reduce community emissions by 250,000 tonnes per year by 2020. Because of increasing interest from municipalities, utilities, and private developers to extract sewage heat for space heating and cooling, Metro Vancouver retained Kerr Wood Leidal Associates (KWL) to examine the viability and implications of allowing sewage heat recovery projects. KWL's analysis suggests that up to 30 MW to 45 MW of sewage heat recovery may be possible in the City of Vancouver. This could offset approximately 60,000 tonnes to 90,000 tonnes of greenhouse gas emissions, which is about 25% to 40% of Vancouver's target.

This project was completed on a tight timeline – it took approximately three months from project initiation to the first successful model run. Including the literature review and development of a technical reference document, the overall project was completed in a nine-month timespan. In order to achieve this schedule, KWL assembled three teams working in parallel. The literature review team was even proficient in eleven different languages in order to get a global viewpoint on sewer heat recovery. As we discovered, BC is already a worldwide leader in using recovered sewer heat for heating buildings!

Project Objectives

The objectives of the project were to develop an understanding of the technical implications of allowing access to the sewers for sewage heat recovery projects, and to develop the tools needed to evaluate sewage heat recovery requests in a regional context. Metro Vancouver plans to develop a policy to regulate the use of regional sewers for heat recovery projects. This project is integral to the policy development.

Solutions and Achievements

The main question was: How much heat can you safely recover without endangering sewage treatment processes, both now and in the future? To answer this question, KWL developed the Heat-Seeking Sewer Model (the Model), the first of its kind capable of mapping an entire large sewer network and calculating temperature changes caused by multiple sewage heat recovery projects.

[1] The Challenge Series, http://www.thechallengeseries.ca/chapter-05/neighbourhood-energy-utility/

The modelling area included the five wastewater treatment plant catchment areas that comprise the regional sewer network, and the Model was applied to each. Heat resource availability is now known in each pipe segment throughout Metro Vancouver's regional sewer network.

KWL's work included a worldwide literature review of sewage heat recovery best practices and the development of the Heat-Seeking Sewer Model and supporting documentation.

Software Overview

KWL developed the Model to map, quantify, and analyze the sewage heat energy capacity throughout the Metro Vancouver system. The Model calculates the sewage flow rate and associated sewage temperature at nodes (i.e. manholes, valves, junctions, grit chambers, wastewater treatment plants, etc.) within the sanitary sewer network. The sewage heat capacity throughout the system is calculated by tracking the flows and temperatures of each component of the sewage separately. The sewage components are:

- Residential population based flow;
- Industrial, commercial, and institutional based flow;
- Groundwater infiltration; and
- Rainfall-derived inflow and infiltration.

Each of the above components has a temperature and flow rate associated with it. This data is inputted by the user, and the model calculates the downstream sewage heat characteristics.

Modelling Engine and Outputs

The modelling engine consists of two modules: a hydraulic modelling engine and an advective temperature modelling engine. The hydraulic modelling engine is based on a steady-state hydraulic engine, which calculates the daily average flow at each node in the collection system. The advective temperature modelling engine tracks sewage temperature and available energy by using a mass balance of the sewer flow components. The advective temperature modelling engine also tracks the total energy recovered from the system by sewage heat recovery projects.

Once run, the model outputs three files: a Results Report, Node Results, and Sewage Heat Recovery Project Results. The Results Report summarizes the model results for each wastewater treatment plant. The Node Results are modelling results for each node, including sewage flow, and inflow/outflow sewage temperature. The Sewage Heat Recovery Project Results are modelling results for each sewage heat recovery project, including inflow/outflow sewage temperature for the project as well as the node outflow sewage temperature.

Scenario Management and Model Validation

Various scenarios and sensitivity analyses can be run with the software by changing the variables and the loading information. These variables can be adjusted at a node level or at a global level. Variables that can be modified include Population; Residential and ICI Area; Industrial Equivalent Population Rate; Institutional Equivalent Population Rate; Commercial Equivalent Population Rate; Base Sanitary Flow Rate Per Capita; Groundwater Infiltration Rate; Rainfall Derived I&I Rate; Residential Sanitary Temperature; ICI Sanitary Temperature; Rainfall Derived I&I Temperature; and Groundwater Inflow Temperature. To confirm the validity of the model run, the model results were compared to the flow and temperature monitoring data available at each wastewater treatment plant and found to be accurate within 7% or better.

Modelling Scenarios and Constraints

The Model was run under three scenarios: summer dry weather flow; winter dry weather flow; and winter wet weather flow. Under all modelling scenarios, two temperature constraints were applied. The first was that the sewage temperature, at any given time, could not drop below 6ºC. The second was that the inflow temperature at the wastewater treatment plant was set to a minimum of 11ºC.

Why Recovering Too Much Heat is Harmful

The 11ºC parameter for influent at the wastewater treatment plant is important because biological treatment processes at wastewater treatment plants are adversely affected if the temperature of the sewage falls below 11°C. Drop the temperature too far, and the microbes will die, and sewage will not be adequately treated. Although supportive of sewage heat recovery initiatives, Metro Vancouver's vital concern was that such projects not in any way adversely affect sewage treatment.

Too much heat demand can also occur upstream in the collection system. If multiple heat recovery projects are located on one sewer trunk, the upstream projects benefit from higher efficiency because the sewage is warmer, whereas downstream projects may struggle to recover heat. Metro Vancouver will now be able to develop effective policy to govern use of sewage heat resources.

Why a Sewer Model was Needed

Accurately assessing how much sewage heat is available, and the best locations to recover it, is a complex problem. The sewer system is a dynamic system where a myriad of variable influences affect sewage temperature. Population growth, changes in land use, water conservation measures, rainfall and groundwater infiltration – to name just a few – all affect the temperature of sewage. Recoverable sewage heat comes primarily from warm sewage discharged from residential sources as well as industrial, commercial, and institutional sources. The heat in these discharges can be lost to the surrounding soil, groundwater, and to the air in the headspace of the sewers, but mostly remains in the sewage through the collection systems to the treatment plants, and is ultimately discharged to the environment. To ensure the proper functioning of the treatment system and assess whether a sewer heat recovery project is advisable, it is critical to understand what is happening at any given point in the system, and to know what is influencing changes to sewage temperature. The importance of this is heightened in cities such as Vancouver where major development and redevelopment is occurring, and the city is determined to recover renewable sewage heat and promote resource conservation as part of its effort to become the "Greenest City". As Metro Vancouver's sewers pass through many municipalities, efficient allocation of heat is another key consideration for policy development.

Until the Heat-Seeking Sewer Model was developed, no model existed that could calculate these discrete changes for a large sewage network with multiple sewage heat recovery projects, and no sewer heat recovery model existed that would provide a GIS interface and mapping capabilities. The Model estimates the available energy capacity within the sanitary sewer system as a whole and in each pipe section. It also identifies key factors that may affect energy capacity, and estimates the range of quantities of energy available for sewage heat recovery projects, given the downstream constraints such as the heat requirements of wastewater treatment plants and existing sewage heat recovery projects.

The Model is an effective tool for Metro Vancouver to manage and safeguard the sewage system, allowing it to permit sewage heat recovery projects at locations in the collection system that will not adversely affect sewage collection and treatment processes, and preventing them at locations that will. It has enabled Metro Vancouver to assess the energy capacity of sewage for proposed sewage heat recovery projects, and allocate available resources in an effective manner. Because of its mapping capability, the Model also enables energy planners to match sewer heat resources to potential development areas, thus optimizing the utilization of sewer heat. The Model can be run and rerun to assess and reassess changing conditions in the system. This is crucial to determining the viability and advisability of proposed sewage heat recovery projects.

> *"The sewer heat model is a great example of the kind of tool we need to support Metro Vancouver's goal of using liquid waste as a resource, as stated in Metro Vancouver's Integrated Liquid Waste and Resource Management Plan. The model will help Metro Vancouver enable valuable, environmentally responsible sewer heat extraction projects in the region."*
>
> *– Jeff Carmichael, Division Manager, Utility Research & Innovation, Metro Vancouver*

Environmental, Economic, and Social Benefits

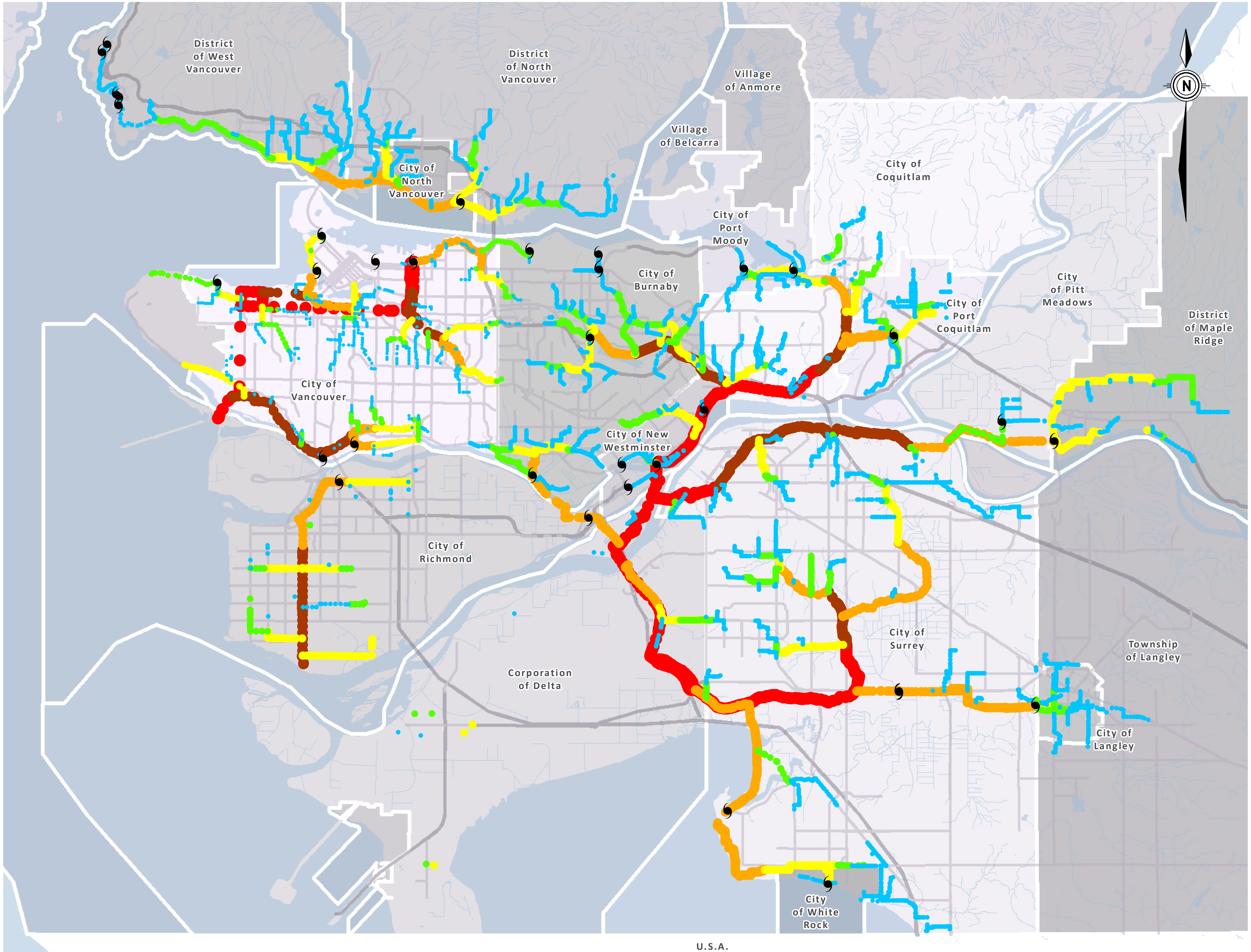
Plenty of Sewage Heat Available

The Model results show that there is plenty of heat in the sewer system to heat homes, with the average hourly sewage temperature generally above 11^{o}C year-round. Under current conditions, there are about 45 MW of recoverable sewage heat that can be recovered to heat buildings in Vancouver, and about 100 MW region-wide. This translates to a 90,000 tonne reduction of greenhouse gas emissions per year in Vancouver, and 200,000 tonnes per year region-wide. To help illustrate the scale of what this recovered energy will heat, 1 MW of recovered sewage heat would heat the equivalent of 6 to 7 high-rise buildings, so the 45 MW of excess sewage energy could heat up to 300 high-rise buildings in Vancouver.

Moreover, sewage heat temperatures will likely rise in future years. Much of the waste heat comes from domestic activities such as running dishwashers and hot showers, and pouring hot cooking water down the drain. Water conservation measures, such as the widespread use of low flush toilets and high efficiency washing machines, will result in warmer domestic wastewater entering the sewer system because less cold water will be discharged. In addition, sewer rehabilitation projects that replace cracked and aging sewers will decrease the amount of groundwater and stormwater runoff entering the sewer system. Sewer separation projects that separate sanitary sewers from storm sewers will also contribute to higher sewage temperature by diverting groundwater from the sewer system.

> *"Results from the sewage heat model will assist in developing North America's first Sewage Heat Policy Framework by showing where the heat resource may be limited and where sewage heat project opportunities should be explored."*
>
> *– Genevieve Tokgoz, Project Engineer, Utility Research & Innovation, Metro Vancouver*

Although this Model was applied to the Metro Vancouver sewage collection system, it can be deployed in any sewer collection system. This will enable widespread implementation of viable sewage heat recovery projects *and* effective management of the underlying sewage collection and treatment systems.



Metro Vancouver
Tools for Implementation of Sewer Heat Recovery

Legend

- Municipal Boundary
- Pump
- Force Main
- Gravity Main
- Pressure Main

Available Sewer Heat Supply

- .01 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- > 50

Reference: Topographic map reproduced under licence from Her Majesty the Queen in Right of Canada, with permission of Natural Resources Canada.

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Project No.	Date
251-286	January 2014

Regional Heat-Seeking Model Results, Showing Available Heat

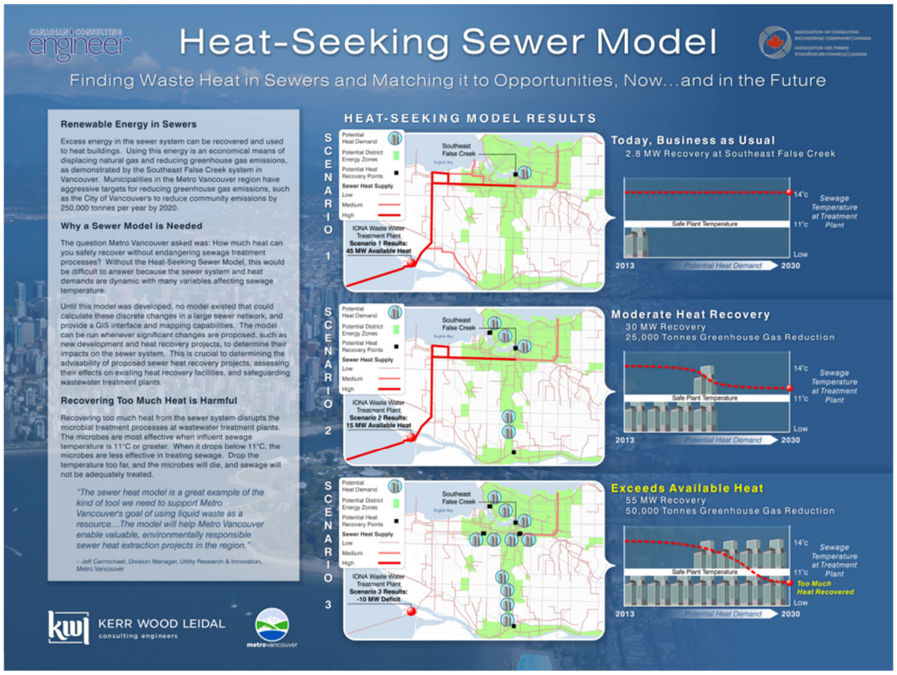

Image 1: How the Heat-Seeking Sewer Model finds renewable heat in sewers.

Image 2: Winter dry weather sewer flow results.

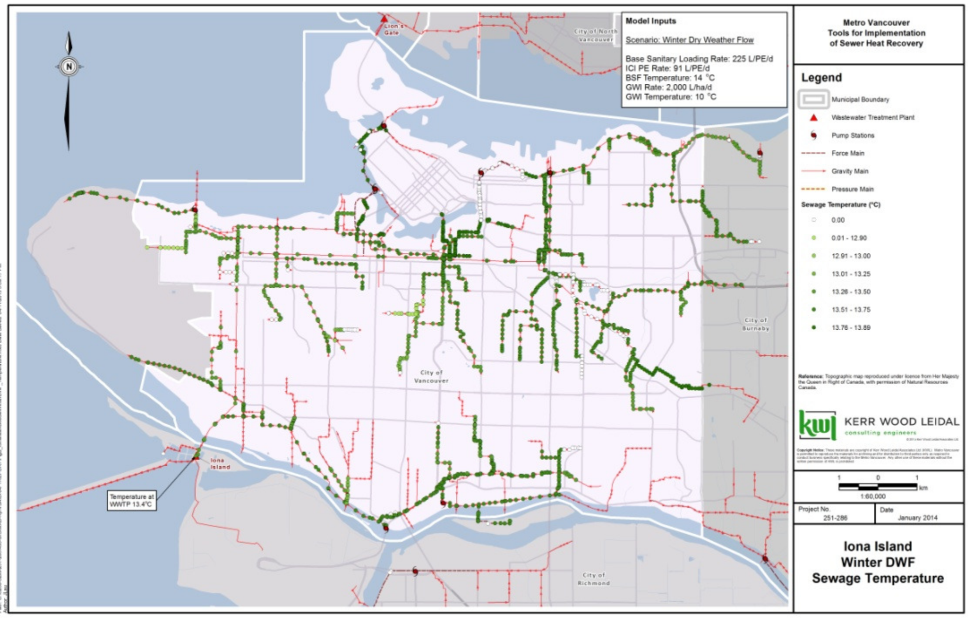

Image 3: Winter dry weather sewer temperature results.

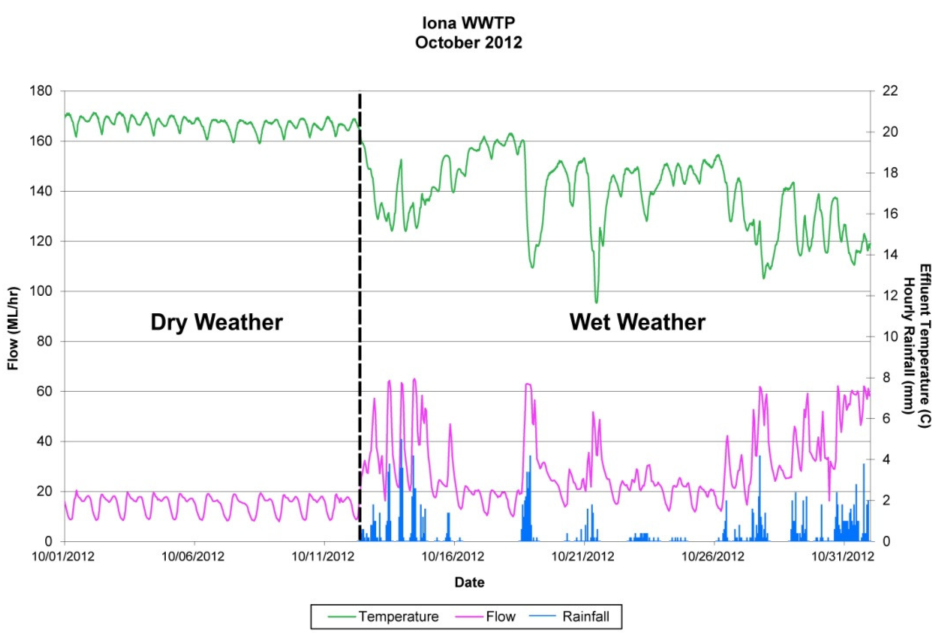

Image 4: Winter sewage flow and temperature at Iona Island wastewater treatment plant, showing influence of rainfall on temperature and flow.

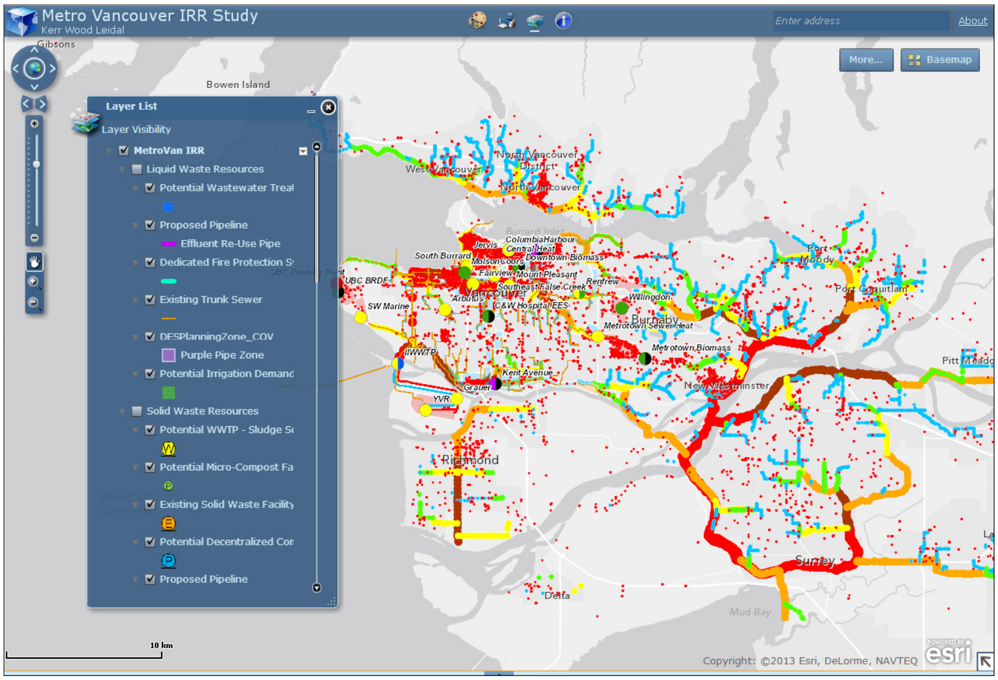

Image 5: Screen shot of web-enabled Resource Recovery Map, illustrating regional context for use of recovered sewer heat.

Image 6: Metro Vancouver's Lions Gate wastewater treatment plant.