COMMUNITIES OF TOMORROW
Innovation For Real Life

Current Projects

Infrastructure Evaluation
(Monitoring and modelling of infrastructure operations, condition, deterioration and effects of climate extremes, soil-structure interaction, etc.)

1. Investigation of Failure Mechanisms of Asbestos Cement Pipes

Principal Investigator: Dr. Yafei Hu, NRC Research Officer

Objective:
Analysis of City of Regina historical failure data to determine the factors contributing to the failure of AC water mains; development of new models for the physical mechanisms that cause pipe failure; instrumentation of AC water main sections to monitor pipe behaviour in Regina clay under environmental conditions (including trial of Fibre Optic Sensors); carry out soil-pipe interaction modelling to simulate the behaviour of asbestos cement pipes under typical working conditions; and develop methods to predict the remaining service life of the pipes and guidelines for the operation and maintenance of AC pipe assets.

2. Management of Leakage for Water Distribution Systems

Principal Investigator: Osama Hunaidi, NRC-IRC Ottawa

Objective:
Development of best practices for communities to efficiently recover water loss due to leakage and to demonstrate the implementation of the resulting leakage management practices in 3 major Canadian Cities, Regina, Ottawa and Halifax.

3. Non-Destructive Evaluation of Concrete Pipes

Principal Investigator: Dr. Riad Al-Wardany, NRC-CSIR

Objective:
The project aims to develop non-destructive method(s) for the condition assessment of concrete pipes - Pre-stressed Concrete Cylinder Pipes (PCCP) & Asbestos Cement pipes (AC). This includes the detection of signs of distress in concrete, longitudinal and circumferential cracks, mortar coating delamination, steel cylinder corrosion and wire breaks in PCCP. The research is planned through an experimental program, which includes: simulation of typical defects of concrete pipes, investigation of the applicability and accuracy of existing non-destructive methods, development of promising approaches for dewatered and water-filled pipes, automation of the process and finally field applications.

4. Test Bed Development for Pipe Inspection Using A Spherical Digital Video Camera

Principal Investigator: Dr. Raman Paranjape, U of R

Objective:
Closed circuit television (CCTV) systems are now a commonly used method for sewer/water pipe system inspection. However, the field of view with single video camera is rather limited. Therefore, multiple cameras could be applied to extend the field of view for the pipe inspection. A spherical digital video camera which integrates six high quality digital cameras that enable the inspection sytem to collect video from more than 75% of the full sphere can in principle to address these issues. Such a camera would be

useful - directly for visual inspection, but also for other projects such as laser-based scanning, automatic defect identification, system positioning and even navigation.

5. Alternative Communication Model for Water Monitoring System

Principal Investigator: Dr. Yasser Morgan, U of R

Objective:
The project aims to research methods pertaining to establishing alternative approaches to data collection combined with wireless technologies. Data over power-lines augments common wireless approaches; however, the integration requires detailed analysis and thorough investigation. The project defines ways of integrating alternative wireless and data-over-power-line solutions to serve the water and sewage network monitoring. The project identifies the best economical solutions pertaining to specific operational situations. The project enhances the quality of the current water system and adds to the sustainable wireless infrastructure.

6. Behavior of AC Water Mains in Expansive Soils

Principal Investigator: Dr. Yafei Hu, NRC-CSIR
Co-Principal investigator: Dr. Shahid Azam, U of R

Objective:
The work is designed to study the structural response of AC pipe to varying soil movements and ways to measure and predict soil movements and structural behaviour of AC pipe. The newly established soil-pipe-environment empirical and numerical models will be used to predict typical scenarios that lead to the AC pipe failure. A full understanding of the working environments of the AC pipes and the typical scenarios leading to the failure of AC pipes would help municipal engineers develop practical strategies for operating, maintaining, and managing their AC pipe assets. It would also be helpful in the design and construction of new water mains in unsaturated soil environments.

7. Design and Development of a 3D Omni-directional Optical Laser Scanner for Inspecting Water/Sewer Pipes

Principal Investigator: Dr. Mehran Mehrandezh, University of Regina

Objective:
The goal of the project is to design and develop a 3D pipe profiler using an omni-directional laser scanner with multiple circular projection patterns. The main industry-oriented objective is to inspect the ovality, pitting, and denting in water/sewer pipes through non-destructive methods. An imaging system based on vision and laser is proposed.

8. Hydraulic Reliability Assessment and Optimal Repair Schedule for Water Distribution Systems

Principal Investigator: Dr. Rene V. Mayorga, University of Regina

Objective:
The purpose of this seed project is to develop a new prototype software tool for use with existing water system network simulation software to optimize repair and replacement plans and schedules to reflect system-wide differences and variations in health, safety and demand priorities.

9. Design and Development of the Field Trial version of the Regina Pipe Crawler (RPC)

Principal Investigator: Dr. Mehran Mehrandezh, U of R

Objective:
This project is the 2nd phase of design and development of a smart vehicle for doing inspection on live water pipes. Design and development of a field trial version of the Regina Pipe Crawler is envisioned. The robot will be deployed to do inspection on Asbestos Cement (AC) pipes with 6-8 inch of diameter. AC pipes are widely used within the water supply network of the City of Regina. The Field Trial RPC (or for short, FT-RPC) will be utilized in scheduled repairs for doing a quick inspection on AC pipes running between two valves on a city block within the time frame available on each repair.

Water Infrastructure
(Wastewater, water treatment, water quality, water recycling, etc)

1. Technical Assessment of Integrating Waste Water Irrigation with Biomass Co-generation in the Northern Plains

Principal Investigator: Regina Regional Economic Development Authority

Objective:
This project is one step in a larger initiative to derive sustainable economic value from urban waste water management. By redesigning waste water systems to release into plant ecosystems costs are lowered, value is created, and aquatic systems sustain undisturbed. The objective of the project is to define a conceptual plan for biomass co-generation implementation in terms of which type and scale of biomass co-generation site provide the greatest revenue potential.

2. Development of a sustainable technology for the removal of phosphorus from stormwater runoff

Principal Investigator: Dr. Dena McMartin, University of Regina

Objective:
This project focuses on developing an effective and affordable treatment technology for stormwater management in municipalities. The technology developed will also have applicability in the reclamation and reuse of stormwater and greywater, as well as treatment of wastewater. The investigation will focus on phosphorus (P) removal, but the technology will be capable of removing a wide range of pollutants in stormwater and wastewater.

3. Development of a Power Supply System for Wireless Underwater Sensors in Pipes

Principal Investigator: Dr. Mehran Mehrandezh, University of Regina

Objective:
The purpose of the project is to design and develop a stand-alone electrical generator to supply power for in-pipe sensors and wireless communication devices used for continuous monitoring of pipe conditions in operating water mains. The project is a part of a strategic research project that aims, based on the North American market need, to develop and commercialize an innovative and long-term condition monitoring system for drinking water pipes, using non-destructive testing technologies.

4. Intelligent Sustainable Water Management System

Principal Investigator(s): Xue Dong Yang, Howard Hamilton, Gordon Huang, Boting Yang, Jingtao Yao, and Yiyu Yao (University of Regina)

Objective(s):
The proposed **Intelligent Sustainable Water Management System** will facilitate:

- Collection of historical and current data from a variety of different sources;
- Web-based survey mechanism for pooling public opinions on specific issues;
- Simulation and prediction of water supply, distribution and consumption under dynamic and uncertain conditions through advanced mathematical modeling and optimization techniques;

- Web-based interactive functionality that allows decision makers to play with “what-if” scenarios by varying control parameters in order to make intelligent optimal decisions;
- Web-based interactive functionality that allows policy makers to access and analyze information in intuitive visual forms; and
- Web-based education center to promote public awareness of sustainability of water consumption and conservation.

5. Development of Novel Treatment Method to Eliminate Harmful and Pathogenic Microorganisms in Community Drinking Water

Principal Investigator: Dr. Venkatesh Meda, Department of Engineering, U of S

Objective:
The development of a drinking water treatment method using electromagnetic and optical based treatment, which will be simple, energy efficient, and economical.

6. Water Quality in Drinking Water Distribution Systems

Principal Investigator: Dr. Syed Imran, NRC-CSIR

Objective:
The main purpose of the project is: the evaluation of how changes in water sources can affect different components of the distribution network; the evaluation of unintended effects of changes to water treatment processes; the evaluation of the effect of changes in water composition on the host pipes in terms of both the duration and frequency of these changes; the development of a decision-support system to help utilities evaluate the effect of changing water-treatment practices on the deterioration of different pipe materials.

7. Remote On-line Monitoring of Water Quality in Municipal Infrastructure

Principal Investigator: Dr. Dunling Wang, NRC-CSIR

Objective:
Monitoring (real-time, remote) and evaluation of water quality in small to medium sized communities and water utilities (including towns, cities and First Nations).

8. Cryptosporidium Research

Principal Investigator: MR2 McDonald & Associates

Objective:
Various parasitic protozoan led contamination events have created the need for more effective detection and analysis and treatment techniques. There is a need to develop new technology and equipment necessary to monitor drinking water at the source, at various stages of treatment, at critical points in the transmission and distribution networks, and at point of use to detect the presence of water borne parasites that constitute a health risk. n addition, more treatment options would be beneficial. This project will provide a needs assessment and market survey regarding cryptosporidium and giardia related to drinking water issues.

9. Investigation of Microbial Growth, Community Structures and their Effects on Drinking Water Quality and the Integrity of Distribution Pipes

Principal Investigator: Dr. Dunling Wang, NRC-CSIR
Co-Principal Investigators: Dr. Gordon Huang, U of R; Dr. Roy Cullimore, Droycon Bioconcepts Inc.

Objective:
The proposed project will further develop methodologies for sampling and testing of microbes in water pipes, for identifying bacterial species and studying the activities and community structures of microbes in the bulk water and on the surfaces of distribution pipes. The study is expected to reveal the roles that each group of microorganisms plays in the microbiologically influenced fouling and corrosion of the distribution pipelines and the influence of pipe materials on biomass development.

10. Technical and Market Assessment of Opportunities for New Technologies and Processes Arising from Municipal Water Shortages

Principal Investigator: Communities of Tomorrow

Objective:
The proposed study is intended to provide a comprehensive assessment of those opportunities to serve as a road map for development of cluster programs and projects for research and development of water and wastewater technology. This will advance the water strategy going forward for the cluster partners.

11. Ozone-Assisted Biofilter – Prototype and Demonstration

Principal Investigator: Allan Finney, Envron Environmental

Objective:
This project would see the building and installation of two greywater recycling systems in Regina homes and a third unit for testing at the company's facilities in Regina. All of these systems would be used to get "real world" feedback on the system, gather data on water quality and assess how well the systems are functioning from an end user and technical standpoint.

12. Autotrophic Biological De-Nitrification with Hydrogen

Principal Investigator: Ashref Darbi, KGS Group

Objective:
The objective of the project was to investigate the applicability and feasibility of autotrophic biological denitrification using H2 as an electron donor on nitrate contaminated groundwater. Biological removal of nitrate from groundwater using hydrogen was expected to reduce the nitrate from groundwater without any chemical addition to the treated water and the nitrate will be converted to nitrogen. Biological removal of nitrate from groundwater using hydrogen has many advantages including: lower cell yield; elimination of carryover of added organic electron donor to the product water; the relatively low solubility of H2, which makes it easy to remove from the product water by air stripping; and the low cost of H2.

Sustainable Roads and Transportation Systems

1. Innovative Porous Materials for Urban Traffic Noise Reduction

Principal Investigator: Dr. Liming Dai, U of R

Objective:
This project intends to reduce noise pollution and improve the environment of Canadian cities. By incorporating recyclable materials into porous pavement mixtures, the waste materials can be removed from the landfills and convert them into commercial products, in addition to building roads with higher functional quality and low traffic noise. The project is anticipated to uncover a thorough and theoretically and practically sound comprehension of the mechanism responsible for the noise reduction contributed by porous materials. On the basis of the comprehension, it is expected that an ideal material for noise reduction and strong durability can be designed for various applications. It is also expected that the findings of the project will contribute to the generation of new noise reducing materials for noise barriers, offices and manufacturing buildings.

2. An Investigation of Sensors Required for a Smart Snow Plow

Principal Investigator: Dr. Nima Sarshar, U of R

Objective:
SmartSnowPlow (SSP) Project aims at developing technologies that enable ordinary snowplows to operate more safely and efficiently by (1) informing the driver of the proximity of the snowplow blade to the curb, (2) alerting him of vehicles and obstacles approaching from front and behind, (3) enabling the snowplow to gather geographically referenced information about the status of snow removal operation, including the volume of snow pile at side roads and the need for deicing (i.e., salt or sand application). The major question that will be assessed is whether one can estimate the proximity of the snowplow sensor blades to the curb or guiderail using sensors that are installed only on the snowplow itself (and not on the road).

3. Roadway Preservation with in Place Recycling with City of Regina and Ministry Transportation and Infrastructure – Sustainable Infrastructure Demonstration and Monitoring Project (Phase 1)

Principal Investigator: Tom Wiley, Battle River Asphalt Equipment Ltd.

Objective:
This project is to implement medium quality methods for smaller than full segment road repairs, thereby preserving the entire segment at a more affordable cost. The best technology is Hot in Place Recycling of Asphalt pavement, developed to a high level of performance over the past twenty years. When this method is properly planned and implemented, the end result will be the equivalent of new pavement. The purpose of this project is to monitor this process, document existing conditions, methods and apparent results to produce a construction phase report that will identify costs per unit, competitiveness with other methods, best applications and best practices.

Remediation Processes and Technologies

1. Vacuum Enhanced Electrocoagulation (VEE) Technology

Principal Investigator: Ground Effects Environmental Services Inc. (GEE)

Objective:
GEE proposes to use a system of electrocoagulation for the treatment of contaminated water based fluids. This new technology has the potential to eliminate the vast quantities of contaminated waters that would otherwise require specified disposal techniques. The cost associated with the increased water usage as well as disposal increases exponentially, however as the cost of water usage and the environmental impacts become more critical, methods must be developed for the reclamation of contaminated water.

2. In Situ Remediation Strategy for the Treatment for Heavy End (>C34) and Bituminous Hydrocarbons

Principal Investigator: Ground Effects Environmental Services Inc. (GEE)

Objective:
Ground Effects Environmental Services Inc. (GEE) proposes to use its new electrokinetic remediation process to remediate heavy end hydrocarbons (greater than C34), including bituminous materials. This type of contamination is of the highest degree of difficulty to remediate, and traditionally has just been dug up and removed to a landfill site. It is GEE's desire be able to remediate this heavy end hydrocarbon contamination *in situ*, eliminating the cost both to the client as well as to the environment through the process of eliminating dig and dump.

3. Perchlorethylene (PCE), TCE, PCB and F3 and F4 Remediation Bench Scale Tests

Principal Investigator: Sean Frisky, Ground Effects Environmental Services Inc.

Objective:
GEE will conduct a number of laboratory analysis using a variety of contaminated soils, and a unique approach in methodology associated with electrokinetics to determine the most successful outcomes. If the techniques used for these contaminants are successful, EK3 will be a model for brownfield remediation across Canada and around the world. It would mean easier, more cost-effective land reclamation and reuse of contaminated, abandoned urban areas and renewed tax income for municipalities.

Other Projects Related to Sustainable Municipal Infrastructure

1. Nature's Sewage Conditioner

Principal Investigator: Koenders Windmills Inc.

Objective:
The natural degenerative process in a sewage lagoon is very slow. The objective of the project is to install aeration windmills and introduce a bacterial fluid to further speed up that process. It is anticipated that the introduction of a windmill with the biological accelerator will produce carbon dioxide rather than hydrogen sulphide and volatiles, thereby removing the smell. As well, the local community will benefit because of less contamination in the air and watertable.

2. Composite Structural Module for bridge decks and floor structures

Principal Investigator: Michael Dombowsky, NorthWind Innovations

Objective:
NorthWind has discovered an innovative concept for lightweight, pre-finished bridge decking known as Composite Structural Module (CSM). This system could greatly reduce the materials needed for bridge construction. Because of the adaptation of new coatings technology, there would also be a reduction in the need for resurfacing and maintenance costs. Additionally, the inherent qualities of the CSM would naturally limit or eliminate the formation of frost on the bridge deck.

3. An Integrated Approach to Sustainable Management of Municipal Infrastructure Assets

Principal Investigator: Dr. Mahmoud Halfawy, NRC-CSIR

Objective:
A prototype GIS-based asset management software is under development. The software is based on the proposed integrated framework and data/process models. Work on a prototype mobile GIS-centered software to facilitate field data collection during inspection, data validation, and routine field operations, and the integration of field data to asset data repository.

4. Landfill Gas Collection and Hydrogen Conversion Project

Project Leader: Gary Nieminen, Sewer, Water & Waste, Engineering and Works, City of Regina

Objective:
This project involves collection of landfill gas from City of Regina's landfill. Gas will be cleaned and used in a demonstration scale process using solar energy in a catalytic process to convert the gas to hydrogen. Surplus cleaned landfill gas can be sold as "green" substitute for natural gas.

5. WTTP Receiving Environment - Environmental Monitoring Assessment Study

Project Leader: Gary Nieminen, Sewer, Water & Waste, Engineering and Works, City of Regina

Objective:
A continuing study on the water quality/aquatic conditions of the receiving environment (Wascana Creek

and the Qu'Appelle River System) of the City's wastewater treatment plant discharge. Study provides planning and operational data for proposed WWTP improvements.

6. Wastewater Treatment Plant Methane Gas Utilization Project

Project Leader: Gary Nieminen, Sewer, Water & Waste, City of Regina

Objective:
Study to determine feasibility and best method to fully utilize methane gas generated at the STP. Saskatchewan Research Council conducted digester gas monitoring and analysis to provide key data for the study.

7. National Benchmarking Initiative

Project leader: Stella Madsen, Engineering and Works, City of Regina

Objective:
The National Benchmarking Initiative is a collaboration of over 30 of Canada's largest municipalities providing standardised benchmark measures for sewage collection and treatment, water supply and distribution and storm drainage. City of Regina was a founding member of the national initiative.

8. Waste Management Partnership

Collaborators: City of Regina and U of R Faculty of Engineering

Objective:
The City of Regina funds U of R research and staff resources to conduct applied research on waste management issues identified by the City. Most recent project involves applied study of the Leachate Movement in Regina Clay near the landfill (Dr. Y.C. Jin's Project - City of Regina Landfill Groundwater Model Study). The next study will involve a waste characterization study.

9. Landfill Capping Trial Evaluation

Project Leader: Gary Nieminen, Sewer, Water and Waste, Engineering and Works, City of Regina

Objective:
A City of Regina project conducting field trials of two landfill capping designs to determine performance.

10. Innovative Regional Waste Management

Principal Investigator: Greg Vogelsang, Clifton Associates Ltd.

Objective:

The project will assess the feasibility of developing an innovative approach to regional waste management services. The feasibility assessment would examine options and applications that could be applied to the current waste management practices in the Regina region and potentially to other areas throughout the province. As the City of Regina advances towards development of a new landfill, there may be opportunities to develop new best management practices and technology to substantially improve upon the current waste management practices.

11. Data Management and Modeling for the Environmental Impacts of the Use of De-icing Chemicals on Saskatchewan Highways

Principal Investigator: Dr. Y.C. Jin, Environmental Systems Engineering, U of R
Collaborator: Saskatchewan Department of Highways and Transportation

12. Managing Pathogen Levels in Irrigation Water Supply Reservoirs through Natural and Mechanical Inactivation and Aeration – Planning Strategies and Resource Material Development

Principal Investigator: Dr. C. Jost, U of R Faculty of Science
Collaborator: Saskatchewan Vegetable Growers Association

13. Environmental Chamber for Hydrological and Environmental Effects of Stormwater Runoff

Principal Investigator: Dr. Gordon Huang, U of R; Dr. Darryl Dormuth, NRC-CSIR

Objective:
Over the past decades, the management of stormwater runoff has emerged as an issue of major concern to urban municipalities. It has been recognized that it is difficult to develop cost-effective designs for Best Management Practices (BMPs) due to the incomplete knowledge of the complex interrelationships between hydrological and environmental behaviors associated with stormwater runoff under various meteorological and land-use conditions. This project will include construction of an environmental chamber in Regina to conduct scaled-down simulations of urban stormwater runoff under various climate and land-use conditions, to improve the understanding of the complex interrelationships between hydrological and environmental processes, and to provide commercial test services.

14. Reliable Long-Range Wireless Communications Solutions for the Service of Infrastructure Operations

Principal Investigator: Dr. Mohamed El-Darieby, U of R

Objective:
A reliable communication system is key in ensuring field crews can coordinate their work effectively and be responsive to changing events. This project aims at providing a solution for wireless communication among mobile and nomadic infrastructure operators and headquarters. The solution must be reliable, secure, and scalable in terms of both number of users and coverage area. In addition, the solution must provide communication in voice and data formats. The output of this phase of the project will be a report where relevant different wireless technologies are identified, studied and compared. The study will include their availability, operability, and cost effectiveness.

15. A New Approach to Recover Nitrogen from Wastewater as an Organic Fertilizer

Principal Investigator: Dr. G. Lakshman System Ecotechnologies Inc.

Objective:
The activities performed by the proponent will be to conduct laboratory investigations using different ammonia sources such as sewage and hog manure. The proposed technique will use a variety of high

speed nozzles of different flow-through capacities and orifice pressures to produce sparging of dissolved ammonia into a chamber evacuated to different vacuum pressures. The efficiency of ammonia separation will be monitored at various pressure differentials, flow velocities and concentrations of dissolved gases. The effect of chemical parameters such as pH on the efficiency of ammonia separation and the minimum pH for ammonia removal will be determined. The effect of intermittent or pulsed aeration on the expulsion of ammonia from the wastewater will be determined.

16. Infrastructure Asset Management Business Processes

Principal Investigator: Stella Madsen, Engineering and Works, City of Regina

Objective:
The Cities of Regina and Saskatoon are collaborating on studies of current best practices for condition assessment and service levels over the life cycle of underground utilities and internal municipal business practices for improving municipal infrastructure asset management. The two cities have retained VEMAX Management as consultant and NRC-CSIR staff are available to provide expert review.

17. Municipal Infrastructure Investment Planning (MIIP) Consortium Participation

Principal Investigator: Dr. Dana Vanier, NRC-IRC-UI Ottawa

Objective:
MIIP is a project sponsored by a consortium of municipalities and agencies. The Institute for Research in Construction and its MIIP consortium will evaluate existing asset management practices. The work will include the following tasks: survey the state of asset management in Canada and identify existing tools and techniques used to plan, prioritize and schedule maintenance and construction; compare, evaluate, and carry out field trials of those tools and techniques using criteria established by experts; research decision support software (DSS); and build, test and validate a prototype DSS with consortium partners.

18. Sustainable Management of Urban Storm Water Systems

Principal Investigator: Dr. Darryl Dormuth, NRC-CSIR

Objective:
This research program will investigate the factors (such as aging infrastructure, changes in land use, changes in regulatory requirements, and climate change) that could affect the sustainability of effective stormwater drainage in Canadian cities. An important part of this investigation will be the assembling and (if necessary) measuring of data for long-term performance trends of the various drainage components so that the impacts of these factors can be assessed. These data will be used to develop and validate models that will predict the response of stormwater infrastructure to the effects of the above factors. The results of this research will help municipal engineers make the best-informed decisions for the sustainable management of urban stormwater drainage.

Projects Funded Under Previous CT Mandate

1. Engine Conversion from Diesel to Waste Vegetable Oil (Student Project)

Principal Investigator: Josh Dumalski, Ian Rivett, Tania Andrews (U of R)

Objective:
The main goal of the project is to design a waste vegetable oil conversion kit for a diesel direct injection engine to operate within the Canadian climate in both an efficient and economical manner. This project is aimed at using renewable resources, waste vegetable oil, found locally in place of non-renewable petroleum-based, diesel, fuels. The desired output of the project is to have a diesel engine running on filtered waste vegetable oil.

2. Aboriginal Housing Improvement

Principal Investigator: Dr. Rob Dumont, SRC

Objective:
The design and construction of manufactured homes within First Nations communities with both improved durability and measurably reduced energy and environmental impact. The end product will be manufactured homes with both improved durability and measurably reduced energy and environmental impact. At a minimum, the houses will have performance equivalent to the R-2000 standard for energy efficiency. The project will also benefit First Nations communities in their quest for affordable housing with affordable utility costs. Regina First Nations communities will also benefit when these improved houses are built in Regina.

3. Quantifying Social Costs Related to Municipal Infrastructure Rehabilitation

Principal Investigator: Dr. Darryl Dormuth NRC-CSIR, NRC Technical Officer and U of R Ph.D. Candidate Anastassia Manuilova

Objective:
A full cost accounting of several construction projects in Regina and other Saskatchewan cities – these costs to include non-direct costs, such as noise and other health-related effects on residents, potential loss of business & tourism, etc. This will allow decision support tools for municipal policy-makers, senior staff and elected officials to use to compare the full cost of conventional construction methods (trench cut and cover) versus trenchless technologies (e.g. relining of pipes from the inside). Work will be conducted primarily by a Ph.D. candidate of Dr. Huang's working on a term technical officer assignment paid by NRC-CSIR. Other potential collaborators include the Saskatchewan Institute of Public Policy at the U of R and the Department of Social Sciences.