CITY OF TORONTO WATER LOSS STUDY & PRESSURE MANAGEMENT PILOT

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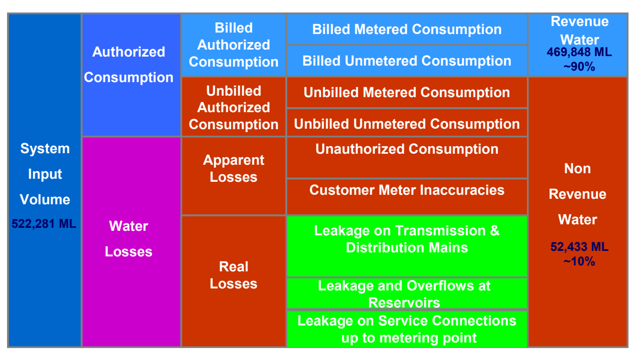
INTRODUCTION

The City of Toronto water distribution system is comprised of over 5,500 km of watermain and services over 464,000 connections. Traditionally, water loss levels have been tracked via a rudimentary Unaccounted-for Water (UFW) analysis which compares the volume of water supplied into the distribution system to the volume of water sold to customers. Historically, this value has varied between 10 to 15% - a figure believed to be reasonably good.

Prior to amalgamation in 1998, many of the former municipalities, comprising the City of Toronto, had active leak detection programs. However, post amalgamation the City of Toronto had eliminated most of the active leakage control program and focused their leak detection efforts more on a reactive program of dealing with reported watermain breaks due to the aging infrastructure. In 2003, the City of Toronto adopted a long-term Water Efficiency Plan (WEP) that identified water loss reduction targets of 19 MLD to be achieved prior to 2011. A more aggressive water loss reduction program was also highlighted in the 2005 Toronto Water Business Plan.



In 2000, a new international best practice for standardizing the terminology and assessment of non-revenue water, and for the determination of water loss performance indicators was introduced by the International Water Association (IWA). This methodology known as the IWA Water Balance was adopted by the Canadian InfraGuide in March 2003 and the AWWA Water Loss Control Committee (WLCC) in August 2003 as the current industry best practice for the assessment of non-revenue water and performance indicators. The AWWA WLCC further recommended that the term UFW no longer be used as an assessment measure or performance indicator for water losses.

Toronto Water, in recognizing the benefits of this new methodology and need to establish a long-term water loss reduction plan to achieve the reduction targets of the WEP, initiated in 2005 a Water Loss Assessment & Leak Detection Study focused on the establishment of a clear economic leakage level and reduction plan to be implemented over a five year period. The following paper provides the details associated with the scope of work and results associated with this study. In addition, specific details on the design, implementation and results of an advanced pressure management initiative are provided.

SCOPE OF WORK

Following a competitive request for proposal process, the City of Toronto selected Veritec Consulting Inc. as their engineering consultant to assist them in the completion of this study. The goal of the project was defined as follows:

> *"To provide the City of Toronto with a long term and sustainable water loss reduction strategy following current industry best practices."*

The project objectives were established as follows:

- Complete a Standard IWA/AWWA Water Audit & Balance
- Complete a Review of Current Practices
- Test & Evaluate Loss Reduction Strategies on a Pilot Basis
- Prepare a Long-Term 5-Year City-Wide Loss Reduction Strategy

In order to achieve these objectives, the project was divided into specific tasks, each implemented individually but for which the results were used collectively to establish the long-term reduction strategy. The tasks were assigned as follows:

- Task 1 – IWA Water Audit for 2004
- Task 2 – Review Existing Practices
- Task 3 – Best Practice Water Loss Strategies
- Task 4 – DMA & PMA Chamber Design
- Task 5 – Pilot Testing of Strategies
- Task 6 – City Wide Program Development
- Task 7 – Overall Project Management
- Task 8 – IWA Water Audits for 2005 and 2006*
- Task 9 – Transmission Watermain Leak Detection Pilot*
- City Staff Training Program
- One Year Maintenance of Permanent PMA

* These tasks were additional scope items added to the project in order to provide supporting information to the City wide program.

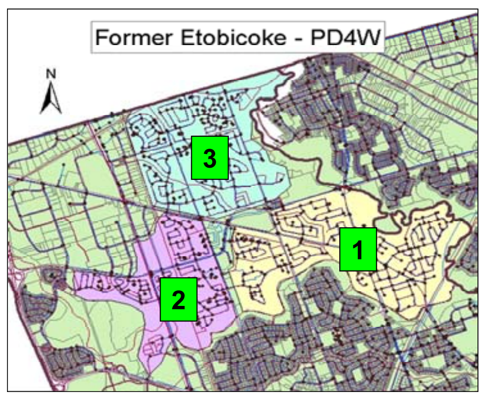
OVERALL STUDY RESULTS

The 2004 water audit and water balance completed as part of the study established the current level of Non-Revenue Water (NRW) and real losses within the City of Toronto. In 2004, Non-Revenue Water was calculated at 52,433,000 m^3 or 10% of the total system supply. From this, the system leakage or real losses were calculated at 103 MLD. This volume of real losses is equivalent to supplying the daily demand of a system servicing a population of approximately 250,000 people or filling over 15,000 Olympic sized swimming pools daily.

In addition to setting the current level of real loss within the system, the project also involved the establishment of temporary district metered areas (DMA) to evaluate the benefits of several real loss reduction strategies.

The DMAs were implemented in two pilot areas – one in the former East York PD2 and one in the former Etobicoke PD4W. The real loss reduction strategies tested included the following:

1. Zone Flow Analysis
   a. District Metered Areas (DMA)
   b. Minimum night flow analysis
   c. Step testing
2. Acoustic Leak Surveys
   a. Basic Hydrant Survey
   b. Comprehensive Survey
   c. Noise and leak mapping
   d. Leak pinpointing & correlation
3. Acoustic Noise Logging
   a. Basic Noise Logging
   b. Correlating Noise Logging
4. Pressure Management
5. Transmission Main Leak Detection



The testing revealed that the most economic and effective strategies include basic hydrant acoustic surveys with minimum night flow analysis and pressure management. As for leak pinpointing, the preferred tools included leak noise correlators with supporting use of noise logging correlators.

During the implementation of the pilot DMAs and real loss reduction strategies, a total of 8 leaks were located and repaired for a total savings of 0.2 MLD.

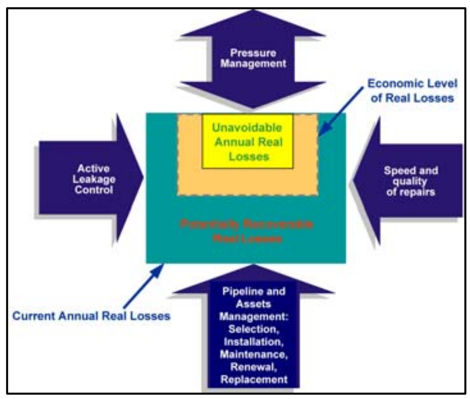
PROPOSED CITY WIDE WATER LOSS REDUCTION PROGRAM

Following the implementation of the various water loss reduction programs, the determination of the current level of real losses and the segregation of real losses into their individual components of background, reported and unreported leakage, an economic leakage level (ELL) analysis was completed.

The ELL evaluation determined that the most appropriate and cost effective measures for the City of Toronto to implement on a City wide basis include:

- Active leakage control program – comprised of routine hydrant sounding and leak pinpointing surveys.
- Improved awareness, location and repair times of reported leaks.
- Large scale pressure management program covering approximately 50% of the entire distribution system.
- Temporary DMA implementation with minimum night flow analysis.

With the appropriate level of intervention utilizing the real loss measure listed above, an economic leakage level benchmark ILI of 2.5 is an achievable goal for the City of Toronto. This reduction in real losses equates to 49 MLD in real loss savings (exceeding the WEP target) with an estimated 4.1 to 1 benefit to cost ratio. In order to achieve this target saving, the City will require an investment of approximately $14M over the next five years, however within the first three years of the program; the net benefits will outweigh the programs costs with the final benefit to cost being achieved at the end of the fifth year.



Benefit to cost will increase to 6.3 to 1 over a ten year horizon as the continuation of the water loss reduction program will incur only ongoing maintenance costs associated with the implemented measures with limited additional capital expenses.

PRESSURE MANAGEMENT PILOT – EAST YORK

Pressure management has been identified as an important measure for the long term reduction of real losses in the City of Toronto. The principle behind pressure management is quite simple – lower system pressures during periods of lower demands (when system pressures normally rise) and reduce the flowrate from existing background leakage (those small weeping leaks from fittings and joints). An additional benefit of pressure management is the related reduction in watermain break frequencies which in turn help to extend the life of the underground infrastructure.

As part of the Water Loss Assessment and Leak Detection Study, the City of Toronto was to implement two pressure management areas (PMA) utilizing an advanced scheme of flow modulation, one PMA in each of the selected pilot areas within East York and Etobicoke. The East York pilot PMA was successfully implemented during the summer and fall of 2007 and the Etobicoke PMA is currently in final stages of construction and commissioning.

The remainder of this paper addresses the stages of design and implementation as well as the results of the PMA pilot in East York.

Pressure Management Area Design

There are several stages associated with the design of a pressure management area. The primary tasks include the following:

1. Selecting hydraulic boundary of PMA.
2. PMA demand analysis including fire flow requirements.
3. PMA flow and pressure field measurements.
4. Selection and sizing of pressure reducing valves.
5. Selection of type of control and control limits.
6. Civil design of PRV and metering chambers.
7. Estimating expected leakage savings.

Figure 1 below provides an overview of the selected PMA boundary in East York.

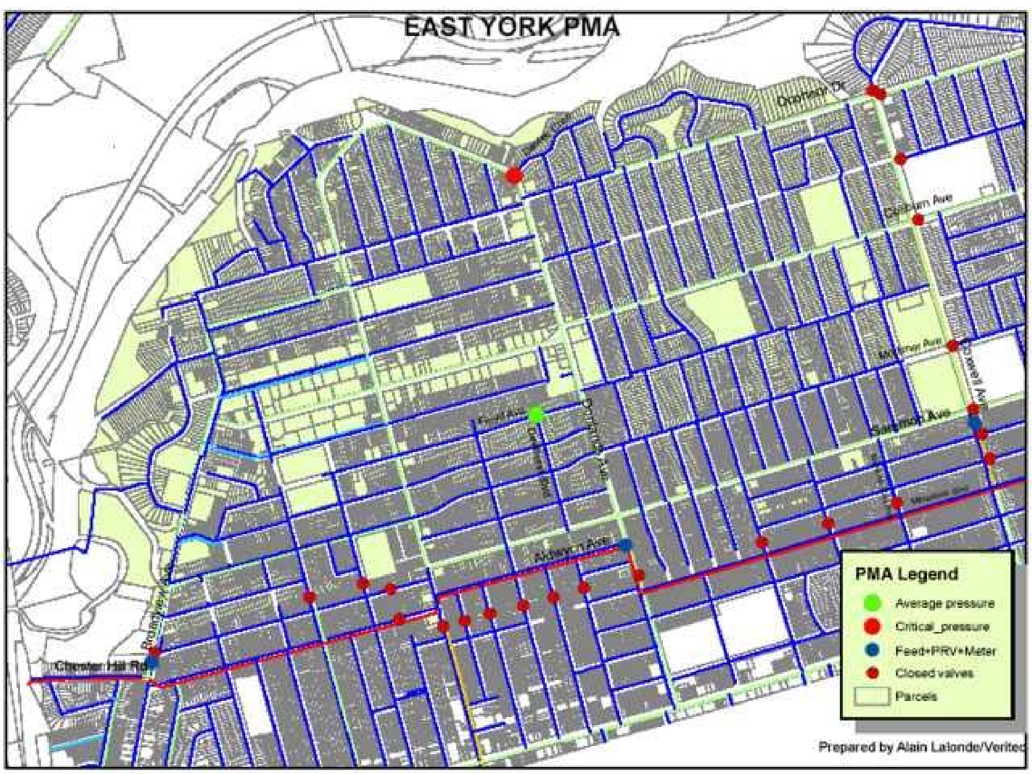


Figure 1 - East York Pressure Management Area Schematic

The following table illustrates the characteristics of the PMA in East York. This information is critical in the demand analysis and also in the evaluation of minimum night flow to assess the current level of background leakage to determine potential control limits and expected savings from flow modulation.

Table 1 - East PMA Characteristics

Component	Value
Total length of watermains	51.7 km
Total number of services	7290
Total number of hydrants	415
Number of closed valves	25
Average system pressure	58 psi
Minimum system pressure	52 psi
Maximum system pressure	68 psi

The East York PMA encompasses the entire portion of pressure district 2 in the former East York and as such, this area had been previously segregated into an area supplied by three metered connections to the former Metro Toronto transmission system. During the implementation of the temporary DMA in East York, the existing meters servicing this area were datalogged to obtain the demand characteristics of the area. A minimum night flow analysis was conducted and proper sizing and assessment of the required pressure reducing valves was completed to ensure peak demand and fire flow requirements can be met at all times.

The demand analysis determined that all three existing supply points need to be maintained to meet maximum demand plus fire flow requirements but that only one supply point needed to be utilized during normal demand periods. As such, the sizing and selection of PRVs was determined as being 300 mm (12”) reduced port PRVs at each of the three supplies to the PMA. The area would be supplied by a master PRV during normal demand periods with two supporting slave PRVs set to open during peak demand and fire flow conditions.

The preferred control methodology selected for pressure management in this area was flow modulation. The principal of flow modulation is to adjust the PRV outlet pressure based on the demand in the PMA. As demand rises, the PRV is adjusted such that the outlet pressure is increased. During low demand periods, such as during the nighttime period, the PRV outlet pressure is lowered in order to reduce the flowrate of background leakage. Flow modulation is preferred as pressures are adjusted based on demand which offers the best option for systems requiring fire flow capacity.

In most flow modulated pressure management installations, the standard components include a flow meter providing a pulse output to a battery operated controller which in turn sends a hydraulic control signal to the PRV in order to adjust pressure based on the flow signal. The issue associated with this approach in East York is that in order to reduce the construction and installation costs associated with constructing a new metering and PRV control chamber, the project team was considering options available for utilizing the existing Metro meter chambers. The size of the existing chambers made it impossible to utilize the traditional meter and PRV assembly and therefore an alternate solution was needed.

Following enquiries made to the PRV manufacturers, a suitable solution was provided by Cla-Val Canada Inc. and their distributor Devine & Associates which included a fully automated flow metering and modulating PRV. The advanced pressure management valve includes a basic PRV coupled with a differential pressure transducer and valve position indicator used to determine the corresponding flow through the valve with the e-flow calculator and providing the flow signal to the e-smart flow modulated controller which signals the e-drive servo motor controller to adjust the PRV outlet pressure based on the demand in the PMA. The solution was totally provided by Cla-Val and although each of the components had been successfully implemented and trialed in the field independently, the use of all the components on the same valve in order to achieve a fully flow modulated PRV assembly was the first of its kind in North America. It must be noted that having existing power with SCADA connections in the existing metering chambers made these installations even more cost effective. The following figures illustrate the PRV assembly with all the components as well as the control assembly wiring diagram.

Figure 2 - Cla-Val Flow Modulated PRV Assembly

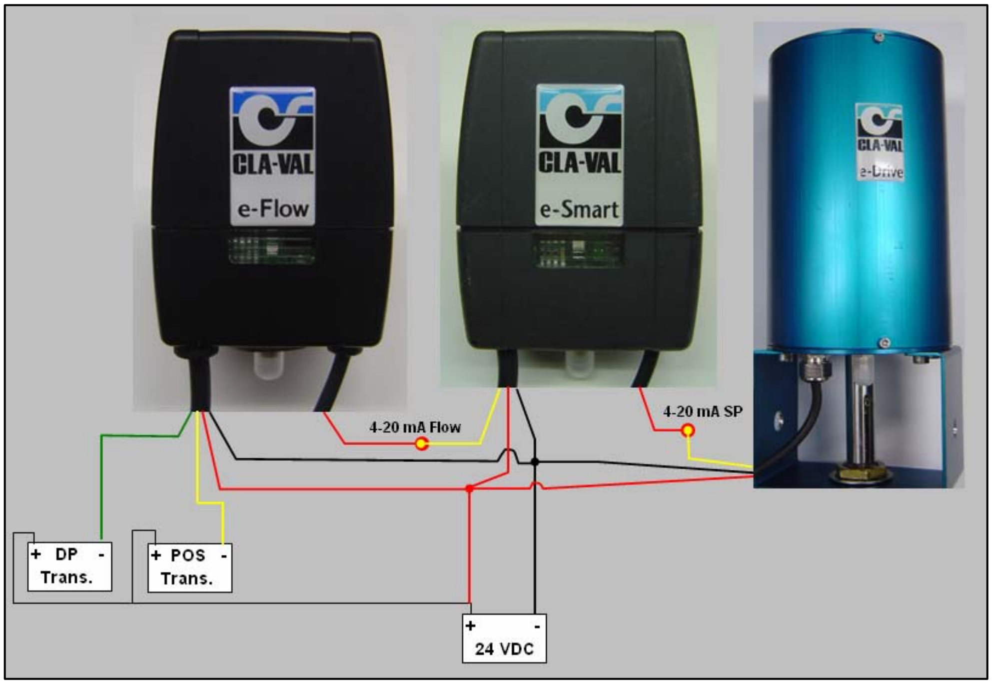


Figure 3 - Cla-Val Flow Modulation Controller Wiring

Following the selection of the flow modulation control system, a mechanical design of the PRV installation into the existing Metro metering chambers was completed. The following figure illustrates one of the three mechanical designs showing the existing twin turbine assembly and the proposed re-configuration of the chamber to accommodate the PRV and strainer assembly.

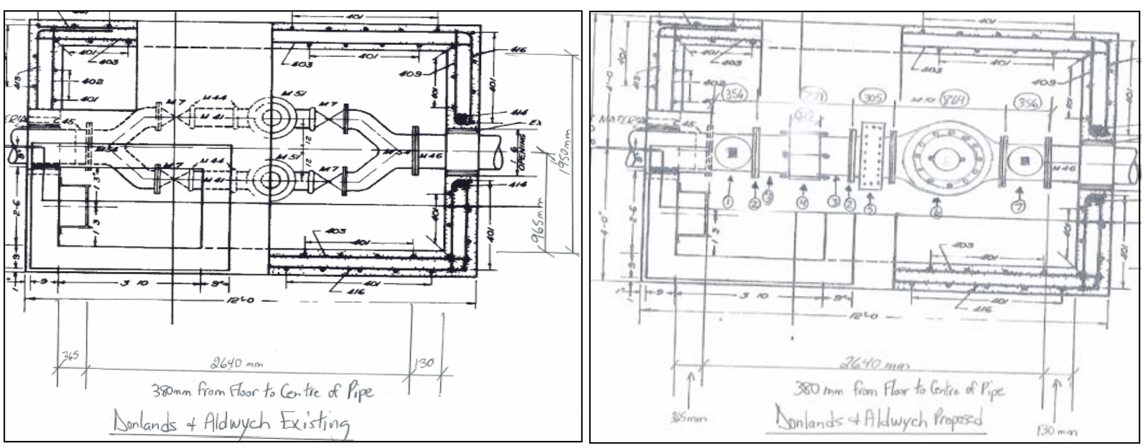


Figure 4 - Donlands & Aldwych - Existing & Proposed Chamber Configuration

PMA Implementation & Commissioning

The first stage of the implementation of the PMA was to complete the PRV installations in the existing chambers. The mechanical installations were completed by City operational staff during June and July 2007. It should be noted that although all precautions were taken during the design process, some issues associated with pipe alignment were encountered during installation. However these issues were easily resolved and installations were successfully completed.

The following figure illustrates the Donlands and Aldwych PRV installation. Please note that an additional expansion joint was utilized in order to accommodate the deflection between the existing metering chamber flanges.

Figure 5 - Donlands & Aldwych Flow Modulating PRV Installation

The next stage of implementation included the installation of the control panel and wiring for the PRV. The PRV control panel provides for isolated output signals of flow, inlet pressure and outlet pressure to be recorded both locally and utilizing the City's existing SCADA network. The figure below shows the control panel assembly and wiring strip.

Figure 6 - PRV Control Panel & Wiring Strip

With the PRV and control panel installed, each PRV was commissioned and tested. The flow signal was calibrated and the PMA area isolated in order to obtain the current demand profile. The PMA was left in a fully non-pressure managed state for a period of one week in order to obtain the baseline flow and pressure information from all three supply points.

The collected information was used to establish the control limit parameters for each supply point such that one master PRV was programmed in full flow modulation mode with the other two valves programmed as slaves in order to support peak demand and fire flow requirements.

The entire pressure management scheme was successfully launched in late October 2007 following two trial and adjustment periods and has been fully operational since.

PMA Results – East York Pilot Area

In order to establish the volumetric savings associated with the reduced flowrate from existing background leakage, a no-control vs. control flow profile was established and compared. The following graph illustrates the results of this comparison. The resulting profiles show a distinct reduction in minimum night flow from the reduce leakage. In addition, during morning peak demand periods, the outlet pressure of the PRV closely matches the pressure recorded during no control (or no pressure reduction) to ensure sufficient pressure when needed. Pressure savings during the minimum night flow exceed 12 psi or a 20% reduction from an open system.

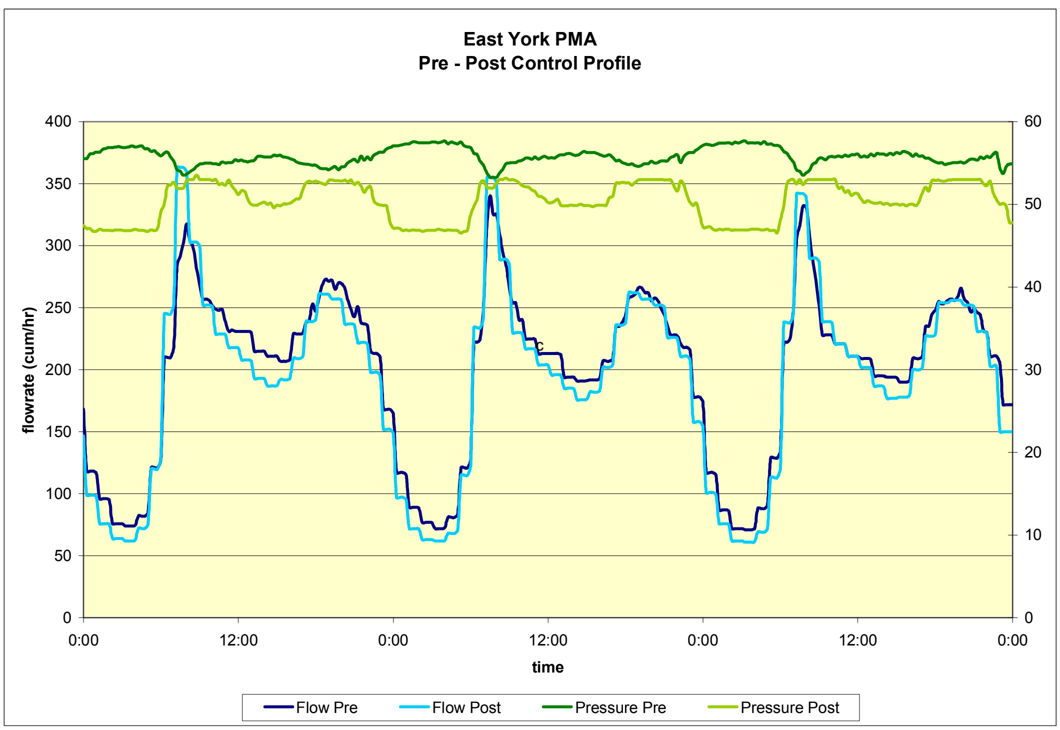


Figure 7 - No-Control vs. Control PMA Flow & Pressure Profile

The following table provides the calculated results from the PMA implementation.

Table 2 - East York PMA Savings Comparison

	PMA Demand	Leakage Component of PMA Demand	Daily Average Zone Pressure
Pre-Control	4747 m^3/day	616 m^3/day	58 psi
Post-Control	4575 m^3/day	444 m^3/day	50 psi
Savings	**172 m^3/day**	**172 m^3/day**	**8 psi**
Percentage	**3.6 %**	**27.9 %**	**13.8 %**

In addition to the leakage flowrate savings, in must be noted that there is a clear indication that the area is also experiencing a reduction in watermain break frequency. Historical watermain break information for this area between 2000 and 2005 shows an average watermain break frequency of 6 to 8 watermain breaks per year with most of these breaks occurring between the period of November to March. Although the PMA has only been in service since October 2007, there have been no recorded watermain breaks within the PMA boundary. This is further qualified by the fact that watermain breaks outside the PMA boundary have occurred during the same period. Although not fully conclusive yet, the information collected to date is highly supportive of the watermain break reduction assessment. Extensive monitoring of this location will continue for an additional year under this contract.

Based solely on water savings, the calculated simple payback period of the East York pressure management area is 4.5 years. With the added benefit of the reduction in watermain breaks, the payback is further reduced to less than 4 years. With an expected life cycle of 25 years for these installations, the life cycle benefit to cost ratio is over 3 to 1.

CONCLUSION

In conclusion, the City of Toronto Water Loss Assessment & Leak Detection Study has successfully assisted the City in understanding the current level of real loss in their water distribution network and identifying a cost effective long term reduction program. The City is currently evaluating the best options for implementation of the proposed plan and is likely to initiate a full roll out program starting in 2009.

In addition, the study also illustrated the benefits of pressure management with respect to water loss control and infrastructure management. Pressure management can and is a valuable tool to achieve targeted water loss reduction levels and to extend the life of your underground infrastructure.