ONTARIO CENTRE FOR MUNICIPAL BEST PRACTICES

200 University Ave., Suite 801, Toronto, Ontario, M5H 3C6

BEST PRACTICE SUMMARY REPORT

February, 2008

Water and Wastewater

WATER LOSS MANAGEMENT – CATHODIC PROTECTION

Abstract:
The Region's fully developed and implemented Cathodic Protection Program has proven to be a cost effective method of reducing water main breaks, associated water loss and of protecting and extending the life of pipes. The program is also reviewed annually through the Annual Cathodic Protection Report. This report describes the Region's program which includes hot spot, reactive, proactive and monitoring system program elements.

Additional information regarding water loss management and the OMBI Water and Wastewater Expert Panel 2007 Business question for which this report has been written can be found in the Project Approach and General Water Loss Management Practices documents.

Practice Identification: Water and Wastewater

Case Study Municipality:
- Region of Durham

Municipal Profile:

Municipality	**Region of Durham**[1]
Population	528,514 (Based on the Water Service Population)
Water Distribution	2,324 km of watermains with 149,452 service connections, and 20 pump stations
Wastewater Collection	1,998 km of sanitary sewers, with a total of 136,234 sewer service connections, and 51 pump stations

[1] Municipal Profile is based on 2006 Data

Water Treatment Plants	Population Served	Average Day Demand (ADD)
Ajax	188,028	48.27 ML/day from Lake Ontario
Oshawa	174,571	59.41 ML/day from Lake Ontario
Whitby	101,354	68.68 ML/day from Lake Ontario
Beaverton	3,782	1.25 ML/day from Lake Simcoe
Bowmanville	32,813	11.72 ML/day from Lake Ontario
Newcastle	8,118	2.34 ML/day from Lake Ontario
The Wells	24,905	6.95 ML/day
Wastewater Treatment Plants	**Population Served**	**Annual Average Flow (AFF)**
Lake Simcoe	3,697	2.05 ML/day
Uxbridge	9,634	2.91 ML/day
Nonquon	8,900	3.51 ML/day
Newcastle	7,694	2.63 ML/day
Port Darlington	31,885	12.14 ML/day
Harmony Creek	153,000	57.77 ML/day
Corbett Creek	88,442	54.06 ML/day
Pringle Creek	27,811	9.49 ML/day
Duffin Creek	920,653 (includes York's serviced population)	373.26 ML/day

Key Words:
- Water Loss Management, Water Audit, Non-Revenue Water, Watermain Breaks, Asset Management, Cathodic Protection

Related National Benchmarking Goal(s):
- Operate a Reliable and Sustainable Water Infrastructure
- Meet Service and Performance Requirements at Sustainable Cost
- Environmental Protection

Related Performance Measures:
- Operating Cost ($000's) / Megalitre Treated Water
- Megalitres of Water Treated per 100,000 population
- Operating Cost of Water Distribution per km of Water Distribution Pipe
- Number of Watermain Breaks per 100 km of Distribution Pipe
- Average Day Utilization of Individual Water Treatment Plants
- Peak Utilization Rate of Individual Water Treatment Plants
- Litres of Non-Revenue Water per connection per day
- Cubic meters of non-revenue water per km per day (Transmission System)
- 5 Year Running Average Capital Reinvestment / Replacement Value
- Infrastructure Leakage Index (ILI)

Related InfraGuide Best Practices:

- Water Use and Loss in Water Distribution Systems

Description of Case Study

In 1983, the Region of Durham completed a pilot study on the installation of cathodic protection on existing ductile iron watermains in Ajax. The successful results of the study spurred the development of the Region's annual Cathodic Protection Program.

The program includes the following annual activities:

- Prioritization of areas where the Cathodic Protection Program will be implemented
- Pre-Anode Surveys to record existing conditions
- Soil sampling to determine electrical resistivity, pH, amount of sulphides, and moisture content in soil surrounding pipes
- Supply and Installation of Anodes
- Post-installation surveys and documentation of survey results .
- Inspection and maintenance of the Anodes, on a 3-year cycle

Cathodic protection utilizes sacrificial anodes to minimize the effects of external corrosion on existing ferrous watermains, valves and hydrants. The sacrificial anodes are installed underground and are connected to watermains by insulated copper wires. The placement of the anode allows for the anode to corrode instead of the watermain or appurtenance to which it is connected. Installation of several anodes along a pipe is required as each anode is only effective over a relatively short range of pipe length. The temporary corrosion prevention system reduces watermain breaks caused by corrosion, extending the life of watermains. The anode can extend the life of an existing water main by 10 to 20 years at a fraction of the replacement cost. Typically, 35-50 anodes can be installed per day which could cover an entire watermain that services a residential street.

The Region's cathodic protection strategy first consisted of hot spot and reactive programs to combat the areas most seriously affected by corrosion in the Region through an asset management and maintenance approach. Although the goal of the initiative was not based on water loss management, its asset management approach provided a key tool for reducing water loss. With great success, the program quickly evolved into a preventative maintenance program for ductile iron and cast iron pipes, and has expanded to consist of hot spot, reactive, proactive and monitoring system programs.

<u>Hot-Spot Program</u>

The Hot-Spot Protection Program entails the investigation of existing watermains which have been affected by corrosion in the past and the installation of cathodic protection. The Hot-Spot Program, implemented in 1983 through the Cathodic Protection Program, is a maintenance tool which provides cathodic protection to slow the deterioration of ferrous watermains throughout the Region, reduce watermain breaks, inconvenience to customers and increase the security of the water supply and, allow for an increased level of service. Watermain history, break data, and requests received from Regional Depot staff illustrate that the hot-spot protection program continues to provide a means of reducing the amount of emergency watermain repairs, and is ultimately delaying the replacement of protected watermains throughout the Region. In addition, the program has aided in reducing service disruptions, and high, unexpected restoration costs which are typically associated with the replacement of watermains.

Reactive Program

Due to the positive outcome of the annual Cathodic Protection Hot-Spot Program, the Region adopted a reactive program. The Reactive Program requires anodes to be placed on all ferrous watermains in which a break has occurred. The anode is installed when a ruptured ferrous watermain is excavated and repair work is carried out. This program is now a service level standard for the Region of Durham on both regional watermains and private water services.

Non-Ferrous Watermains

To aid in Durham's efforts to maintain and prevent further corrosion of the Region's watermains, a moratorium was issued in 1985 on the use of iron pipes; the moratorium prevents installation of corrosion prone iron pipes. PVC material was designated for watermains which had diameters under 400mm. All remaining ferrous components of the distribution system (valves, hydrants, fittings, and tracer wire), which are susceptible to corrosion, are cathodically protected ensuring durability, and increasing their life expectancy.

Proactive Program

Coinciding with the Hot-Spot Program, the Proactive Program was initiated to proactively protect watermains; cathodic protection is installed on mains that do not have a history of corrosion but are in areas where other pipes have been impacted by corrosion.

For new construction, the cost of cathodic protection (approximately $230/ location) is included in the Unit Cost for the various components of the distribution system that are part of a contract.

Monitoring Program

The subsequent monitoring program ensures that the cathodic protection system has been installed and continues to provide the level of service and protection for which it has been designed. The Region also conducts annual measurements prior and post installation of the cathodic protection system.

In order to ensure that the data available for monitoring and designing the cathodic protection systems is accurate and deficiencies within the system are found, the Region conducts corrosion potential surveys on a five year cycle. The survey is important to maintain the existing cathodic protection system and also increase the levels of service.

The installation of anodes on watermains for hot-spot and proactive cathodic protection involves three steps to ensure minimal required restoration as follows:

- The first step comprises of the excavation of an area in which a small diameter circle of existing sod is removed
- A hole is excavated at the top of the target watermain
- The second step involves the installation of a magnesium anode which is cad welded to the watermain pipe
- The third step involves backfilling the excavated area
- Standard backfilling compaction with native material or sand is used if the area was vacuum excavated
- After backfilling the excavated area, the sod cap is then reinstated
- Following installation, anodes are attached to an above ground test station so that the effectiveness of the installed anode can be measured
- Residents on the selected street are notified within 48 hours of excavation by way of a letter delivered to their door

Currently 193 kilometers of watermain has been cathodically protected, approximately 25% of ductile iron and cast iron watermains, using 17,032 anodes and 1,330 test stations in the Durham Region. Asset inventories show that Durham's system has of 124 kilometers of ductile iron watermains and 68 kilometers of cast iron. Ten kilometers of the ductile iron and one kilometer of cast iron watermains have been replaced with non-ferrous pipes primarily in conjunction with local road reconstruction.

While the Region's Cathodic Protection Program has been proven to extend the life expectancy of watermains, the Region still acknowledges that planning for and budgeting for the inevitable need to eventually replace these watermains is required. As such, the Region has established a special Asset Management Reserve Fund for watermain replacement work based on 3% of the previous year's user rate revenues into a reserve fund. In 2007 this equated to $2,076,000 for distribution assets.

Benefits

- Slowed deterioration of ferrous watermains throughout the Region
- Reduced watermain breaks
- Reduction of water loss
- Reduction of emergency repairs due to corrosive breaks of ferrous watermains and the delay of replacements of the water distribution system assets.
- Reduced inconvenience to customers
- Increased security of the water supply
- Increased level of service.

The cathodic protection system is a cost effective maintenance tool as it needs only to be replaced several years after its first installation without imposing service interruptions or watermain replacement. The introduction of the program has dramatically reduced the frequency of watermain breaks on ferrous watermains from approximately 100 breask/year in 1983 to 25 breaks/year in 2005. This has resulted in costs savings for corrosion repairs in the range of $3,400,000 to $10,500,000 between 1983 and 2005 based on an estimated number of break which could have occurred if cathodic protection was not installed. These costs are demonstrated in further detail in the figure below.

COST COMPARISON OF WATERMAIN BREAKS REPAIRED BEFORE AND AFTER CATHODIC PROTECTION

NOTE: THE FOLLOWING COSTS ARE EXPLAINED IN TABLE 4-B

		Total Corrosive Break Costs (Actual Costs)		Additional Corrosive Break Costs (Conservative Estimate)		Additional Corrosive Break Costs (Non-Conservative Estimate)	
Budget Year	Average Cost per Break	# of Breaks / Year	Estimated Repair Cost	# of Breaks / Year	Estimated Repair Cost	# of Breaks / Year	Estimated Repair Cost
1983	$1,216	98	$119,181	0	$0	0	$0
1984	$1,579	103	$162,628	58	$91,577	118	$186,311
1985	$1,659	104	$172,529	116	$192,436	236	$391,508
1986	$1,852	70	$129,672	174	$322,327	354	$655,768
1987	$2,044	88	$179,858	232	$474,171	472	$964,694
1988	$2,197	76	$166,952	290	$637,055	590	$1,296,077
1989	$2,346	61	$143,087	348	$816,300	708	$1,660,749
1990	$2,686	51	$136,966	406	$1,090,357	826	$2,218,312
1991	$2,427	48	$116,475	464	$1,125,925	944	$2,290,675
1992	$2,762	47	$129,822	522	$1,441,850	1,062	$2,933,419
1993	$3,510	45	$157,956	580	$2,035,883	1,180	$4,141,968
1994	$4,496	40	$179,824	638	$2,868,194	1,298	$5,835,292
1995	$3,909	42	$164,166	696	$2,720,462	1,416	$5,534,733
1996	$3,957	21	$83,096	754	$2,983,529	1,534	$6,069,938
1997	$3,892	51	$198,508	812	$3,160,558	1,652	$6,430,100
1998	$5,404	38	$205,348	870	$4,701,380	1,770	$9,564,876
1999	$3,778	31	$117,116	928	$3,505,924	1,888	$7,132,741
2000	$4,170	37	$154,283	986	$4,111,435	2,006	$8,364,644
2001	$2,930	32	$93,764	1,044	$3,059,058	2,124	$6,223,601
2002	$3,919	26	$101,901	1,102	$4,319,014	2,242	$8,786,959
2003	$5,119	20	$102,370	1,160	$5,937,460	2,360	$12,079,660
2004	$3,611	30	$108,315	1,218	$4,397,589	2,478	$8,946,819
2005	$5,303	28	$148,479	1,276	$6,766,405	2,596	$13,766,134
Total Additional		**1,187**	**$3,272,295**	**1,276**	**$6,766,405**	**2,596**	**$13,766,134**

Please Note: This table is representative of the breaks which occurred on all streets, which have been cathodically protected (1983-2005), during the corresponding budget year.

The system has been successful, reliable and a cost effective method of minimizing the effects of external corrosion and extending the life expectancy of the watermains.

In terms of water loss reduction, a reduction in breaks also translates into cost savings in terms of water treatment. A single break with a flow rate of 1500L/hr left undetected for one year can cost a municipality approximately $920 utilizing a marginal cost of water production of $0.07/m^3$. In 1983 when the program was first implemented the Region was experiencing approximately 100 known breaks per year as a result of corrosion. In 2005 there were 28 known corrosive breaks; a reduction of 72 breaks.

Efficiency

The efficiency of the cad weld system contributes to the cost effectiveness of the cathodic protection program. Using the cad welding system, 35-50 anodes can be installed per day which can cover an entire watermain that services a residential street

The approximate cost of replacing all ferrous watermains that are now cathodically protected is $135,400,000 (including watermains, connections, valves, hydrants, and engineering, contingency, and general item costs). The delay of replacement or avoidance of replacement provides a greater return on the Region's investment. This can be seen in the fact that the total cost to cathodically protect watermains throughout the

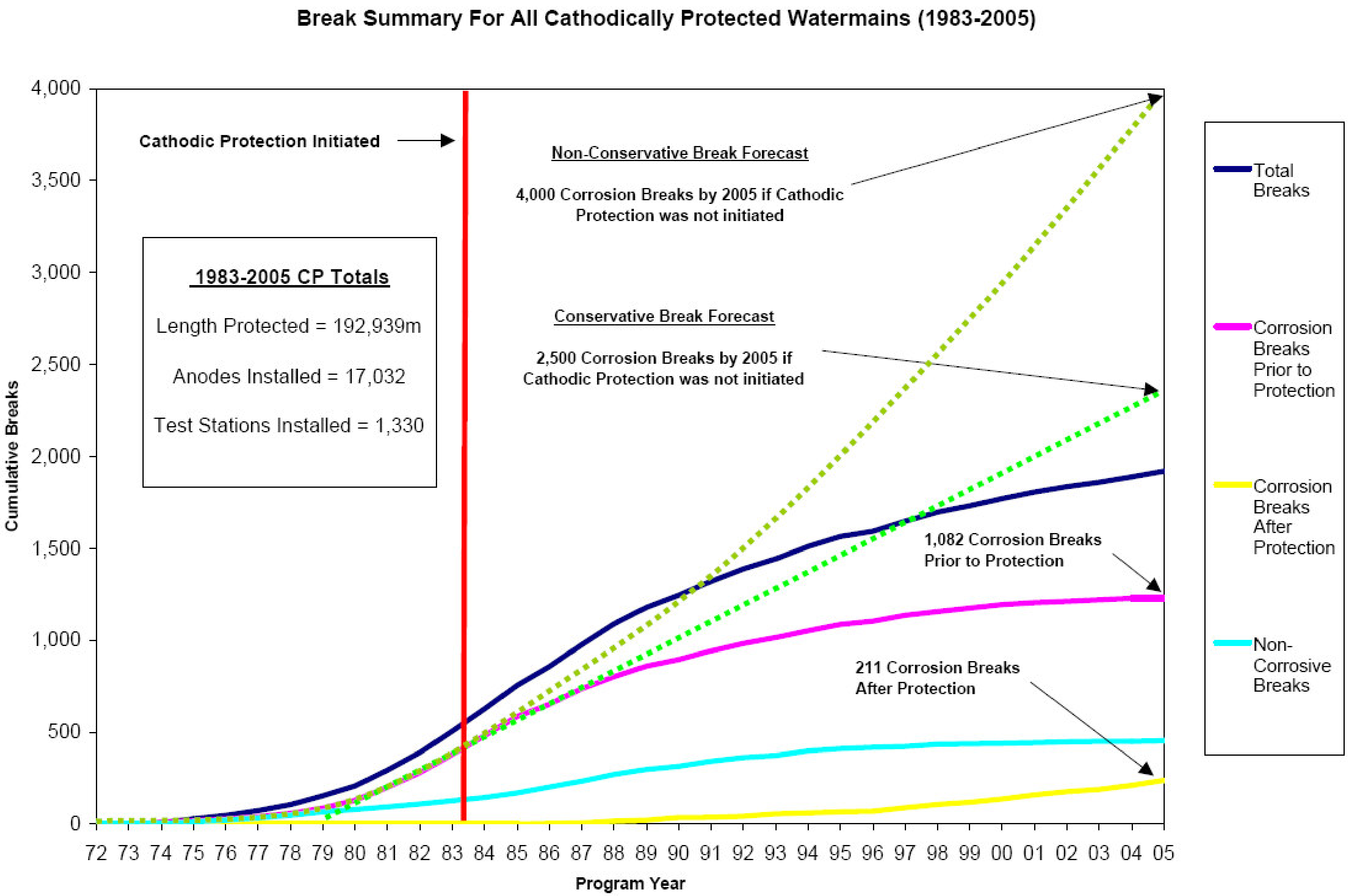
Region between 1983-2005 is approximately $5,120,000 which is less than 4% of the cost of replacement.

Effectiveness

The frequency of corrosion breaks between the cathodically protected watermains and the frequency of breaks on these pipes had they not been protected were compared. Two estimates were established to determine the frequency of corrosion breaks that would have occurred on protected pipes had they not been protected. The estimates were achieved by graphing trend lines based on actual break totals experienced for cathodically protected pipes.

A conservative estimate was determined assuming that the rate of corrosion would not increase or decrease over time. A non conservative estimate was also prepared which assumed the rate of corrosion would be compounded and increased over time.

The results as illustrated in the figure below indicate that the frequency of corrosion breaks on protected watermains was drastically reduced since the initiation of the Cathodic Protection Program in 1983. A conservative estimate of 2500 corrosive watermain breaks on protected water mains and the non conservative estimate of approximately 4000 corrosive watermain breaks on protected streets had protection not been installed indicates the advantage of investing in pipe protection.


Break Summary For All Cathodically Protected Watermains (1983-2005)
Cathodic Protection Initiated
Non-Conservative Break Forecast
4,000 Corrosion Breaks by 2005 if Cathodic Protection was not initiated
1983-2005 CP Totals
Length Protected = 192,939m
Anodes Installed = 17,032
Test Stations Installed = 1,330
Conservative Break Forecast
2,500 Corrosion Breaks by 2005 if Cathodic Protection was not initiated
1,082 Corrosion Breaks Prior to Protection
211 Corrosion Breaks After Protection
Total Breaks
Corrosion Breaks Prior to Protection
Corrosion Breaks After Protection
Non-Corrosive Breaks
Cumulative Breaks
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05
Program Year

Community or Environmental Outcomes

Customers are more assured that their water distribution system is safe and reliable with minimum inconvenience of water shut-offs and roadwork resulting from watermain breaks.

Statutory Requirements
None

Replication of the Case Study
The Cathodic Protection System endorsed by the Durham Region is a cost effective water loss reduction and asset management initiative. It is suited for municipalities in which ferrous pipes are present in potentially corrosive soil. Ferrous pipes are prone to corrosion due to the potential difference between the material and the soil. The appropriateness of this program can be determined through assessing the watermain pipe inventory characteristics and the type of soil to which it is exposed. Once ferrous pipes have been identified they can then be tested for corrosive damage. The hot spot and proactive programs are the first steps in slowing the process of deterioration and protecting those pipes that have not experienced corrosion but are in close proximity to pipes that have a break history due to corrosion. The reactive program addresses the implementation of cathodic protection on pipes in which breaks have already occurred. The subsequent monitoring program ensures that pipes continue to be adequately protected.

Other OMBI Members that have implemented this practice:

City of Ottawa
The City of Ottawa began a cathodic protection program in 1990. With 1,750 kilometers of cast iron and ductile iron pipes installed between 1874 and 2002, the cathodic protection program has resulted in clearly observed decreases in breakage rates. The figure below ("Gloucester and Cumberland Failure History as Cathodic Protection is Applied") demonstrates the comparison of failures prior and post anode installation in an area of Ottawa with approximately 200 kilometers of metallic watermains. The second figure below ("Number of Main Line Breaks, Actual and Trend") provides the overall break history as the cathodic protection program was implemented for the entire City.

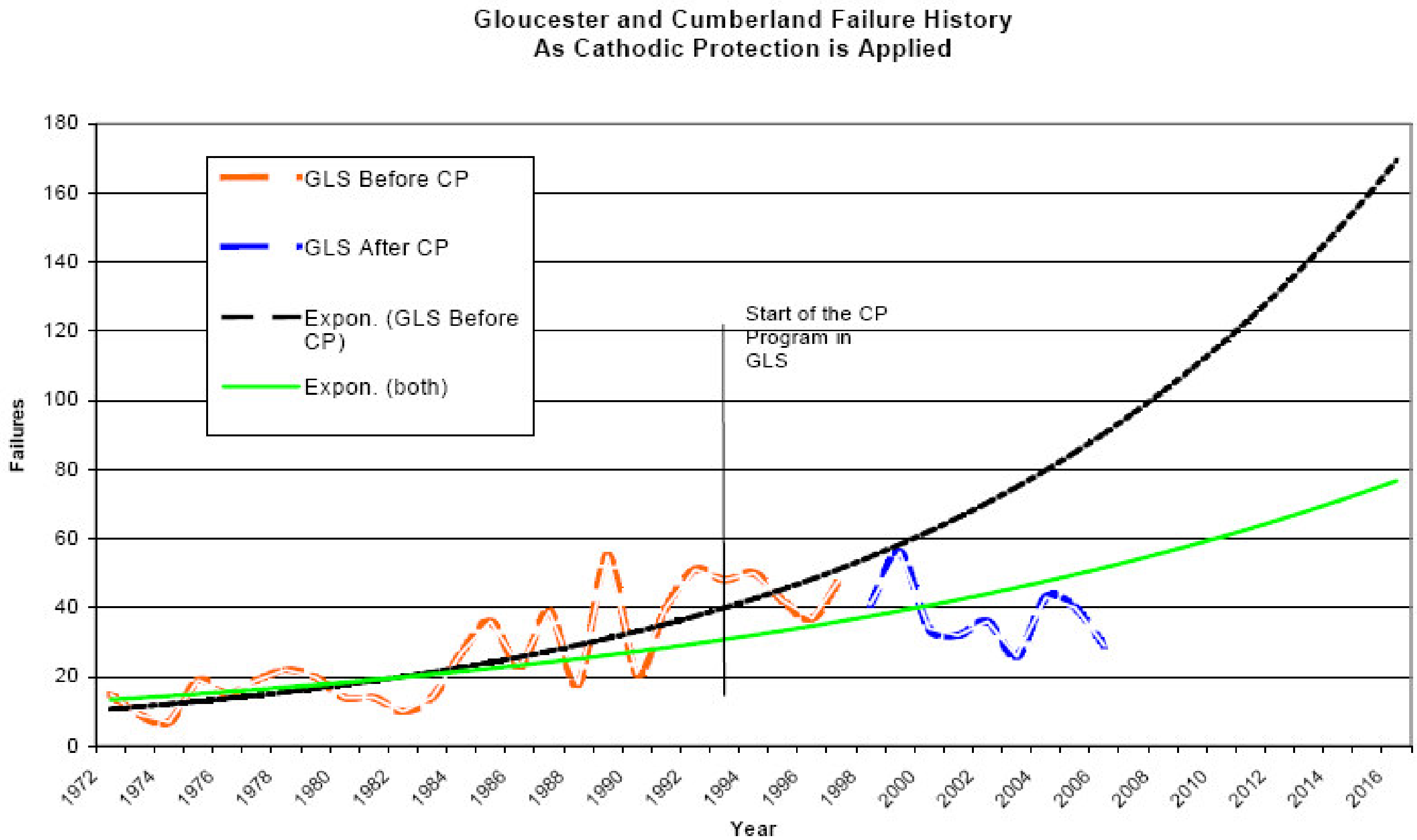
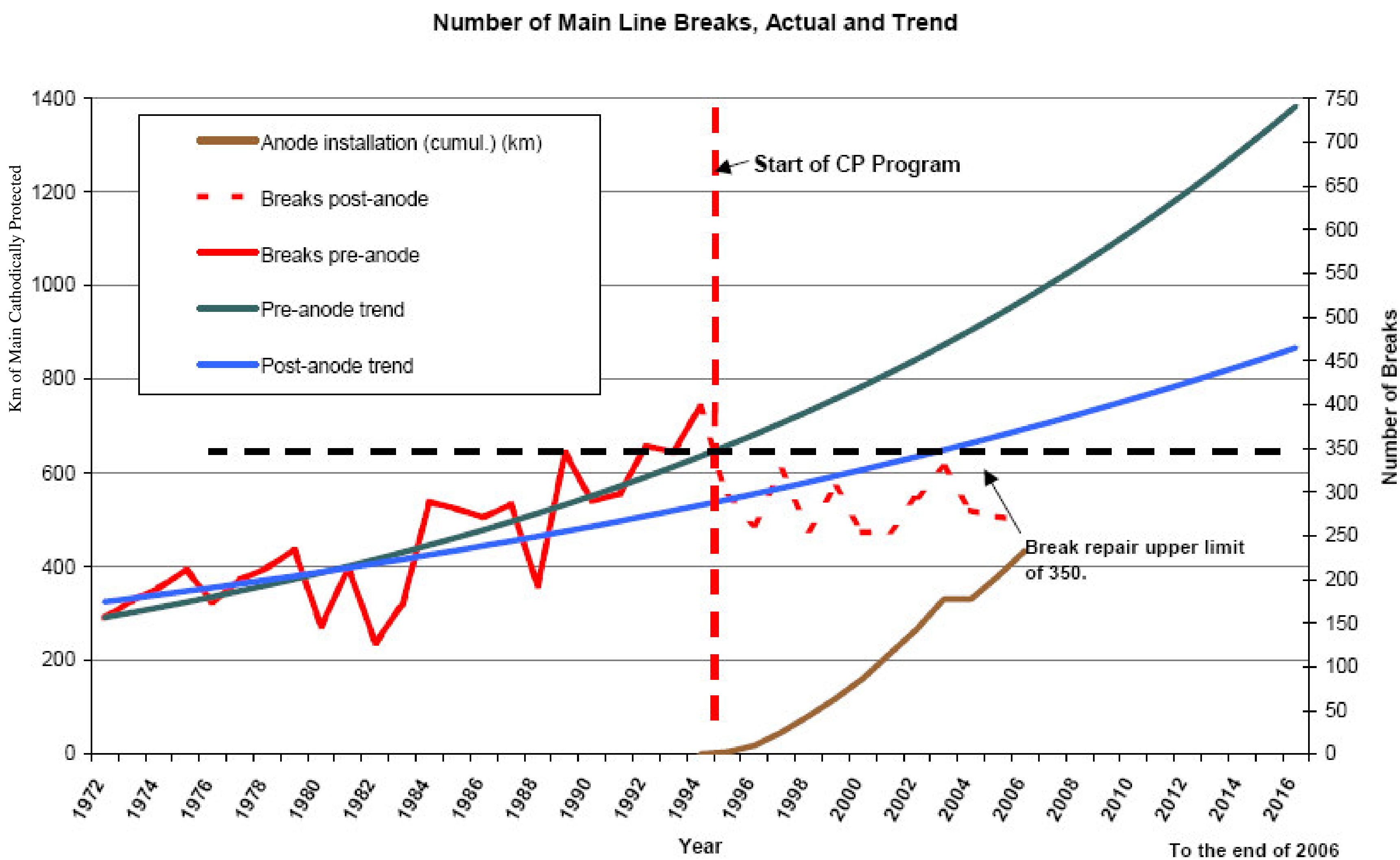


Figure 11, Part of the City of Ottawa (formerly the City of Gloucester)


Number of Main Line Breaks, Actual and Trend
Km of Main Cathodically Protected
Number of Breaks
Anode installation (cumul.) (km)
Breaks post-anode
Breaks pre-anode
Pre-anode trend
Post-anode trend
Start of CP Program
Break repair upper limit of 350.
0
200
400
600
800
1000
1200
1400
0
50
100
150
200
250
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2014
2016
Year
To the end of 2006

City of Toronto

The City of Toronto has also implemented cathodic protection for approximately five years and like Ottawa and Durham has observed that the lives of pipes are being extended. Currently the practice is to cathodically protect pipes based on age as well as to protect all new pipes. The cost of cathodic protection is marginal which in itself justifies the cost of cathodic protection.

City of Thunder Bay

Thunder Bay has a program to prevent and decrease corrosion rates on existing infrastructure. Cathodic protection is being used on new and existing systems. Every mechanical joint, all fittings on non ferrous mains and copper services are cathodically protected. The City estimates that cathodic protection has extended the life of distribution assets by approximately 25 years.

Region of Halton

Halton completed a study confirming that the Region of Halton faces a high amount of watermain breaks due to galvanic corrosion. Although all of Halton has similar soil corrosivity, the report identified Milton's break-rate as the highest of all the other local municipalities. The current program consists of an annual allocation of $200,000 over the next three years, and $300,000 for the following seven years, to implement corrosion protection for the ductile and cast iron watermains.

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