Controlling Odour and Corrosion in the Collection System: Region of Peel's Trunk Sewer Odour and Corrosion Control Master Plan

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ABSTRACT

The Region of Peel (population 2.3 million, located west of Toronto, Canada) had multiple odour and corrosion problems in its collection system ranging from extensive areas of light damage to isolated pockets of severe corrosion. In an effort to be pro-active in solving its odour and corrosion problems, the Region of Peel commissioned a comprehensive odour and corrosion control strategy/master plan for its entire 155 mile (250 km) trunk collection system. The master plan not only addressed the current odour and corrosion issues but also focused on the preparation of design guidelines to ensure that future changes would help to protect the system from corrosion and would prevent odour issues as the system evolves and expands. The results of these efforts were used to create a Region wide odour and corrosion control master plan presented in terms of short-term and long-term capital improvement requirements.

KEYWORDS: Collection system, odour control, corrosion control

INTRODUCTION

Odour and corrosion issues in the collection system have been addressed on an ad-hoc and reactive basis in many municipalities across North America. This approach is usually focused on a specific problem area and hence the recommended solution often lacks understanding of the overall corrosion context needed to properly address the problem. The Region of Peel on the other hand felt that a broad based, comprehensive solution to odour and corrosion control would be more effective. Hence the Region decided to develop a long term regional master plan to deal with odour and corrosion throughout the trunk collection system (see Figure 1).

In 2006 the Region retained a consulting team to undertake the master plan project including comprehensive monitoring and pilot testing activities. The goal of the project was to develop short-term and long-term strategies to control odours and corrosion in the trunk collection system. Project objectives were:

- Compile a Region-wide inventory of odour and corrosion problems
- Test the effectiveness of chemical and physical control options
- Establish reasonable long term odour and corrosion control objectives and targets
- Develop short-term and long-term recommendations to meet the stated objectives
- Make appropriate operational and policy recommendations.

Scope
The consulting team performed H_2S gas and differential air pressure monitoring at over 40 locations to identify and prioritize specific odour and corrosion issues. As part of this monitoring program, pilot testing of three different treatment processes was conducted at four key sites in the collection system. In addition, the team conducted performance monitoring of existing odour control facilities, evaluated corrosion trends based on annual condition assessment records, and performed wastewater sulfide generation modeling based on future improvements to the collection system. The team also reviewed and assessed the Region's existing sewer-use bylaw and current design guidelines in order to establish the context for planned operational changes.

Master Plan Process
The results of these efforts were used to create the Region wide odour and corrosion control master plan. Overall system characteristics (such as H_2S monitoring results, ventilation dynamics characteristics and existing condition assessment results) were used to identify eight distinct sectors within the Regional system. A detailed needs assessment for each of these eight sectors of the collection system was then used to make specific odour and corrosion control recommendations. One of these sectors, the Bolton Sector, will be reviewed in more detail in the paper in order to illustrate how issues were defined, how individual sector solutions were identified and selected and how these individual solutions were 'rolled-up' to form a comprehensive regional master plan. Results of cost-benefit analyses were used to select the most economical and effective approach for controlling odour and corrosion.

Results
The purpose of this paper is to illustrate how the master planned system enabled the Region of Peel to address chronic odour and corrosion problems in a more effective and pro-active way. The paper provides an overview of the steps that lead to identifying the need for a master plan, the means used to create the plan and the expected overall targets for odour and corrosion control. The overall master plan will be presented in terms of specific short-term and long-term capital improvement requirements. Using the Bolton trunk sewer system as an example, it will be shown how results from the master plan were used to select long term chemical treatment over capital intensive corrosion protection. Recommended operational and policy level changes are also reviewed.

FIELD INVESTIGATIONS

The master plan process included an extensive field investigation program. The purpose of the following discussion is to provide an overview of the two primary focuses of the field investigation program; trunk sewer inspection/condition assessment and chemical pilot testing. An outline of findings and a list of conclusions and recommendations are discussed following. An extensive H_2S gas and air pressure background monitoring program was also undertaken in conjunction with pilot testing work.

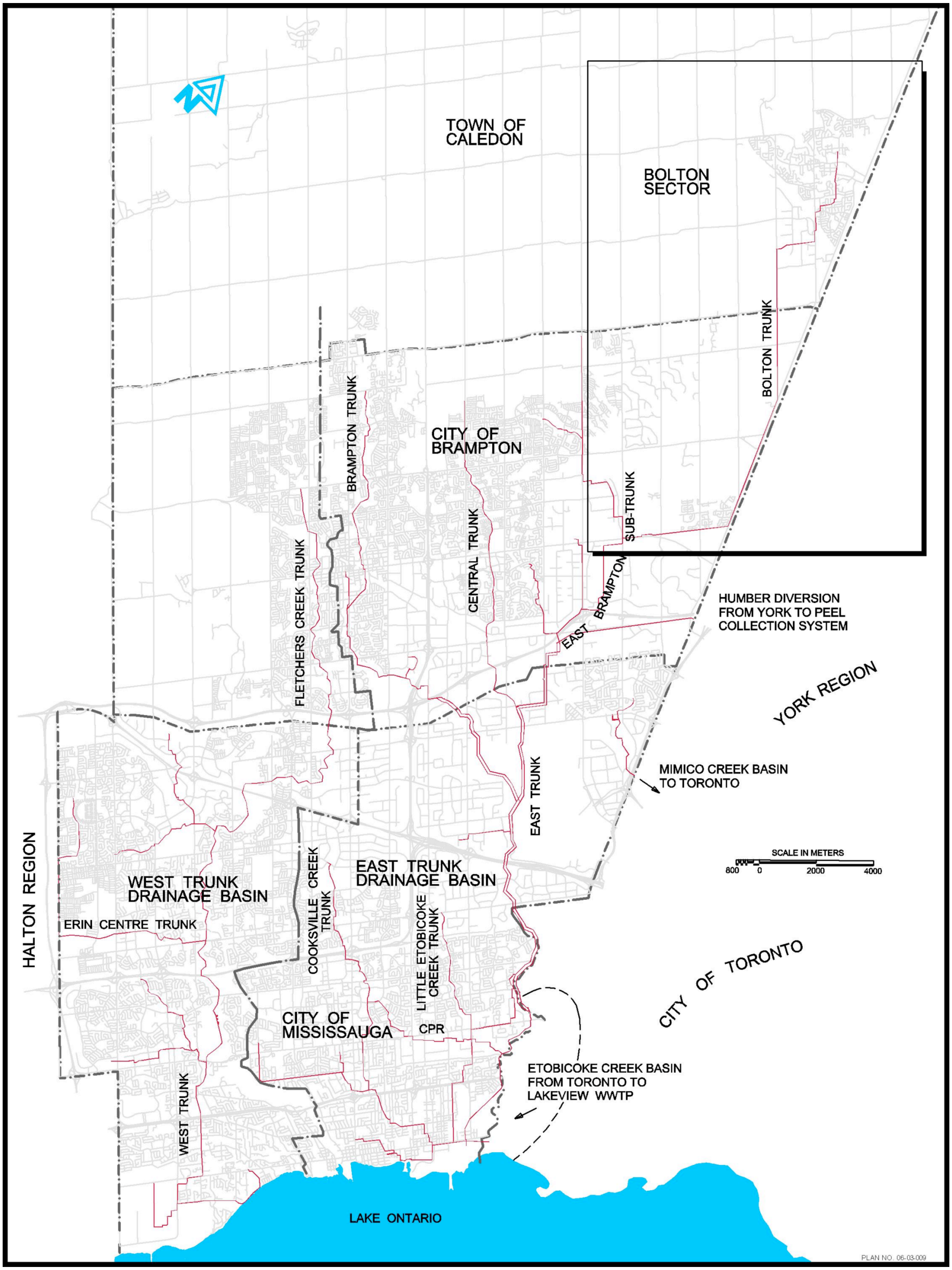

Figure 1 STUDY AREA

Trunk Sewer Inspection - Programming

An extensive trunk sewer inspection and condition assessment program has been in place at the Region since 1999. The results of this program formed, in large part, the basis for developing the inventory of odour and corrosion issues for the master plan project. Additional, supplemental inspections were also performed to confirm relevant long term trends. The purpose of the following discussion is to outline the sewer and manhole inspection methodology and present the rationale used to select inspection locations.

Criteria for selecting trunk sewer segments for supplemental inspection were:

- Areas of previously observed moderate to heavy corrosion. Objective: to identify trends including increase in extent and rate of corrosion.
- Areas without previously observed corrosion but where corrosion is now anticipated. Objective: to identify possible increase in distribution of corrosion.
- Areas without previous corrosion and where minimal corrosion is anticipated. Objective: control sections.
- Areas where inspection can be carried out safely and with reasonable expectation of success.

These criteria apply equally to both sewers and manholes. Candidate sewer sections were initially identified based on inspection information available from the previous condition assessment reports. The candidate list was also refined based on specific requirements of the Master Plan.

A previous attempt was made to re-inspect a portion of the East Trunk sewer in the Southcreek area. In particular, the area downstream of the existing energy dissipation structure was targeted for re-inspection in 2003 in order to record any increase in deterioration due to corrosion. This area had been previously identified as having moderate to very heavy pockets of corrosion during initial inspection in 1999. However, due to significant increases in flow and velocity between 1999 and 2003 the planned re-inspections could not be fully completed. Flows were too strong and too turbulent to allow for safe inspection. Criteria 4, above, has been included based on this experience in the Southcreek area. Careful site reconnaissance, especially in terms of constraints at existing crossovers on the twinned portion of the trunk, was undertaken prior to finalizing the inspection plan in order to confirm the feasibility of inspecting the preferred sewers.

Trunk Sewer Inspections - Results and Implications

Inspection and condition assessment showed that the extent and degree of the previously observed corrosion was increasing. In some places, major infrastructure is approaching a state of irreversible structural damage. This damage in most cases drove the selection of short and long term options to control corrosion.

The early stages of hydrogen sulphide related corrosion were observed in recently twinned portions of the several major trunk sewers. Flow characteristics in the newly built twin pipes were found to be fast and turbulent and hence conducive to hydrogen sulphide release; the numerous sharp curves throughout various reaches enhances H_2S gas release. It was concluded that options to control corrosion in the newly twinned pipe was an important consideration for the Master Plan.

Inspections also showed that several hydraulic conditions were causing excessive turbulence, due in large part to progressively increasing flow. This turbulence in turn was causing increased corrosion activity and sewer headspace restrictions.

Chemical Pilot Testing

The purpose of the chemical pilot testing program was to evaluate various liquid phase odour control chemical alternatives at predetermined facilities in the collection system. The Region previously conducted chemical pilots on an ad-hoc basis and desired a more complete, methodical approach to evaluate the effectiveness of chemicals at various locations in the collection system. Consequently the Region decided to conduct a structured chemical pilot testing program as part of the master plan process to evaluate various chemical treatment options. The general goal of the testing was to determine the effectiveness of these chemicals to reduce dissolved and atmospheric sulphide concentrations.

The pilot testing locations were selected by first identifying areas that had a history of odour and corrosion problems. The presence of a feasible dosing location for the pilot program that could also potentially be used as a location for a permanent dosing facility was also considered. Areas where odour and corrosion issues were of immediate concern were an important additional consideration. The chemical pilot locations were ultimately selected based on inspection, monitoring and knowledge of the areas. Chemical piloting was conducted at the following locations:

- Bolton Pump Station (BPS)
- Etobicoke Creek Trunk Sewer (ECTS)
- former Brampton WWTP site
- Markland Golf Course (on the ECTS)
- Control point at the South Creek Energy Dissipation Chamber

Two approaches for chemical treatment were considered. One was a chemical treatment alternative that would be effective at reducing sulfide over long distances. These chemical treatment options are typically the most economical, but do not react instantaneously and may not completely eliminate sulfide. Ferrous chloride and calcium nitrate were piloted for this condition. Another chemical treatment alternative that was considered would provide quick reaction and complete removal of sulfide but may not work over long distances. Sodium hypochlorite was selected to pilot for this condition. This chemical can work immediately and is capable of complete sulfide removal, but typically it is the most expensive chemical option.

Ferrous chloride and calcium nitrate were tested at the Bolton PS and Brampton sites. When tested at Bolton PS, both chemicals were effective in meeting the stated objectives at the specific control points for that system. On its own, ferrous chloride dosing at Brampton was not fully effective. However, it was effective when dosed in combination with sodium hypchlorite at the Markland site.

The data collected during chemical pilot testing is generally transferable to other locations. As such the testing program was undertaken in a way that results can be carried forward for inclusion and consideration in the overall development of strategies for odour and corrosion control.

PROBLEM DEFINITION AND MODELLING

The results of the field investigations, especially the trunk sewer condition assessment activities, were used to develop a list of odour and corrosion issues within the study area. These issues effectively define the problems to be addressed through the master plan. Other sources of background information including staff interviews, field monitoring and earlier condition assessment results were also been considered.

The study area for this project is extremely large and complex with numerous hydraulic inter-relationships. In order to facilitate a clear understanding of issues the entire Regional trunk sewer system was divided into geographic sectors: (1) Bolton Sector, (2) East Brampton Sector, (3) East Trunk Sector (4) South-east Mississauga Sector and (5) West Trunk Sector. Each sector presented representative characteristics and were hydraulically isolated (and hence to the extent possible odour and corrosion independent).

In order to provide planning level estimates of the degree and extent of biogenic H_2S corrosion within the trunk sewer system and to corroborate the sampling and monitoring data collected, it was necessary to understand the amount of dissolved sulphide that could be generated and released to the sewer atmosphere. A predictive computer model was used to estimate the potential range of dissolved sulphide generation and H_2S stripping. The primary model routine is based on the classical Pomeroy/Parkhurst dissolved hydrogen sulphide generation equations, upon which the majority of other sulphide generation models are based. The model also has subroutines and algorithms for sulphide stripping at points of turbulence (i.e. drop manholes, sharp changes in slope, etc.).

BOLTON SECTOR – SYSTEM ANALYSIS

Overview

Given the size and complexity of the entire Regional collection system it is difficult to provide a complete discussion of the analysis used to select the preferred control alternatives for each system component. Therefore, the Bolton Sector has been chosen for a detailed discussion of the analysis used to identify the preferred control alternatives (see Figure 2). The Bolton Sector comprises two trunk sewer systems. The Bolton Trunk which is tributary to the McVean Pumping Station (MPS) and the upper reach of the East Brampton Trunk Sewer (EBTS).

Condition Assessment

The BTS includes three areas; the Bolton leg, the Coleraine/Highway 50 leg and the McVean leg. In the Bolton leg, the trunk functions as a collector sewer through the developed portion of the Town of Bolton. The extreme upper terminus is the outlet point for the Bolton Pumping Station (BPS) forcemains. The sewer comprises 37 sections of 600, 675 and 750 mm diameter concrete pipe. All sections have been found to be in Good condition except for seven in Fair condition. These later sections experience various degrees of infiltration and minor surface spalling. As a

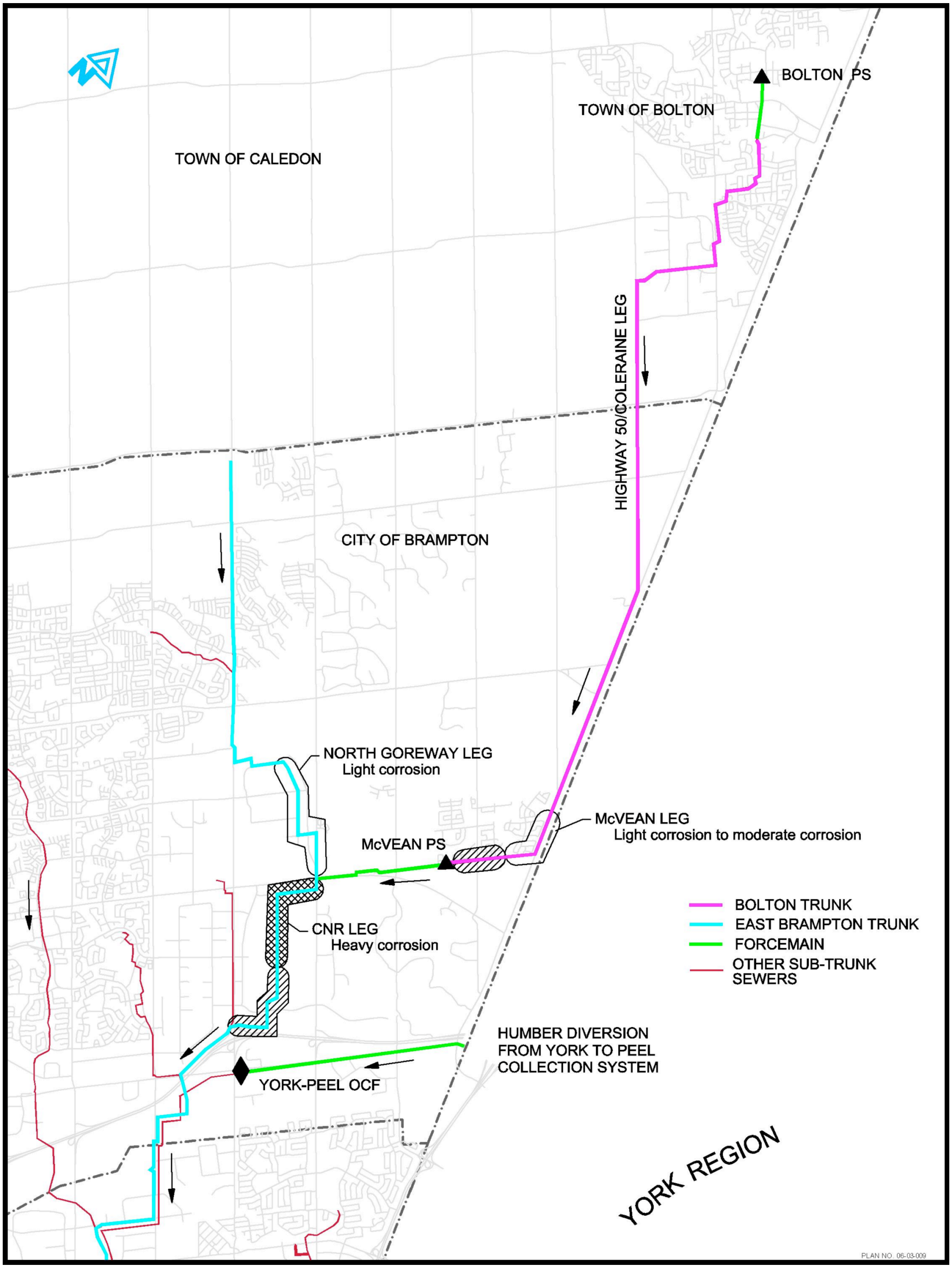

Figure 2 BOLTON SECTOR

result there is little or no evidence of corrosion in the area.

The Coleraine/Hwy 50 leg functions as a transmission main and conveys sewage from the Town of Bolton to the Ebenezer Road and McVean Pumping Station (MPS) area. The route passes primarily through areas of agricultural land use and minor highway commercial uses. As such there are no significant connections to the sewer. The sewer comprises some 65 sections of 750 mm concrete pipe. Only 16 sections were found to be in Good condition. The remainder are in Fair and Poor condition due to various degrees of infiltration and light to medium surface spalling (H2S related corrosion). Of the six sections in Poor condition, three were rated this way because of medium spalling. The observed heavier spalling appears to be related to isolated areas of turbulence (either due to horizontal bends or increased sewer slope).

Along the McVean Leg, intensive residential land development is occurring. For the most part the sanitary sewage for this developing area is collected in a relatively new trunk sewer constructed along the north side of Ebenezer Road. As a result the Bolton Trunk sewer receives little flow from the new development and effectively functions as a transmission main through the area. All 36 sections in this leg were found to be either in Fair or Poor condition due to H2S related corrosion. One section was downgraded to Poor because of possible longitudinal fractures. Active infiltration at joints was also observed in various sections. The heaviest corrosion effects were observed in the 11 downstream sections of the sewer. These sections of sewer have significantly steeper slopes and hence, increased operating velocities.

No significant odour or corrosion issues were identified by Regional staff at the Bolton Pumping Station (BPS). The BPS was used as one of two baseline stations for odour and air dispersion modeling. There have been recurring odour complaints at the McVean Pumping Station (MPS) and ongoing corrosion issues in the wet well. High H2S concentrations in the station have lead to worker health and safety concerns. These issues have, in small part, been attributed to the sewage hauler's dump site at the station. Due to ongoing residential development in the drainage basin, the need for capacity expansion was identified in the Region's Master Servicing Plan. These issues are being dealt with through the reconstruction and expansion of the MPS. At the time of writing, reconstruction of the station is in an advanced stage with commissioning anticipated late in 2008. On-going corrosion in the wet well has been addressed through appropriate liner installation and odour issues addressed through provision of a vapour phase treatment facility on-site.

BOLTON SECTOR - ALTERNATIVES

Alternative 1 – Do Nothing

The steeper segments of sewer on Ebenezer Road are currently experiencing advanced corrosion. It is expected that some irreversible damage has already occurred in the steeper leg of the sewer. Without corrosion control further, more widespread, damage is expected such that significant structural damage will occur within 5 to 10 years and isolated structural failure could occur. Partial or complete blockage could occur with significant environmental discharges. Observed pockets of corrosion along Coleraine Road and Highway 50 will continue to deteriorate. Irreversible damage will likely occur only in very isolated pockets within the planning horizon of this project.

Alternative 2 – Chemical Dosing
Corrosion potential can be controlled, that is average H2S concentrations reduced to below the 5 ppm threshold, through chemical dosing. Dosing at the existing BPS site would be the most appropriate location. Results of pilot testing show that control of current H2S levels can be adequately reduced. Pilot testing was carried out during limiting warm weather periods and hence
dosing through cooler periods of the year may not be necessary. Dosing rates would need to be set based on the worse case gas concentrations in the steeper downstream reach the Ebenezer Road leg. As a consequence the milder upstream corrosion would also be controlled. Based on pilot testing results and chemical selection criteria, nitrate is expected to be the best suited chemical. The following discussions are therefore based on the use of nitrate.

Advantages:
• Well understood and easily applied technology
• Can be adjusted to mirror on-going system and population growth
• Low capital cost

Disadvantages:
• Material has high safety and maintenance needs
• Requires regular and frequent operator involvement
• Requires on-going monitoring and periodic/seasonal adjustments

A portion of the downstream segment of the Ebenezer leg of the sewer needs to be rehabilitated due to current structural deterioration, regardless of which long term corrosion control alternative is selected.

Based on the foregoing parameters it was determined that the operating costs for dosing will be in the order of $75,000 per year. This assumes dosing rates of 190 l/d for 6 months and 142 l/d for 6 months during warm and cold weather periods respectively. The expected 25-year life cycle cost for this alternative is therefore approximately $1,200,000. These sewer segments require structural relining which is estimated to cost approximately $2,500,000. The total life cycle cost for this alternative is therefore $3,700,000 ($1,200,000 plus $2,500,000).

Alternative 3 – Pipe Protection
Rather than reducing corrosion potential the existing sewer can be protected against ongoing corrosion. Internal lining or coatings can be applied to adequately resist corrosion. Both the sewer and manholes would need to be protected. Numerous protection options are available. Both in-situ liners and coatings could be applied; both would require by-pass pumping during installation. Although the capital cost of coatings are less expensive than permanent liners, the cost of by-pass pumping is high and hence tends to balance the capital cost of either option. Since coatings need to be re-applied (and hence by-pass pumping re-done) on a 5 to 7 year cycle their life-cycle cost is significantly higher than in-situ liners. Therefore only liners are carried forward for further evaluation.

Liners, such as cured-in-place liners, can also enhance or replace lost structural resistance. Loss of resistance due to previous corrosion effects can be replaced with a suitably designed liner. Although the installed liner reduces the internal diameter of the host sewer, improved friction factors results in no loss of hydraulic capacity. Furthermore, installation of a liner also tends to improve the water tightness of the pipe and hence reduces any pre-existing infiltration issues. Liners typically have a minimum 25-year life expectancy, and often longer. Hence no replacement is expected within the planning horizon of this project.

Advantages:
- Well understood and easily applied technology
- Easily applied for the size and configuration of the existing sewer
- Minimum 25-year life span; likely longer; does not require regular replacement
- No increase in on-going maintenance or operating costs
- Enhances/replaces lost structural resistance; improves infiltration control

Disadvantages:
- High capital cost
- Requires full by-pass pumping during installation
- Isolated pockets of potential corrosion remain un-protected

The sewer sections on Ebenezer Road are the most vulnerable to corrosion. The observed corrosion in the downstream portion (McVean leg) has likely already lead to irreversible structural damage. It was assumed therefore that relining is needed in this area for structural rehabilitation purposes; long term pipe protection will be a significant supplemental benefit to re-lining. Upstream of MH B18-0019 corrosion effects are less significant. Lining can be therefore be used for long term corrosion protection in this area. Regular monitoring will indicate the priority areas for lining. In any event lining should occur before irreversible damage occurs in order to not incur un-necessary structural risk. As such protection works for the balance of this leg could be staged over a number of years in order to distribute capital cost requirements. A cured-in-place liner has been used as a basis for evaluation for all areas. However, a thorough evaluation of alternate techniques should be undertaken as part of detailed design in order to find a potentially more cost-effective solution. Manhole protection is also required.

Approximately 1,060 m of 750 mm diameter sewer is located in the McVean leg of the sewer on Ebenezer Road. This length needs to be lined in the near future in order to maintain adequate structural safety. The estimated capital cost for these sections is approximately $2,500,000.

Pipe protection may ultimately be required on as much as 50% of the balance of the sewer; that is approximately 1750 m of 750 mm pipe. Total capital cost for this work is approximately $4,125,000. Regular monitoring could be used to determine the required timing for each section and hence this work could be staged over a number of years. For comparative purposes it is assumed that 50% of the work needs to be completed in 2012 and the remainder in 2015. The total 20-year life cycle cost for lining all of the Ebenezer Road sewer is therefore $6,625,000 ($2,500,000 plus $4,125,000).

Preferred Alternative

The do nothing alternative results in an un-sustainable solution. Pipe failure and environmental discharges will ultimately occur. Based on the foregoing discussion, the chemical dosing alternative is preferred for the following reasons:

1. It represents the least life-cycle costs.
2. Monitoring of H2S levels and the rate of future flow increases may allow optimal pacing of dosing rates such that expected dosing costs can be minimized.
3. Requires minimal increase in operator involvement since the dosing equipment can be installed at the existing Bolton pumping station.

CONCLUSIONS – The Master Plan

The recommended long term strategy for controlling odour and corrosion comprises two primary courses of action. First, capital improvements together with associated operational changes, which are required in order to address existing problems. Second, enhancement of Regional design standards to ensure that future system upgrades and modifications present minimal odour and corrosion impacts.

Chemical dosing was the preferred solution for most of the corrosion related issues in the trunk system. Full implementation of the recommended strategy will result in significant annual chemical and maintenance costs for the Region. In order to optimize chemical dosing rates (and hence minimize chemical costs) it was recommended that a long term monitoring program be implemented. This program should ensure that sulphide and H_2S levels are monitored in key locations such that chemical facility interactions are clearly identified.

To ensure that all corrosion and ventilation issues are fully explored and examined it was also recommended that a full scale pilot testing program be carried out for a one year period. The Brampton Sub-trunk/East Trunk system would be a good candidate for such pilot testing and represents many of the critical factors influencing odour and corrosion in the Regional system.

Limited pipe line protection, in the form of CIPP liners for example, was recommended in areas of observed, irreversible damage. Pipes with observed structural deficiencies were scheduled for rehabilitation. It is expected that the recommended chemical dosing will arrest further non-structural corrosion damage in these areas. It was also recommended that the inspection of critical corrosion areas be included in the Region's routine sewer inspection program in order to provide early warning of any unexpected or unusual corrosion issues. If discovered early enough chemical dosing routines can be adjusted to reduce or arrest further irreversible damage.

An integral component of the Master Plan is ensuring that future works do not repeat the odour and corrosion causing conditions that could result in additional problem areas. To this end a comprehensive set of design guidelines were recommended to minimize or eliminate odour and corrosion problems related to future infrastructure projects.