City of Peterborough

MASTER PLAN

Detailed Sanitary Sewer EA for the Mitigation and Management of Extraneous Flows into the Sanitary System

W10-194

March 2012

COLE ENGINEERING

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Introduction

In July 2004, the City of Peterborough (City, "Owner") experienced a severe rainfall event that caused significant flood damages. The cost of the damages to private and public properties was reportedly in excess of $100 million. In addition, the City suffered indirect damages such as disruption to residential living conditions, loss of business, and loss of wages or income. Other studies list four main causes for the flooding: (1) unprecedented heavy rainfall; (2) insufficient storm sewer capacity; (3) poorly defined overland flow routes; and (4) extraneous clear water flows entering the sanitary sewer system as inflow and infiltration (I-I).

In response, the City initiated a detailed sanitary sewer Environmental Assessment (EA) for the mitigation and management of extraneous flows into the sanitary sewer system. This report documents this EA which follows the Master Plan approach and fulfils the obligation under the Canadian Environmental Assessment Act.

Purpose

The purpose of this Class EA is to identify and evaluate alternative flood remediation solutions in the sanitary sewer system involving the reduction of I-I. The study also evaluated onsite storage alternatives for the Peterborough Wastewater Treatment Plant (WWTP) to prevent untreated or partially treated sewage bypasses to the Otonabee River. An analysis was also undertaken to compare the cost of reducing I-I conditions versus the costs of conveying and storing the I-I within the conveyance or at the Peterborough WWTP. The evaluation included physical, economic, environmental, social, cultural, and health factors when comparing alternative solutions to determine the preferred solution.

Scope

The scope includes the area tributary to the Peterborough WWTP (please see **Figure 1**). All the sanitary sewers, manholes, pumping stations, forcemains, etc. available in the City's Geographic Information System (GIS) that contribute sanitary sewage to the Peterborough WWTP have been included. The study area is composed of various land uses, such as residential, employment areas, commercial, institutional, and green space. The sanitary flow discharges to the Peterborough WWTP located at 425 Kennedy Road, Lot 25, Concession 14 at the south end of the City and on the southern slopes of the Otonabee River.

Class EA

The study will follows Approach #2 of the Master Plan approach under the Environmental Assessment document, as outlined in Appendix 4 (MOE, October 2000; amended 2007).

Successful completion of the Master Plan under this approach would fulfil Phases 1 and 2 of the Class EA process. The final notice for the Master Plan would also become the study Notice of Completion for all Schedule 'B' projects recommended within the Master Plan. Public consultation for a Schedule B project includes the notice of commencement, one mandatory public meeting with the option to hold a second discretionary public meeting, notice of completion, and a 30-day review period to solicit comments from review agencies and the public.

The public consultation process was coordinated by City staff. Two public information centres were held in addition to information being made available on the City's website.

The Master Plan Report is the culmination of field investigations, model development, and extensive assessment of the sanitary sewer system and Peterborough WWTP. The preferred alternatives are a combination of municipal works including a combination of source controls (I-I reduction), conveyance, and storage alternatives designed to reduce extraneous flows from entering the sanitary sewer system as well as reduce the frequency of untreated or partially treated sewage bypasses to the Otonabee River.

Approach

An assessment of the existing sanitary sewer system involved several technical tasks as outlined in the main body of this report. These tasks included data collection, review, and analysis; flow monitoring; detailed model development and calibration; analysis of system performance under various scenarios; formulation of alternative solution to elevated flows in the system; evaluation selection; and detailing of the preferred conceptual solution. A target level of flood protection was determined such that the maximum hydraulic grade line (HGL) in the sanitary system would not be allowed to rise any higher than 1.8 m below the ground elevation under a storm event equivalent to the 1 in 25 year return period. 16 locations known as “clusters” were identified and considered to be at risk of flooding based on the above criteria.

Alternatives were evaluated by considering source controls (I-I reduction), conveyance, storage attenuation, or a hybrid alternative based on a combination of source control, conveyance, and storage alternatives. A preferred alternative for each cluster was identified. Prior to design or construction of the recommended works, the GIS sewer network data should be updated, as well as confirm the 1 in 25 year sanitary level of service for I-I reduction and wet weather flow (WWF) in the conveyance system.

Storage options were considered to reduce the occurrence of sewage bypasses at the Peterborough WWTP. After a preliminary space assessment at the plant site, a maximum volume of 25,000 m^3,was set as the upper limit of additional storage.

Results

Analysis of the existing system identified 16 potential flooding cluster areas. The preferred solution for all flood clusters includes as a minimum, I-I source reduction (Alternative 2) and combinations of conveyance and storage options (Alternative 5). The total cost to address extraneous flows entering the sanitary sewer system under the 1 in 25 year design storm is approximately $10,000,000.

Table 1 below shows the peak flows at the Peterborough WWTP under each of the five alternatives considered in the conveyance system during the 1 in 25 year storm event.

Table 1 – Peak flows at WWTP during 1 in 25 year storm event

Existing Peak Pumping Capacity at WWTP (m^3/d)	Alternative 1 Do Nothing (Existing Conditions) (m^3/d)	Alternative 2 I-I Reduction (m^3/d)	Alternative 3 Convenance (m^3/d)	Alternative 4 Storage (m^3/d)	Alternative 5 Hybrid (m^3/d)
190,900	203,314	173,981	205,506	180,050	173,226

Alternative 2 (I-I Reduction) and Alternative 5 (Hybrid) reduce the peak flows to the Peterborough WWTP below existing pumping capacity. This reduces the risk of potential sewage bypasses to the Otonabee River.

The performance of the existing conveyance system was also evaluated under the 1 in 100 year storm with the hybrid alternative in place. Under this approach (hybrid), the costs to provide potential solutions in the sanitary system for the 1 in 100 design event is about $13,000,000. It should be noted that the 1 in 100 year solutions should be considered in conjunction with other capital works in the same area. This alternative will only protect against basement flooding and will not reduce peak flows to the WWTP. During the 1 in 100 year design storm event, the peak flow to the WWTP under existing conditions exceeds the existing pumping capacity of 190,000 m^3/day (note: this is also the case for the 1 in 25 year design storm event under existing conditions, as seen in **Table 1**). Historically when this has occurred, raw sewage has bypassed the treatment plant and discharged directly into the Otonabee River. Therefore, although there may be the possibility to provide potential solutions for flooding during the 1 in 100 year design event, there still exists the possibility of raw sewage bypasses.

Peak flow storage and attenuation options were considered in developing alternatives at the Peterborough WWTP. Suitable options and configurations that could be implemented were selected for further evaluation. The preferred alternative that was selected makes use of the old treatment tankage and lagoons and also provides the lowest long term capital and life cycle costs. This option also makes the best use of space and reuse of existing infrastructure. The preferred alternative would achieve a level of service between the 1 in 100 year design storm (4 hour Chicago Distribution) and the Regional (Timmins) event. The estimated capital cost for the preferred alternative is $20.5 M (including engineering and contingencies; excluding HST), with an approximate increase in operation and maintenance costs of $50,000 per year.

The preferred sewer system alternatives and WWTP storage alternatives reduce the extraneous flows entering the sanitary sewer system and the risk of basement flooding, as well as increases the proportion of wet weather flows receiving secondary treatment prior to discharge to the Otonabee River from 8,000 m^3 to 25,000 m^3.

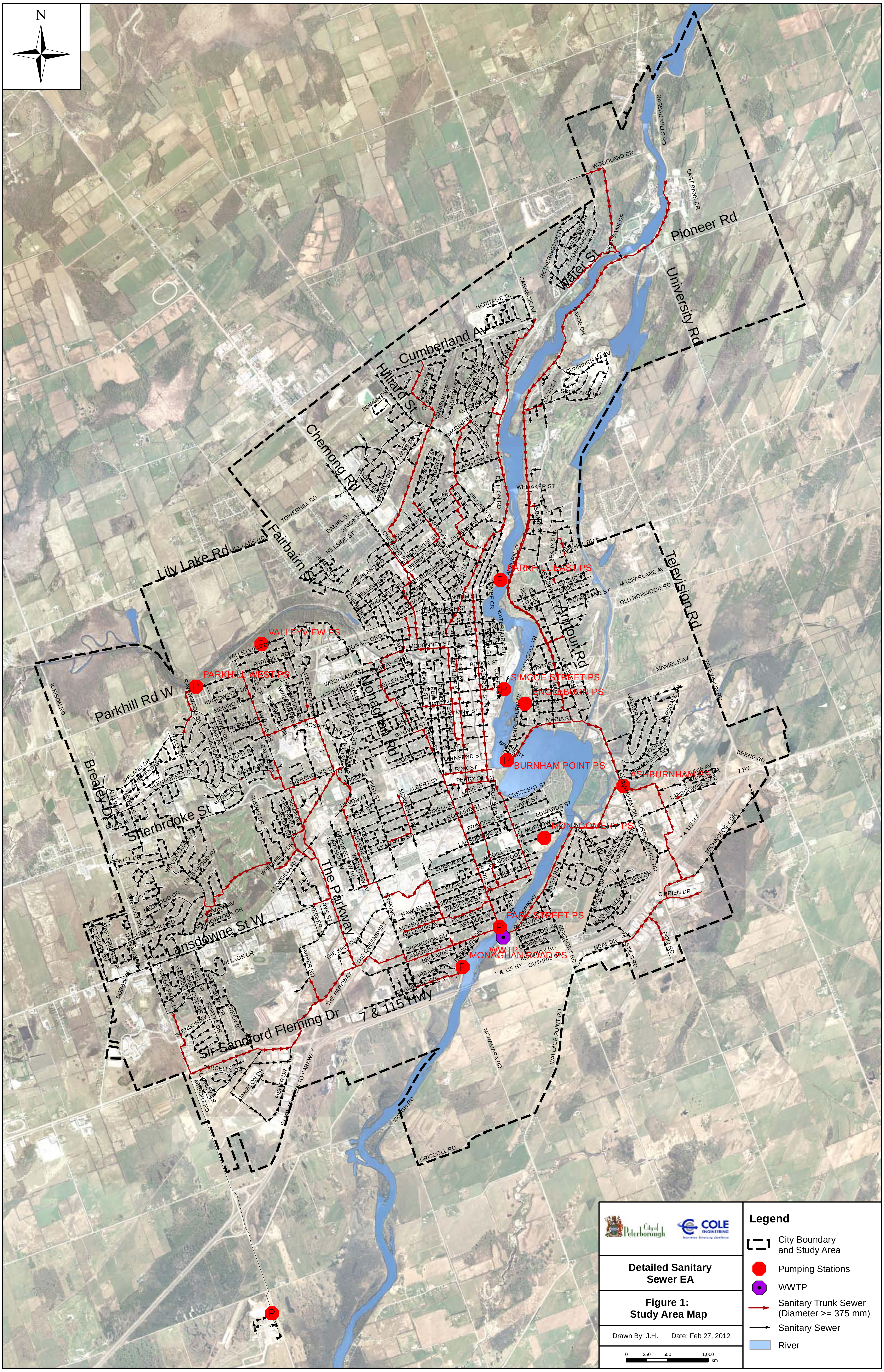


Figure 1: Study Area Map

1.0 Introduction

The City of Peterborough (City, "Owner") and Cole Engineering Group Ltd. (Cole Engineering) has completed this detailed sanitary sewer Environmental Assessment (EA) for the mitigation and management of extraneous flows into the sanitary sewer system. This study follows the Master Plan approach to fulfil the obligations under the Canadian Environmental Assessment Act. The study area includes all sanitary sewers in the City that contribute flow to the Peterborough Wastewater Treatment Plant (WWTP, "plant"). By mitigating and managing extraneous flows into the sanitary sewer system, the City can reduce sewer surcharging and sewage bypasses and maintain or improve the existing sanitary sewer capacity for future growth and development.

1.1. Study Background and Purpose

In July 2004, the City experienced a severe rainfall event that caused significant flood damage. The damage was reportedly in excess of $100 million including indirect physical damages to private and public property. In addition, the City suffered indirect damages such as disruption to residential living conditions, loss of business, and loss of wages or income.

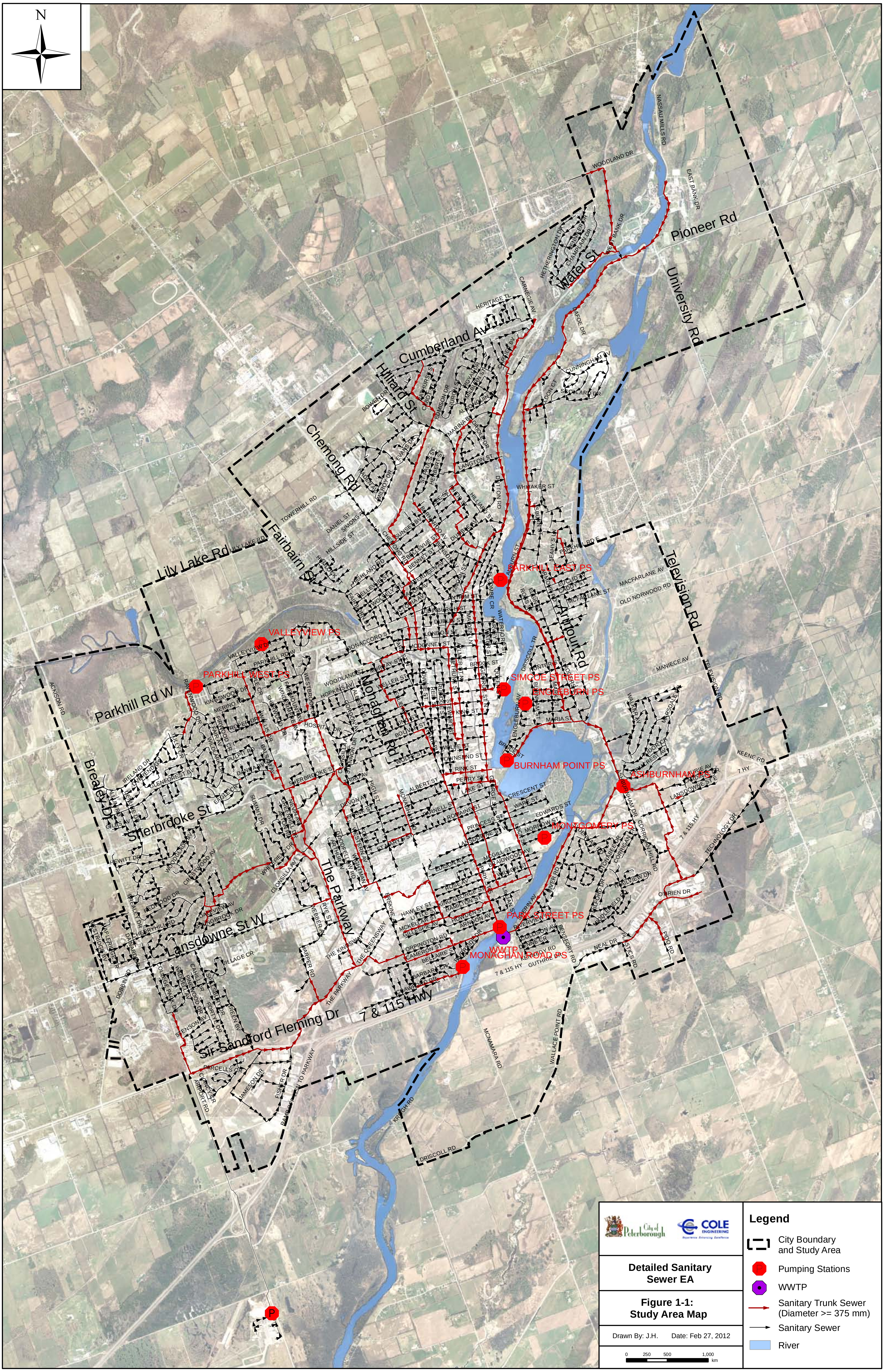
Studies to date have shown that there were four main causes of the flood damage:

1. Unprecedented heavy rainfall;
2. Insufficient storm sewer capacity;
3. Poorly defined overland flow routes; and,
4. Extraneous clear water entering the sanitary sewer system.

Environmental Assessments (EAs) have been completed to examine storm watersheds to:

- Identify the severity and frequency of flooding due to storm drainage system overloading and the associated damages within each catchment area; and,
- Identify and assess alternative cost effective storm drainage system solutions to alleviate existing and potential problems during future development.

This Sanitary Sewer EA is part of the overall evaluation and solution to the existing and potential flooding concerns within the City. **Figure 1-1** identifies the study area as the existing City of Peterborough WWTP sanitary service area.


N
Cumberland Av
Hilliard St
Chemong Rd
Fairbairn St
Lily Lake Rd
Water St
Pioneer Rd
University Rd
Television Rd
Armour Rd
Monaghan Rd
Parkhill Rd W
Brealey Dr
Sherbrooke St
Lansdowne St W
The Parkway
Sir Sandford Fleming Dr
7 & 115 Hwy
PARKHILL EAST PS
VALLEYVIEW PS
PARKHILL WEST PS
SIMCOE STREET PS
INGLEBURN PS
BURNHAM POINT PS
ASHBURNHAM PS
MONTGOMERY PS
PARK STREET PS
MONAGHAN ROAD PS
WWTP
City of Peterborough
COLE ENGINEERING
Detailed Sanitary Sewer EA
Figure 1-1: Study Area Map
Drawn By: J.H.
Date: Feb 27, 2012
0 250 500 1,000 km
Legend
City Boundary and Study Area
Pumping Stations
WWTP
Sanitary Trunk Sewer (Diameter >= 375 mm)
Sanitary Sewer
River

1.2. Study Justification

The purpose of the Class EA is to identify and evaluate alternative solutions for the reduction of inflow and infiltration (I-I) into the City's sanitary sewer system, which was one of the four main causes of flooding during the July 2004 storm event. This study was necessary to compare the cost of remediating I-I at the source versus the costs of doing nothing, conveyance improvements, storage, and treatment of I-I. The alternative evaluation process leading to a preferred solution must include physical, economic, environmental, social, cultural, and health factors.

A detailed hydraulic model of the existing sanitary system was needed and has been created to assess current system performance under various scenarios. Scenarios include variable storm sizes, land use changes, and sewer system modifications. The model has been calibrated using rainfall and flow monitoring data collected prior to and during this study. The detailed model will also be useful to assess local capacity conditions due to future development as well as effectiveness of I-I reduction efforts.

Preliminary design information is necessary to confirm the feasibility and cost of implementation. The study must provide recommendations for addressing short, medium, and long term needs and opportunities, while considering the financial implications to the City.

1.3. Municipal Class EA Process

The Municipal Class EA (2007) process, which is approved under the Environmental Assessment Act, enables the planning of municipal infrastructure projects in accordance with a proven procedure for protecting the environment. There are five phases of assessment in the Municipal Class EA process:

- **Phase 1:** Definition of the problem;
- **Phase 2:** Identification and assessment of alternative solutions and selection of a preferred solution;
- **Phase 3:** Identification and assessment of alternative sites / design concepts and selection of a preferred site / design;
- **Phase 4:** Preparation of an Environmental Study Report (ESR); and,
- **Phase 5:** Implementation.

The projects fall into one of three possible schedules based on their characteristics, referred to as Schedule A, B, or C projects. The schedule under which a project falls determines the planning and design phases that must be followed.

Schedule A projects are minor operational and upgrade activities and can proceed without further assessment once Phase 1 of the Class EA process is complete (i.e., the problem is reviewed and a solution is confirmed).

Schedule B projects must proceed through the first two phases. Proponents must identify and assess alternative solutions to the problem, identify environmental impacts, and select a preferred solution. They must contact relevant agencies and affected members of the public. Provided there are no significant impacts and no requests are received to elevate the project to Schedule C, or to undertake the project as an Individual Environmental Assessment (IEA) (Part II Order), the project may proceed to Phases 4 and 5 (detailed design).

Schedule C projects require more detailed study, public consultation, and documentation as they may have more significant environmental impacts. Projects categorized as Schedule C must proceed through all five phases of assessment. An ESR must be completed and made available for a 30-day public review period prior to proceeding to Phase 5 (project implementation).

In the event that there are major issues that cannot be resolved upon completion of the report, individuals may request that the Ministry of Environment (MOE) call for the proponent to comply with Part II of the EA Act. Upon receiving a Part II Order request, the MOE reviews the request and study information and can make one of the following decisions:

- Deny the request;
- Refer the matter to mediation; or,
- Require completion of an IEA.

The MOE considers a number of factors in making decisions, such as: the adequacy of the planning process; the potential for significant adverse environmental effects after mitigation measures are implemented; the participation of the requester in the planning process, and the nature of the request.

This EA study follows the Master Plan Approach #2 which fulfills the obligations under the Environmental Assessment Act. Approach # 2 is outlined in Appendix 4 of the Municipal Class Environmental Assessment document, October 2000 (as amended in 2007). Successful completion of the Master Plan fulfills Phases 1 and 2 of the Class EA process, and the final notice for the Master Plan would become the Notice of Completion for Schedule B projects recommended within the Master Plan. It is noted that any Schedule C projects would require the completion of Phases 3 and 4 of the Class EA. A detailed description of the EA process is provided in **Appendix A**.

1.4. Stakeholder Involvement

Stakeholder consultation is a key feature in the Class EA process. An effective consultation process provides the opportunity to exchange information and ideas with stakeholders. There are mandatory points of consultation for the various project schedules in the Class EA process. Consultation for a Schedule B project includes the notice of commencement, one mandatory public meeting with the option to hold a second discretionary public meeting, notice of completion, and a 30-day review period to solicit comments from the public and review agencies. As previously stated, Schedule C projects would require the completion of Phases 3 and 4 of the Class EA. **Section 1.0** describes various stakeholder consultation points completed during this project.

2.0 Problem Statement

The problem statement is the starting point in undertaking a Class EA. It becomes the central integrating element of the project and helps to define the project scope. This section outlines the problem statement for the proposed EA. Phase 1 of the Class EA planning process requires proponents to document reasons why the improvement is needed and to develop a clear statement of the problem to be investigated. Phase 2 requires a thorough evaluation of the alternative solutions to the problem. The information considered in the development of the problem statement is presented in **Section 2.1.**

2.1. Problem and Opportunity Statement

In July 2004, the City experienced a severe rainfall event that caused unacceptable flooding damage. The cost of the damage was reportedly in excess of $100 million including direct damages to private and public property. In addition, the City suffered indirect damages such as disruption to living conditions, loss of business, and loss of wages or income. Other Studies completed to date have shown that there were four main causes of flooding:

1. Heavy rainfall;
2. Insufficient storm sewer capacity;
3. Poorly defined overland flow routes; and,
4. Extraneous (unwanted) water entering the sanitary sewer system.

Furthermore, the WWTP has allowed relatively frequent sewage bypasses to the Otonabee River.

This project presents an opportunity to identify the significance of the potential flooding problem, verify the cause of flooding and to mitigate and manage any excessive extraneous “clear water” entering the sanitary sewer system and reduce the frequency of sewage bypasses to the Otonabee River. This sanitary EA is part of the overall evaluation and solution to the existing and potential flooding concerns within the City and bypasses at the plant.

2.2. Objectives

The problem statement presented above has been developed based on a review of the existing sanitary system performance during the 2004 storm event and subsequent flow monitoring conducted by the City. Potential solutions to alleviate extraneous flows entering the sanitary sewer system and to reduce the number of raw sewage bypasses will be evaluated during this EA study.

The Class EA has the following two objectives:

1. Mitigate and manage extraneous flows entering into the sanitary sewer system; and,
2. Reduce the frequency of sewage bypasses at the Peterborough WWTP.

2.3. General Methodology

The study:

- Follows the Master Plan approach in order to fulfil the obligations under the Environmental Assessment Act;
- Identifies and evaluate potential flood vulnerable areas within the City using a detailed sewer system model;
- Defines and evaluate various solutions within the sewer system including “at source” remediation, increased conveyance capacity, flow attenuation using storage and a hybrid alternative combining at source, conveyance, and storage solutions for each of the identified flooding clusters;
- Recommends preferred solutions at potential flooding locations;
- Evaluates potential solutions for wet weather storage at the Peterborough WWTP and recommend a preferred alternative;
- Informs and presents to the public and government agencies all findings;
- Recommends ongoing measures to improve sanitary sewer network operation; and,
- Document findings and submit a project file as per Schedule B of the Municipal Class EA process.

3.0 Public and Stakeholder Consultation

A public consultation program was carried out to keep all members of the public and stakeholders involved. Distinct target groups were identified and contacted with information as part of the process. This exercise helped the project team ensure that all defined groups and their needs were considered and addressed. **Table 3-1** below summarizes the consultation process. The public consultation notices and correspondences are included in **Appendix K**.

Table 3-1 – Consultation Process Summary

Target Group	Objectives	Contact Plan
Agencies	▪ Provide project commencement notice; ▪ Provide regular updates; ▪ Seek comments and feedback; ▪ Obtain approvals in principle, as applicable.	▪ Notice of Project Commencement (mail out and advertisement); ▪ Public Information Centre (two events); ▪ Ongoing correspondence (as needed); ▪ Meetings (as needed); ▪ Notice of Completion (mail out and advertisement).
Public	▪ Provide project commencement notice; ▪ Provide regular updates; ▪ Seek comments and feedback; ▪ Provide responses to questions and comments.	▪ Notice of Project Commencement (advertisement); ▪ Public Information Centre (2 events); ▪ Ongoing correspondence (as needed); ▪ Meetings (as needed); ▪ Notice of Completion (advertisement).
Special Stakeholders	▪ Provide project commencement notice; ▪ Provide regular updates; ▪ Seek comments and feedback; ▪ Resolve reasonable issues.	▪ Notice of Project Commencement (mail out and advertisement); ▪ Public Information Centre (2 events); ▪ Ongoing correspondence (as needed); ▪ Meetings (as needed); ▪ Notice of Completion (mail out and advertisement).

3.1. Public Notification

The following communication methods were used:

- **Mailing Lists** – A mailing list was created which includes contacts for all relevant review agencies as well as local interest groups within the City.
- **Public Information Centre** – Two Public Information Centres (PICs) events were held during the course of the Study. They consisted of a drop-in centre with display panels, a presentation followed by a question and answer period, and an opportunity for the public to speak with project staff. Comment forms were provided to all attendees.
- **Newspaper Advertisements** – Advertisements were placed in the local newspaper to announce the commencement of the EA prior to each open house event. The advertisements invited the public to attend the event and identified ways to obtain more information.
- **Direct Mail** – Notices were mailed to agencies and special stakeholders prior to the first PIC.

Copies of all public consultation related materials and correspondence are provided in **Appendix K**.

3.1.1. Notice of Study Commencement

A Notice of Study Commencement was advertised in the "Peterborough Examiner" and "Peterborough This Week. The notice was also mailed to various agencies and other stakeholders.

3.1.2. Public Information Centre #1

Advertisements for PIC #1 appeared in editions of "Peterborough This Week". The notice was also mailed to various agencies and other stakeholders. The notice introduced the study, explained the objectives, referred to the Municipal Class EA process, and instructed how the public could contribute input.

3.1.3. Public Information Centre #2

Advertisements for PIC #2 appeared in editions of "Peterborough This Week". All agencies and stakeholders on the project mailing list were notified. The notice provided background information identified generic alternatives, as well as the preferred alternative based on the final evaluation criteria. The notice also instructed how the public could contribute input.

3.1.4. Agency Notification

The Notice of Study Commencement was distributed in July 2010 to all relevant review agencies to inform them of the nature and scope of the project.

Specific letters were sent to the following aboriginal contacts to notify them of the project:

- Indian and Northern Affairs Canada;
- Ministry of Aboriginal Affairs;
- Hiawatha First Nation;
- Curve Lake First Nation;
- Alderville First Nation;
- Mississaugas of Scugog Island; and,
- Kawartha Nishnawbe First Nation.

Notices were also sent in November 2010 and May 2011 inviting these groups to attend the PICs and inform them of the recommendations and design options for the preferred alternative solutions.

Following the Notice of Commencement and Notice of PICs, a number of response letters were received from various agencies, including: the Ministry of Aboriginal Affairs, Ministry of Tourism and Culture, Otonabee Region Conversation Authority, Ministry of Health and Long-term Care, Ministry of Natural Resources, Ministry of Environment, and Indian and Northern Affairs Canada. Letters were also received from the Curve Lake First Nation and Alderville First Nation. Each group indicated their respective levels of interest in this study and whether they would like to be kept informed of project updates. These letters are found in **Appendix K.**

3.1.5. Notice of Study Completion

A Notice of Completion was developed and distributed on March 16, 2012 to provide the public with a final opportunity to comment on the project. The notice will indicate the conclusions of the Master Planning / EA process and will indicate where copies of the Master Plan can be reviewed. The Master Plan must be completed to document the Class EA process and must be filed for a 30 calendar day public review. During the public review period, the public and the proponent have the ability to discuss and resolve any concerns the public may have. However, if a resolution cannot be reached, the public has the ability to request a Part II Order to the MOE during the 30 day public review period. After this time period, the MOE will review the case and make the final decision if an individual EA must be completed for the project.

3.2. Public Information Centre

3.2.1. Public Information Centre #1

PIC #1 was held on November 31, 2010 from 6:00 p.m. – 8:00 p.m. at the Canadian Canoe Museum located at 910 Monaghan Road, in the City.

The major elements of the PIC were:

- Study overview and background;
- Overview of the Municipal Class EA process;
- Problem / opportunity statement;
- Generic options;
- Preliminary evaluation criteria; and,
- Further public contact.

The format of the meeting included a drop-in centre with display panels. A presentation was also given followed by a question and answer period. People were then given the opportunity to speak one-on-one with project staff and view displays about area-specific recommendations.

A comment sheet requesting input on the study was provided to participants. Participants were asked to submit their comments to the City within a three week period following the PIC. Ten members of the public signed in at the meeting and one comment sheet was returned, these documents are found in **Appendix K**.

The presentation of the PIC is made available on the City's website. A copy of the presentation is included in **Appendix K**.

3.2.2. Public Information Centre #2

The PIC #2 was held on May 17, 2011 from 6:00 p.m. – 8:00 p.m., at the Peterborough WWTP.

The purpose of the meeting was to:

- Provide project overview;
- Present generic alternatives, evaluation criteria, and preferred alternatives;
- Provide an opportunity for questions about the proposed works; and,
- Outline the next steps of the study process.

Like PIC #1, the format of the meeting was an informal drop-in centre with display panels, a presentation, and question and answer period.

A comment sheet requesting input on the study was provided to participants. A total of seven members of the public signed in at the PIC and one comment sheet was submitted. These are found in **Appendix K**.

The presentation of the PIC was made available on the City's website. A copy of the presentation is also included in **Appendix K**.

4.0 Existing Conditions

4.1. Socio Economic Environment

4.1.1. Land Use

The study area includes the sanitary sewer service area conveying flows to the Peterborough WWTP. It includes most of the municipal boundary, of approximately 5,502 ha. About two-thirds of the area of the City is located west of the Otonabee River and one-third is located east of the river.

The study area is composed of residential, employment areas, commercial, institutional, and green space according to the maps of the City's Official Plan and external areas which contribute sanitary flow. The dominant land use in the study area is summarised in **Table 4-1**. This information was used in the study to estimate waste water flow generation rates.

Table 4-1 – City of Peterborough Land Use

Type	Area (ha)	Percentage (%)
Agriculture	81	1.5
Commercial	425	7.7
Environmental Constraint	69	1.2
Environmental Protection	5	0.1
Hamlet	35	0.6
Industrial	456	8.3
Major Institution	366	6.6
Major Open Space	1058	19.2
Protected Natural Areas	100	1.8
Residential	2063	37.5
Rural	221	4.0
Urban Fringe Control Area	480	8.7
Village	112	2.0
Undefined	32	0.6
Total	**5502**	**100**

4.2. Parks and Natural Heritage

The City's GIS database indentifies 105 parks and 114 heritage property sites. **Figure 4-2** shows the parks and natural heritage sites.

Parts of the Trans Canada Trail are also located within the City. The Trans Canada Trail is the world's longest network of trails and once complete will stretch from the Atlantic to the Pacific to the Artic Ocean. The trail is used for a number of different activities including: hiking, cycling, skiing, horseback riding, canoeing, and snowmobiling. The Trans Canada Trail has predominantly been funded by the Federal and Provincial governments, with additional assistance from private donors.

It should be noted that in the context of this study, there is currently a lack of access to some sanitary trunk sewers, which are located in the vicinity of trails and open space. Sewer access is required to inspect and maintain the sewer in proper working conditions.

4.3. Technical Environment

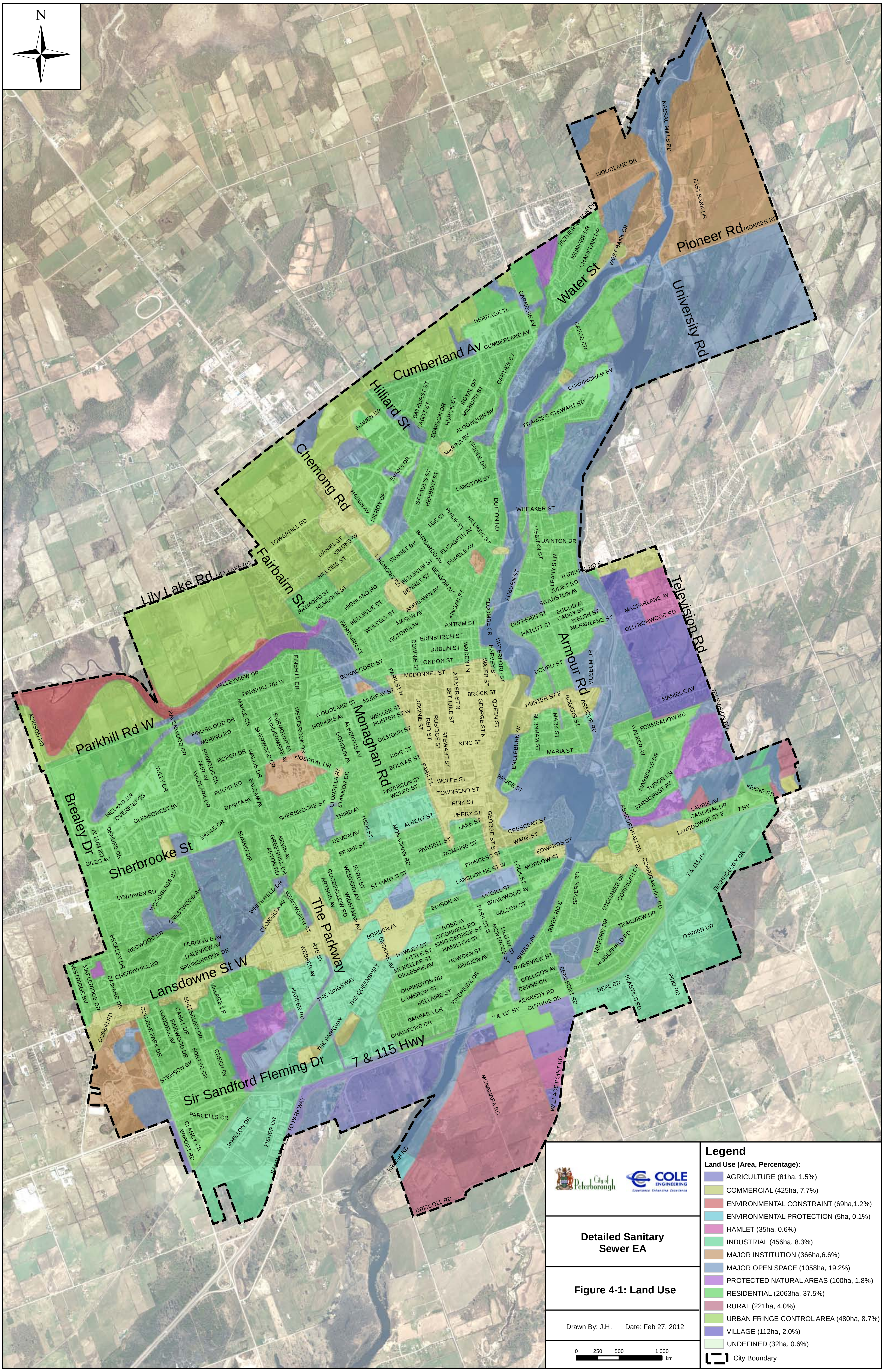
4.3.1. Existing Sanitary Sewer System

Most of the urban area in the City is serviced by separate sanitary sewer systems. In general, the sanitary sewer system generally drains in two directions:

1. A western branch collecting sanitary sewage from the majority of the western portion of the City, eventually converging at the Park Street bypass station; and,
2. An eastern branch collecting sanitary sewage from the majority of the eastern portion of the City, eventually converging near the intersection of Sherin Avenue and Riverview Heights.

The system consists of 358 km of sewers, 5,312 sewer segments, 10 pumping stations and a treatment plant. The Peterborough WWTP is located at 425 Kennedy Road, Lot 25, and Concession 14 at the south end of the City and on the southern slopes of the Otonabee River. The plant services an area of 3,649 ha and a population of 75,685 people, as per 2006 census data.

Figure 4-3 shows the sanitary sewer system service areas. The figure also illustrates the sanitary sewer system in the context of ground elevations in the City. Relative ground elevations are an indicator of the potential groundwater infiltration (GWI) into sanitary sewers.


N
Pioneer Rd
University Rd
Water St
Cumberland Av
Hilliard St
Chemong Rd
Fairbairn St
Lily Lake Rd
Parkhill Rd W
Monaghan Rd
Armour Rd
Television Rd
Brealey Dr
Sherbrooke St
The Parkway
Lansdowne St W
Sir Sandford Fleming Dr
7 & 115 Hwy
Legend
Land Use (Area, Percentage):
AGRICULTURE (81ha, 1.5%)
COMMERCIAL (425ha, 7.7%)
ENVIRONMENTAL CONSTRAINT (69ha,1.2%)
ENVIRONMENTAL PROTECTION (5ha, 0.1%)
HAMLET (35ha, 0.6%)
INDUSTRIAL (456ha, 8.3%)
MAJOR INSTITUTION (366ha,6.6%)
MAJOR OPEN SPACE (1058ha, 19.2%)
PROTECTED NATURAL AREAS (100ha, 1.8%)
RESIDENTIAL (2063ha, 37.5%)
RURAL (221ha, 4.0%)
URBAN FRINGE CONTROL AREA (480ha, 8.7%)
VILLAGE (112ha, 2.0%)
UNDEFINED (32ha, 0.6%)
City Boundary
City of Peterborough
COLE ENGINEERING
Detailed Sanitary Sewer EA
Figure 4-1: Land Use
Drawn By: J.H.
Date: Feb 27, 2012
0 250 500 1,000
km

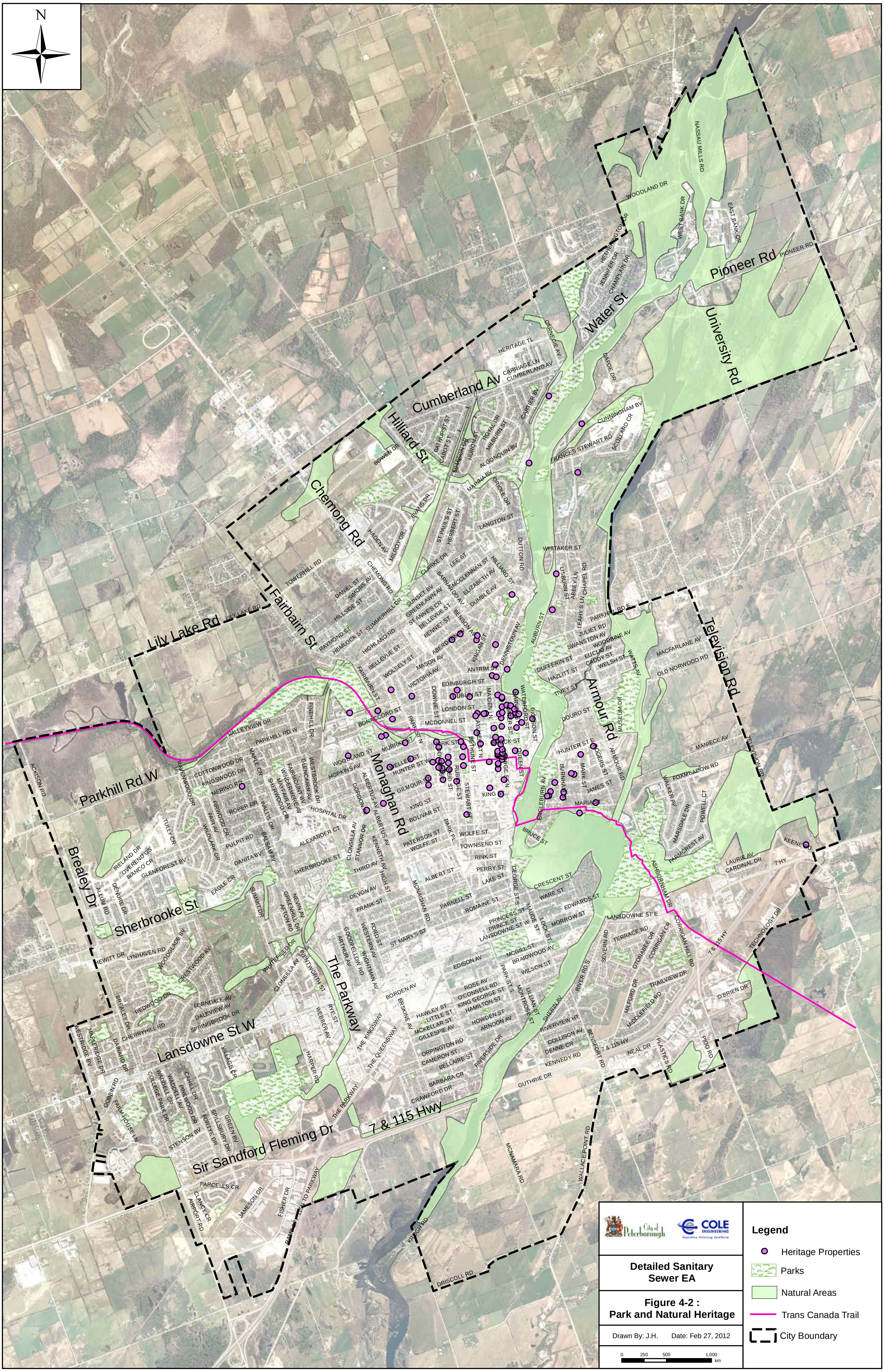
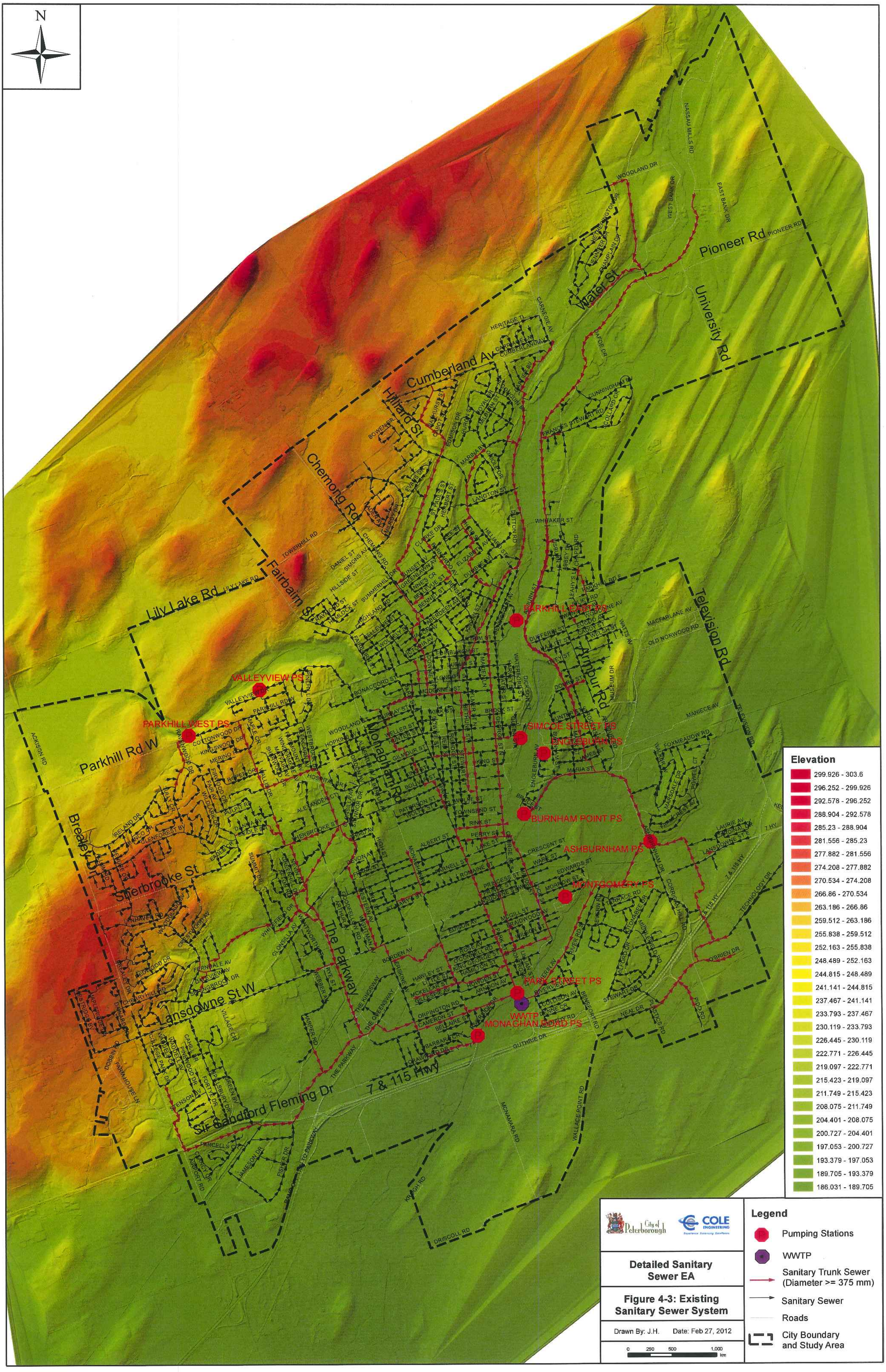


Figure 4-2 : Park and Natural Heritage


N
Elevation
299.926 - 303.6
296.252 - 299.926
292.578 - 296.252
288.904 - 292.578
285.23 - 288.904
281.556 - 285.23
277.882 - 281.556
274.208 - 277.882
270.534 - 274.208
266.86 - 270.534
263.186 - 266.86
259.512 - 263.186
255.838 - 259.512
252.163 - 255.838
248.489 - 252.163
244.815 - 248.489
241.141 - 244.815
237.467 - 241.141
233.793 - 237.467
230.119 - 233.793
226.445 - 230.119
222.771 - 226.445
219.097 - 222.771
215.423 - 219.097
211.749 - 215.423
208.075 - 211.749
204.401 - 208.075
200.727 - 204.401
197.053 - 200.727
193.379 - 197.053
189.705 - 193.379
186.031 - 189.705
City of Peterborough
COLE ENGINEERING
Detailed Sanitary Sewer EA
Figure 4-3: Existing Sanitary Sewer System
Drawn By: J.H.
Date: Feb 27, 2012
0 250 500 1,000
km
Legend
Pumping Stations
WWTP
Sanitary Trunk Sewer (Diameter >= 375 mm)
Sanitary Sewer
Roads
City Boundary and Study Area
PARKHILL EAST PS
VALLEYVIEW PS
PARKHILL WEST PS
SIMCOE STREET PS
ENGLEBURN PS
BURNHAM POINT PS
ASHBURNHAM PS
MONTGOMERY PS
PARK STREET PS
WWTP
MONAGHAN ROAD PS
Pioneer Rd
University Rd
Water St
Cumberland Av
Hilliard St
Chemong Rd
Fairbairn St
Lily Lake Rd
Television Rd
Armour Rd
Parkhill Rd W
Monaghan Rd
Brealey Dr
Sherbrooke St
Lansdowne St W
The Parkway
7 & 115 Hwy
Sir Sandford Fleming Dr

5.0 File and Field Data Collection

The following describes the work completed to collect the data, including rainfall and flow monitoring.

5.1. File Data Collection

Background reports that were available for this study include:

- City of Peterborough – Report on the Sanitary Sewer Flow Monitoring Study – 1994 (Gore & Storrie Limited);
- City of Peterborough – Flood Reduction Master Plan, April 5, 2005 (UMA Engineering Ltd.);
- Comprehensive Process Audit of the Peterborough WWTP, June 16, 2010 (R.V. Anderson Associates Limited and XCG Consultants Ltd.); and,
- City of Peterborough – City Wide Soil and Groundwater Investigation and Monitoring, November 2007 (Geo-Logic Inc.).

Other background sources pertinent to the study include:

- Fog / smoke testing records;
- Dye testing records;
- Flow monitoring records;
- Land use classification (to determine hydrologic properties of the area);
- Water consumption records (to estimate typical wastewater flows);
- Population (to estimate typical wastewater flows);
- Physical sewer network data (to develop detailed model and assess existing and proposed infrastructure performance);
- Aerial photographs (to identify structures and classify land use);
- Digital elevation model;
- Sewer design criteria and sewer use by-law;
- Sanitary Backflow Prevention Subsidy Program;
- Historical precipitation data;
- As-built drawings; and,
- Consultation with City operations staff.

The information derived from the above sources determined work undertaken to date and established the existing conditions used in the model.

5.1.1. Sewer Use By-Law

The City's Bylaw 05-104 states: "No person shall discharge or deposit or cause or permit the discharge or deposit of matter of a kind listed below into or in land drainage works, private branch drains or connections to any sanitary sewer or combined sewer". The list of "matter" of which the Bylaw speaks can be found in Section 2 of The City's Bylaw 05-104: "To Regulate the Discharge of Sewage and Land Drainage in the City". A copy of the by-law is found in **Appendix B**.

5.1.2. Sanitary Backflow Prevention Subsidy Program

The City has offered a subsidy to assist property owners with the installation of a backflow valve and/or a sump pit and pump. The objective is to prevent water from backing up into basements. This was initiated in 2005 following the July 2004 storm event. Through discussions with the City, this program has had varying success. In some areas with high groundwater elevations, the sump pumps have operated continuously and were disconnected with foundation drains having to be reconnected to the sanitary sewer. Further details regarding the program are found in **Appendix B**.

5.1.3. Historical Basement Flooding

The City has a record of previously reported flooding. A figure showing these areas can be found in **Appendix I**. However, the information does not identify the cause or the extent of the flooding. Typically, studies investigating I-I or basement flooding provide a record of flood locations (addresses) during a specific storm event to determine whether the model is accurately predicting flood vulnerable areas. Such information can be used to model flooding during these historical events.

High flood potential from overloaded sewers may not result in actual flooding. Actual flooding depends on the site-specific building and road construction standards in place at the time of construction and the particular design of each building. For example, the analysis would predicts high flooding potential if the HGL in the sewer rises within 1.8 m of the ground elevation. Buildings without basements would not be flooded under this condition. Conversely, buildings with basement elevations below the 1.8 meter elevation of the road will have a higher flood potential. Site-specific investigations would be required to assess building-specific flood potential.

5.1.4. Data Gap Identification and Correction

The City's sanitary sewer network data was reviewed in detail and gaps were identified. Missing manhole inverts, ground elevations, pipe diameter, pipe slope, and pipe length were identified (e.g. zero diameter, zero length, etc). A thorough review was also conducted to identify potential errors in the data by assessing extreme values such as very steep or very shallow pipe slopes, and pipe dimensions that did not appear to be consistent with adjoining pipes.

Original data gaps were addressed partially through additional data received from the City and through assumptions using engineering judgement.

The development of the detailed model (described in detail in **Section 6.0**) shows the delineation of drainage areas to each pipe segment. Since the model includes individual pipe, data infilling was necessary to ensure the model is capable of predicting flood potential within each node (manhole) and pipe segment. A complete list of data gaps can be found in Appendix E.

5.2. Geological Assessment

In 2007, a city-wide soil and groundwater investigation and monitoring study was conducted in the City by Geo-Logic Inc. The study concluded that high ground water levels found in the City contribute infiltration into the sanitary sewer system causing an increase of flow at the Peterborough WWTP in the months of April through June. Sources of infiltration are cracked or broken pipes, root intrusions, and gaps in pipe joints. Due to the high water table, infiltration appears to occur throughout the year and will require sophisticated tracking of sewage flows compared to water usage to isolate seepage areas.

The Geo-Logic study recommended:

- The application of water proofing to sanitary manholes and pipe connections;
- A review of soil types and water table position for sanitary sewers in new development should be carried out to lower infiltration potential;
- Repairs should be carried out in existing sanitary pipes beginning with sewers in high water table areas in sandy soils then continuing through the till areas.
- A review should be carried out of grade requirements and pipe size to determine the possibility of raising the sewer grade in sections to lower the potential of infiltration;
- Where possible, storm sewers should be deepened sufficiently to allow connections of sumps and foundation drains. The disconnection of sumps and foundations drains from the sanitary sewer, without providing an alternative outfall, may result in foundation wall failure due to increased hydrostatic pressure;
- Disconnection and sealing of roof leaders from foundation drains, where they are found to connect to the sanitary sewer;
- Monitoring of flows in the sanitary system versus the water supply with continuous readout to ascertain flow changes relative to time and precipitation events to determine inflow versus infiltration contribution. Where infiltration or inflow is found to be present in a given area, a further detailed investigation may be carried out using smoke testing in the sanitary to pin point sources;
- Where areas of concern are identified, carry out detailed soils investigation and water table monitoring in priority areas in conjunction with weather monitoring to better model infiltration potential;
- Further investigation should be carried out to delineate areas of sand in the west end of Parkhill Road with further soil and groundwater monitoring; and,
- Review sewer invert depths in the sand areas not prioritized because of shallow sewer elevations, since current data provided by the City provides the invert depth at the well locations and not the range in invert elevations for the area.

These recommendations point to hydrogeologic conditions combined with the deterioration and connectivity of the sewer systems which allow for significant wet and dry weather infiltration and inflow.

5.3. Pumping Stations

There are ten pumping stations within the sanitary sewer system service area. **Figure 5-1** shows the location of the pump stations. Pump station parameters critical for model development include: wet well diameter, and off elevations, and wet well elevation, and pumping capacity or rate (pump curves). This information was not available at the start of this project.

Pump station capacities are important as the rates at which sanitary sewage is pumped into the sewer network has an impact on the downstream hydraulic conditions in the sanitary sewers.

Information collected during this study included stations drawings, and background reports. The pump station’s maximum pumping capacity was determined from individual drawdown tests performed at each station. The drawdowns test determined only the “maximum” pump rate.

The results of the pump station investigations are summarised in **Table 5-1**. Details are found in **Appendix C**.

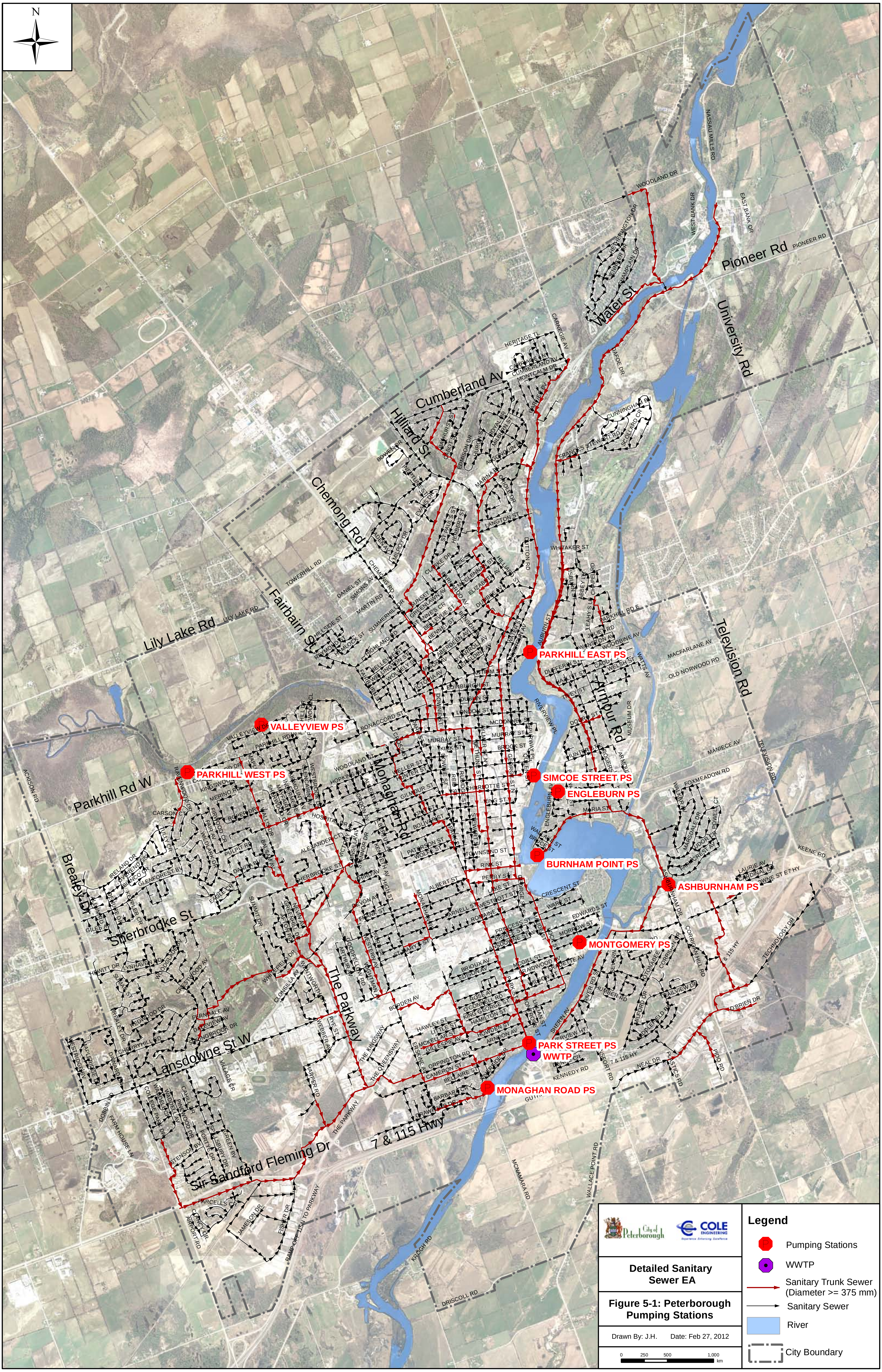

N
Detailed Sanitary Sewer EA
Figure 5-1: Peterborough Pumping Stations
Drawn By: J.H.
Date: Feb 27, 2012
0 250 500 1,000 km
City of Peterborough
COLE ENGINEERING
Legend
Pumping Stations
WWTP
Sanitary Trunk Sewer (Diameter >= 375 mm)
Sanitary Sewer
River
City Boundary
PARKHILL EAST PS
VALLEYVIEW PS
PARKHILL WEST PS
SIMCOE STREET PS
ENGLEBURN PS
BURNHAM POINT PS
ASHBURNHAM PS
MONTGOMERY PS
PARK STREET PS
WWTP
MONAGHAN ROAD PS
Pioneer Rd
University Rd
Water St
Cumberland Av
Hilliard St
Chemong Rd
Fairbairn St
Lily Lake Rd
Television Rd
Armour Rd
Monaghan Rd
Parkhill Rd W
Brealey Dr
Sherbrooke St
The Parkway
Lansdowne St W
Sir Sandford Fleming Dr
7 & 115 Hwy

Table 5-1 – Pump Station Investigations

Pump Station	Wet Well Dimensions (m)	Number of Pumps	Wet Well Elevation (m)	Wet Well Depth (m)	Maximum Pump Rate (m^3/s)
Monaghan Road PS	2.80 X 1.68	2	184.91	5.56	0.13
Burnham Point PS	6.23 X 3.53	2	188.06	3.03	0.09
Ashburnham Drive PS	9.00 X 3.70 (tapers with increasing depth)	4	183.20	3.95	0.39
Parkhill West PS	3.66 dia.	2	231.99	8.69	0.07
Montgomery PS	3.00 dia.	2	183.36	7.15	0.04
Simcoe Street PS	3.05 dia.	2	187.48	5.00	0.14
Engleburn PS	2.44 X 1.22 (tapers with increasing depth)	2	190.38	5.21	0.01
Valleyview PS	3.00 dia.	2	234.60	7.80	0.04
Parkhill East PS	2.44 dia.	2	197.08	4.80	0.03
Airport PS	3.00 dia.	2	183.74	6.40	0.01

5.4. Historical and New Rainfall and Flow Monitoring

5.4.1. Historical and New Rainfall Data

Data from two rain gauges, located at City Hall and at the Peterborough WWTP, and in operation in 2005 and 2006, were provided by the City. Additional precipitation data was obtained from gauges operated by Environment Canada (Trent University: 2005 – 2010) and the Otonobee Region Conservation Authority (2008 – 2010). **Table 5-2** and **Table 5-3** summarize three rainfall events greater than 20 mm in 2005 and three events in 2006 used for model calibration and validation.

Table 5-2 – 2005 Rainfall Data

Event	Event Date	Trent University Rain Gauge Rainfall		WWTP Rain Gauge Rainfall	
		Depth (mm)	Peak 1-hr Intensity (mm/hr)	Depth (mm)	Peak 1-hr Intensity (mm/hr)
1	Sep 14 2005	21	9	10	5.2
2	Sep 25 2005	41	7.9	31	5.4
3	Sep 29 2005	28	18	24	16.2

Table 5-3 – 2006 Rainfall Data

Event	Event Date	Trent University Rain Gauge Rainfall		WWTP Rain Gauge Rainfall	
		Depth (mm)	Peak 1-hr Intensity (mm/hr)	Depth (mm)	Peak 1-hr Intensity (mm/hr)
1	May 11 2006	41	6.9	39	4
2	June 26 2006	31	18.5	19	11.2
3	Oct 11 2006	39	4.1	33	3.6

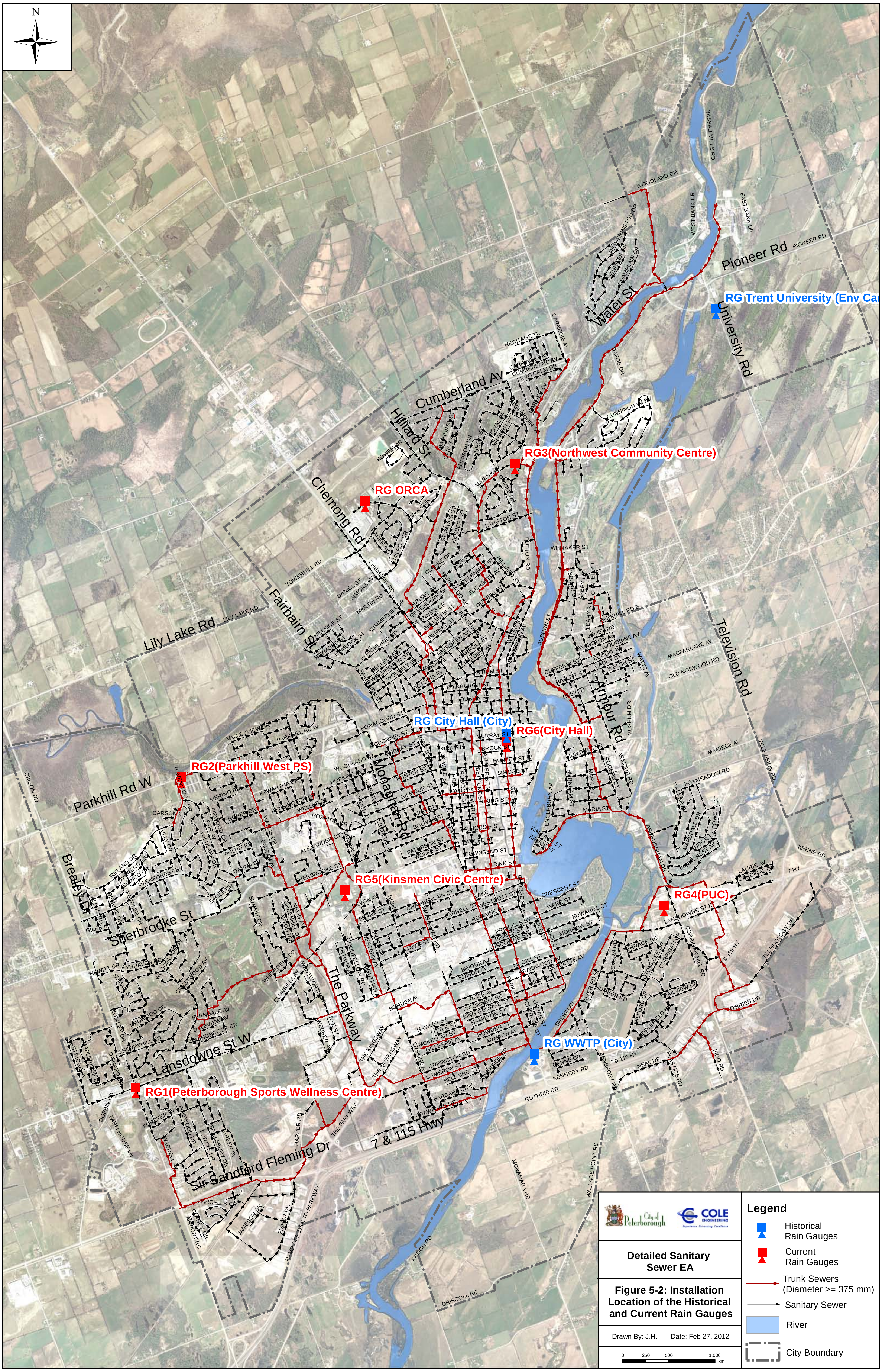
This study also installed and operated six rain gauges from the fall of 2010 to the summer of 2011. Data from these gauges was used to create rainfall surfaces over each catchment area. This approach accounts for the spatial variability of storm events over a relatively large drainage area. **Table 5-4** summarizes the events used in model calibration and **Figure 5-2** shows the rain gauge locations.

Table 5-4 – 2010 Rainfall Intensities and Volumes, RG1 – RG3

Event	Event Date	RG1-Wellness Center Rainfall		RG2-Parkhill West Rainfall		RG3-Northcrest Arena Rainfall	
		Depth (mm)	Peak 1-hr Intensity (mm/hr)	Depth (mm)	Peak 1-hr Intensity (mm/hr)	Depth (mm)	Peak 1-hr Intensity (mm/hr)
1	Nov 16 2010	31	9	30	9	27	9
2	Nov 25 2010	12	15	12	12	12	12
3	Nov 30 2010	39	9	38	9	38	9

Table 5-5 – 2010 Rainfall Intensities and Volumes, RG4 – RG6

Event	Event Date	RG4-PUC Rainfall		RG5-Kinsmen Civic Center Rainfall		RG6-City Hall Rainfall	
		Depth (mm)	Peak 1-hr Intensity (mm/hr)	Depth (mm)	Peak 1-hr Intensity (mm/hr)	Depth (mm)	Peak 1-hr Intensity (mm/hr)
1	Nov 16 2010	29	9	33	15	30	9
2	Nov 25 2010	12	12	12	12	12	9
3	Nov 30 2010	37	6	41	9	41	12



Detailed Sanitary Sewer EA

Figure 5-2: Installation Location of the Historical and Current Rain Gauges

5.4.2. Historical and New Flow Data

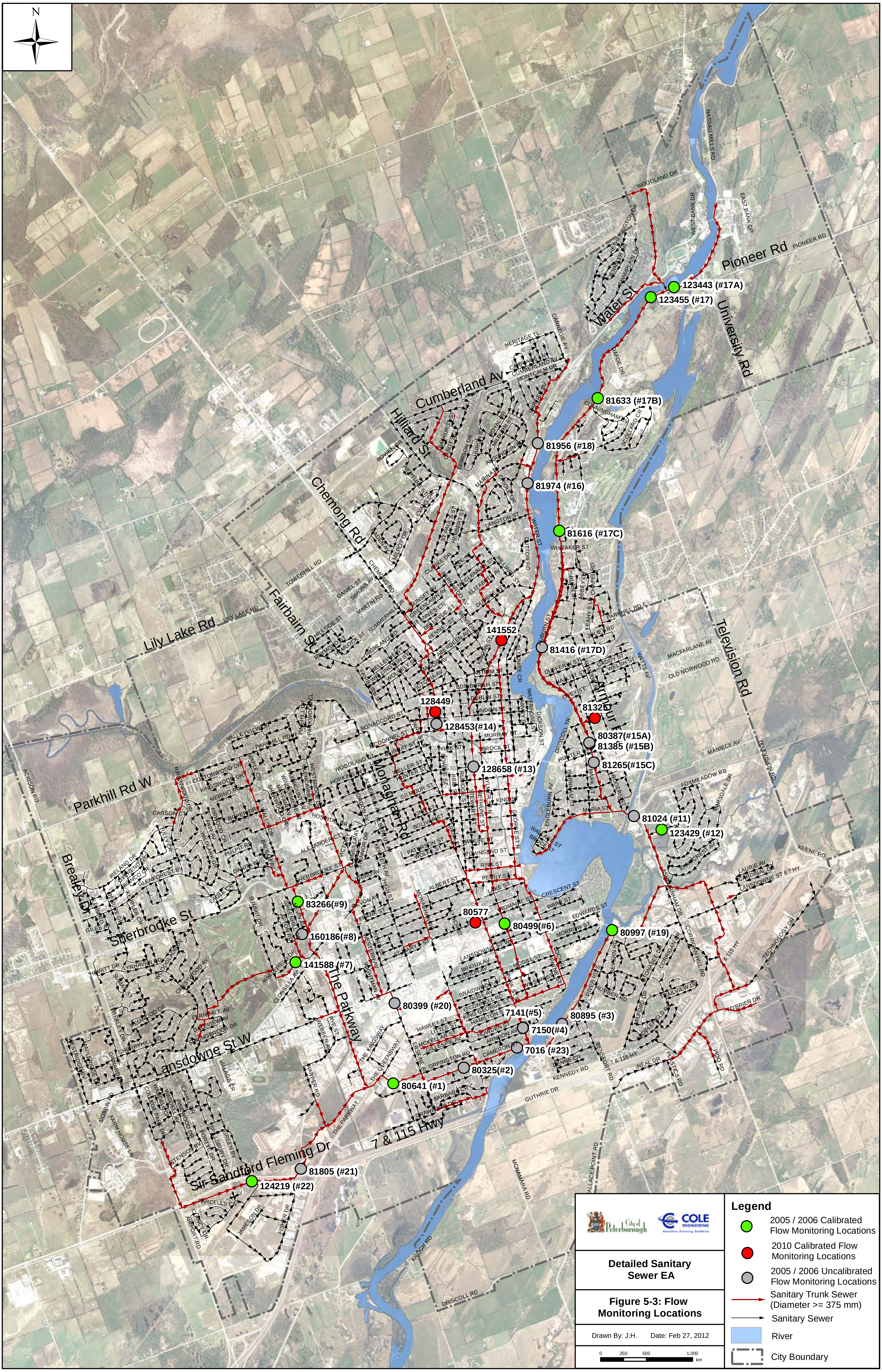
A total of 26 historical flow monitoring stations were installed and operated by others from 2005 to 2006. Four new flow monitoring stations were installed in the fall of 2010 as a part of this study. **Figure 5-3** shows the locations of all flow monitoring stations during the 2005-2006 monitoring program and the 2010 monitoring program. The flow and rain data has been used to:

- Characterise dry weather and wet weather flows in the system;
- Estimate dry and wet weather flow generation parameters; and,
- Calibrate the hydrologic and hydraulic model.

The dry weather flow (DWF) generation parameters were determined using the measured flow data, available population and land use data. The WWF was separated from the total measured flow by subtracting the DWF and quantify the response of the sanitary system during rainfall events. Specifically, I-I is the flow above the DWF caused by rainfall entering the sanitary sewer system through manhole covers, cracked or leaky pipes, roof and foundation drains, and other direct connections such as roof leaders, basement access drains, and other drains.

Upon screening of the flow and rainfall monitoring data from 2005 and 2006, it was found that some of this historical data was insufficient for model calibration. A total of 15 stations were used in the analysis. All four stations from 2010 were used for further analysis.

In addition to assessing dry and wet weather flows, monitoring data was used to calibrate the hydrologic / hydraulic model. Flow monitoring data is found in **Appendix D**. Model calibration is described in **Section 6.3.**



Detailed Sanitary Sewer EA

Figure 5-3: Flow Monitoring Locations

Table 5-6 and **Table 5-7** summarize the DWF and WWF from the monitoring conducted in the 2005, 2006, and 2010 flow monitoring programs.

Table 5-6 – Dry Weather Flow

Flow Station	Drainage Area (ha)	Population	Measured Peak Dry Weather Flow (L/s)
Derived from flow monitoring in 2005			
1	1217	18965	129.3
6	849	21776	117.9
7	266	6440	44.6
9	147	3356	18.9
Derived from flow monitoring in 2006			
12	31	1199	5.4
17	141	1463	33.0
17A	24	5	2.8
17B	151	1581	37.1
17C	213	2334	46.1
19	686	11910	128.5
22	213	2441	28.6
Derived from flow monitoring in 2010			
81325	79	2240	22.8
80577	128	1743	10.1
128449	282	5720	59.9
141552	253	5725	75.8

In residential areas, the majority of DWF in the sanitary sewer system is population derived. The population data available was used to establish per capita dry weather generation rates. **Section 6.0** describes model development.

Table 5-7 – Wet Weather Flow

Flow Station	Peak Wet Weather Flow (L/s)	Peak Measured Infiltration and Inflow (L/s/ha)
Derived from flow monitoring in 2005		
1	60.4	0.05
6	156.4	0.18
7	38.4	0.14
9	24.1	0.16

Flow Station	Peak Wet Weather Flow (L/s)	Peak Measured Infiltration and Inflow (L/s/ha)
Derived from flow monitoring in 2006		
12	14.5	0.47
17	31.0	0.22
17A	8.1	0.34
17B	47.7	0.31
17C	58.3	0.27
19	54.5	0.08
22	19.6	0.09
Derived from flow monitoring in 2010		
81325	20.2	0.26
80577	4.2	0.03
128449	77.4	0.27
141552	83.3	0.33

As shown in **Table 5-7**, I-I rates varied significantly. Seven locations exceeded the City's I-I design criteria of 0.25 L/s/ha during the three monitoring periods in 2005, 2006, and 2010 (details of the City's design criteria are found in **Appendix B**). Since many of the events captured during the monitoring periods were not very intense, further monitoring for a longer duration is recommended in order to quantify I-I.

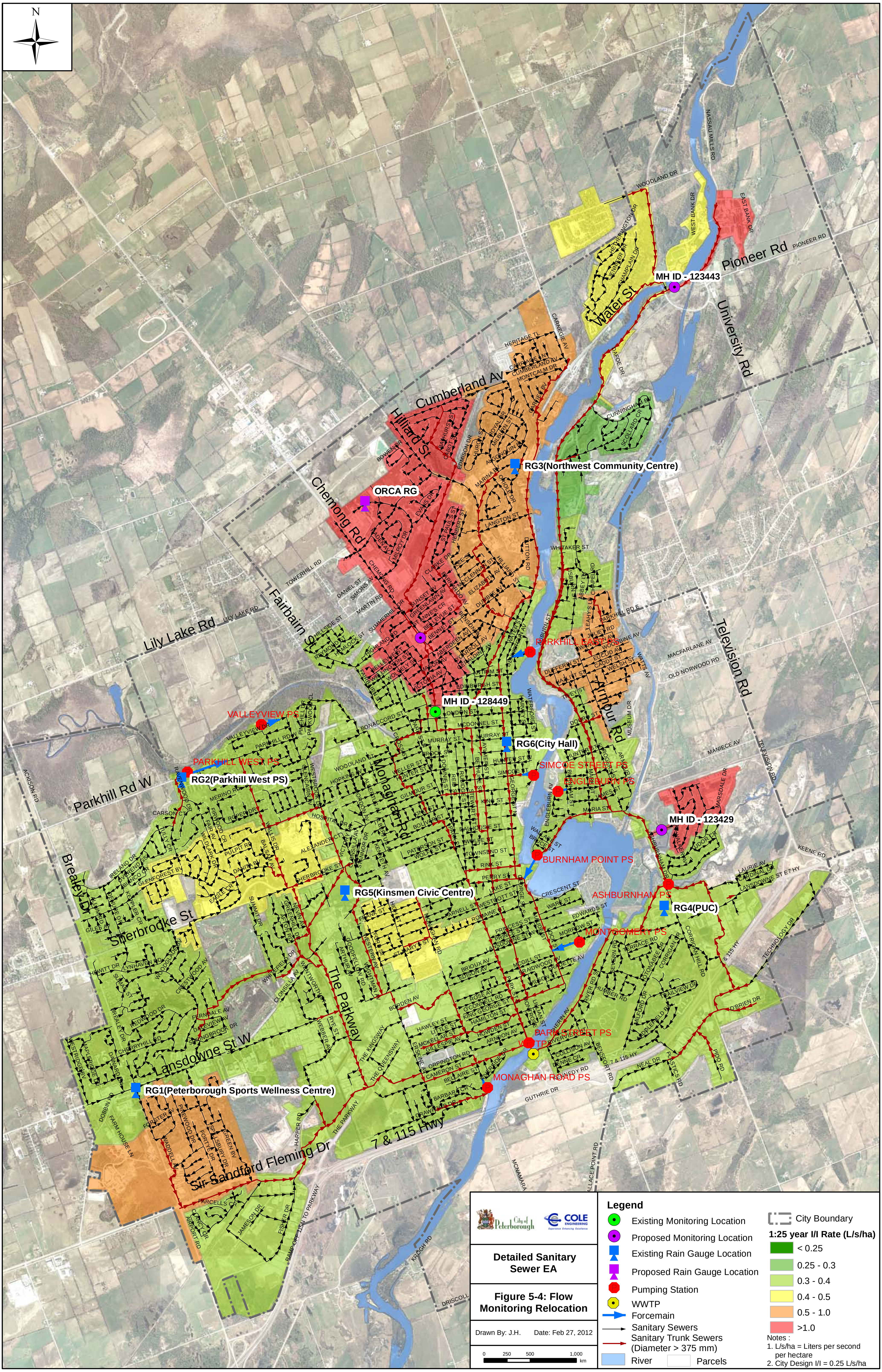
Note that a storm event could deliver significant differences in rain over different catchments. As such, it is difficult to compare I-I throughout a study area unless the storm is "normalised". A normalised I-I, such as that produced by a 1 in 25 year design storm event, must to be determined to assess the relative I-I contributions between areas. I-I characterisation is discussed in **Section 7.1**.

5.4.3. Future Flow Monitoring Strategy

It was recommended that the flow monitor with the highest normalized I-I (128449) remain in its current location. Normalized I-I contributions are discussed in **Section 7.1**. The three remaining flow stations were relocated to other locations where high I-I was predicted by the model. **Figure 5-4** shows locations where the flow monitors were relocated.

It is recommended that future flow monitoring locations consider areas with high GWI as well as high I-I rates. Monitoring should cover a period from spring to fall (nine month period) to capture seasonal variations in GWI and sufficient WWF events to characterize the I-I into the sanitary sewer system. Rain gauge coverage should be sufficient to characterize the rainfall over the tributary area. Furthermore, subdividing areas where high GWI or high I-I have been identified should be considered. This technique, known as "bracket" monitoring, should be used to isolate high contributing areas.

A six rain gauge network provides a good representation of the rainfall distribution over the study area. In addition to the six gauges, the Otonabee Region Conversation Authority (ORCA) agreed for its rain gauge to be a part of the rain gauge network, as part of the ongoing flow monitoring program.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Chemong Rd
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Parkhill Rd W
Television Rd
Armour Rd
Monaghan Rd
Sherbrooke St
Brealey Dr
Lansdowne St W
The Parkway
7 & 115 Hwy
Sir Sandford Fleming Dr
MH ID - 123443
RG3(Northwest Community Centre)
ORCA RG
PARKHILL EAST PS
MH ID - 128449
VALLEYVIEW PS
PARKHILL WEST PS
RG2(Parkhill West PS)
RG6(City Hall)
SIMCOE STREET PS
ENGLEBURN PS
MH ID - 123429
BURNHAM POINT PS
ASHBURNHAM PS
RG4(PUC)
RG5(Kinsmen Civic Centre)
MONTGOMERY PS
PARK STREET PS
WWTP
MONAGHAN ROAD PS
RG1(Peterborough Sports Wellness Centre)
City of Peterborough
COLE ENGINEERING
Detailed Sanitary Sewer EA
Figure 5-4: Flow Monitoring Relocation
Drawn By: J.H.
Date: Feb 27, 2012
0 250 500 1,000 m
Legend
Existing Monitoring Location
Proposed Monitoring Location
Existing Rain Gauge Location
Proposed Rain Gauge Location
Pumping Station
WWTP
Forcemain
Sanitary Sewers
Sanitary Trunk Sewers (Diameter > 375 mm)
River
Parcels
City Boundary
1:25 year I/I Rate (L/s/ha)
< 0.25
0.25 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 1.0
>1.0
Notes :
1. L/s/ha = Liters per second per hectare
2. City Design I/I = 0.25 L/s/ha

6.0 Model Development

6.1. Description of the Sanitary Sewer Model

A detailed model of the sanitary sewer system was developed to assess the performance of the existing sanitary sewer system and to evaluate alternatives. As previously discussed, sanitary sewer network information and population data were compiled from the City's GIS database. All manholes, sanitary sewer pipes, and contributing subcatchments are represented in the model. In total, 5,312 pipe segments and 4,569 subcatchments are included in addition to ten pump stations. **Figure 6-1** illustrates the sanitary sewer model areas.

In addition to flow, the model predicts the hydraulic grade line (HGL), in each manhole. This identity can be interpolated to in each sewer pipe and used to identify surcharged sewers. The basement elevation was assumed to be 1.8 meters below the surface.

Surcharged sewers with an HGL within 1.8 m of the surface were assumed to cause high potential for basement flooding in the nearby properties. It should be noted that the City currently does not have a level of service criteria with regards to flood risk / basement elevation; however, the City's Flood Reduction Master Plan recommends that all parts of the City receive a consistent level of protection against damage from future flooding.

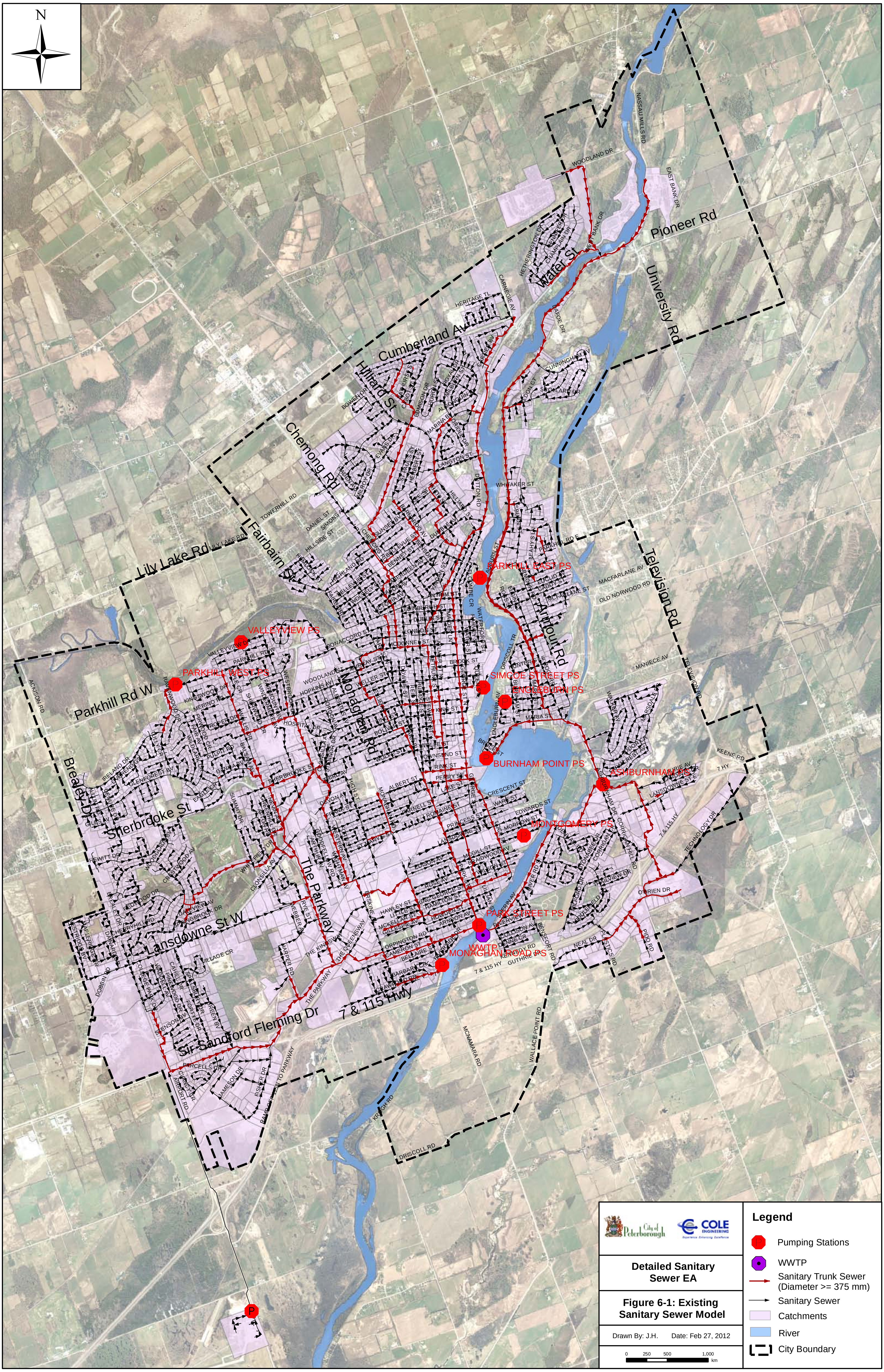
The distance of 1.8 meters from the road surface to the basement level elevation is an assumption. A basement elevation survey should be conducted particularly in the older parts of the City. More surveys may be needed prior to detail design.

6.1.1. MIKE URBAN

DHI's MIKE URBAN computer simulation models were developed for various scenarios. MIKE URBAN integrates hydrologic and hydraulic functions into one interface. The approach produced a model with pipe-by-pipe discretized catchments.

6.2. Existing Conditions Data

Key input data included sewer network data, Digital Elevation Modelling (DEM), aerial photography, parcel fabric, census data, flow and rainfall monitoring data, and pumping station information. The sewer network data includes sewer dimensions, inverts, connectivity, and pipe material. This data was obtained from the City's GIS database. The original data was extensively reviewed and assumptions made to fill in data gaps.



Detailed Sanitary Sewer EA

Figure 6-1: Existing Sanitary Sewer Model

Drawn By: J.H. Date: Feb 27, 2012

6.2.1. Model Setup

The QA / QC identified a significant number of "data gaps" within the existing GIS database. These gaps included missing or inaccurate sanitary sewer inverts, duplicate sewers, missing pipe diameters, missing Node IDs, or a combination of the aforementioned.

Below are several data gap infilling methods applied to complete the model:

- City reviewed the data gaps and added to the existing GIS database;
- Completing (infilling) data gaps based on reasonable assumptions; and,
- Conducting field investigations and surveys for missing data.

Due to time and scope constraints, it was decided that data gaps were to be "infilled" based on reasonable assumptions. These assumptions typically involve methods such as interpolation, extrapolation, and averaging or defining properties based on typical system design and construction practices. While every precaution is taken to ensure the accuracy of any assumptions that are made, it should be noted that the number and degree of assumptions ultimately affect the accuracy of the results and this should be taken into consideration when making decisions based on those results. A complete list of all assumptions made for model development can be found in **Appendix E**. It is recommended to verify the information where data gaps have been identified, which potentially affects the preferred solutions. In other words, the data gap strategy should prioritize filling the data gaps upstream and downstream that may affect the solutions in problem areas.

The model was discretised into individual catchment areas contributing flow to individual pipes. The catchments were delineated pipe by pipe (manhole to manhole) using the parcel fabric shapefile layer provided by the City. Each catchment contributes flow to a manhole located upstream of the catchment. A total of 4,569 catchment areas were defined in the model.

Although the original objective was to develop a sanitary sewer model of the sewer trunk system, I-I is more of a localized problem and it was decided to build the entire sanitary sewer network consisting of both local and trunk sewers to be used in subsequent I-I reduction investigations.

6.3. Model Calibration and Validation

Historical and new monitored rain and flow data was used to calibrate the model. The measured dry weather per capita flow rates and daily patterns were applied to residential areas. Observed rainfall was used to simulate the response of the sanitary system while the observed flow at the monitoring locations was used to verify the flow predicted by the model for a range of rainfall events. The rainfall events used for calibration and validation ranged between 12 mm and 41 mm. The observed rainfall events during the monitoring periods were not extreme and did not produce significant volumes of I-I or cause any known basement flooding. The flow monitoring summary presented in **Section 5.4.2** represent the total dry weather and wet weather flows including upstream flows for a given flow monitoring location. For the purposes of model calibration, dry and wet weather flows were represented incrementally by subtracting the flow from contributing upstream areas. Flow monitoring data used in model calibration is found in **Appendix D**.

6.3.1. Dry Weather Flow

Table 6-1 summarises the incremental DWF used for model calibration.

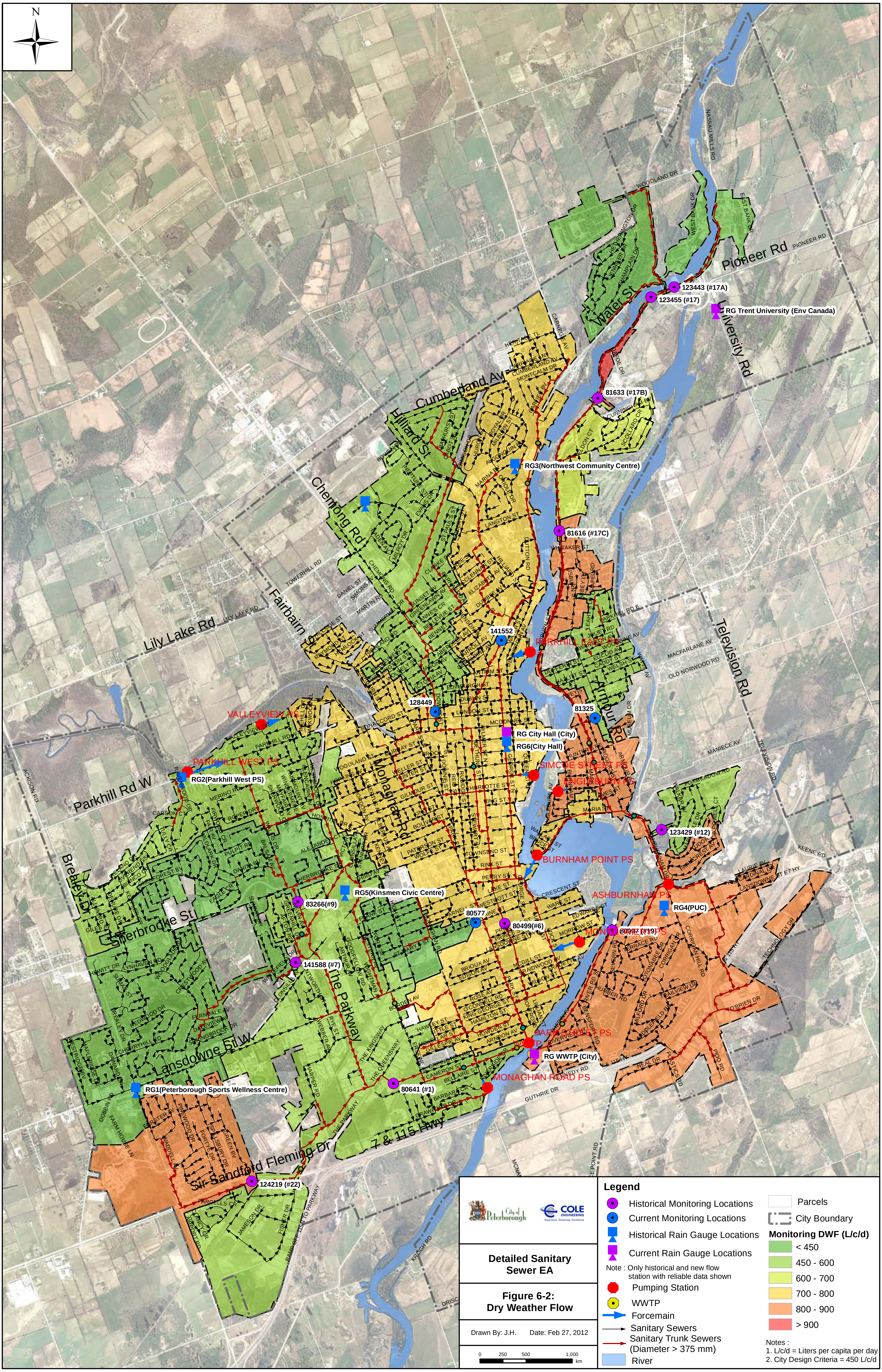
Table 6-1 – Incremental Dry Weather Flow Summary

Flow Station	Incremental Drainage Area (ha)	Incremental Population	Incremental Dry Weather Flow (L/s)
Derived from previous flow monitoring in 2005			
1	591	672	520
6	216	7111	708
7	266	6440	436
9	147	3356	370
Derived from previous flow monitoring in 2006			
12	31	1199	501
17	117	1458	*450 + Measured Inflow
17A	24	5	**Measured Inflow
17B	10	118	*450 + Measured Inflow
17C	62	753	629
19	363	6130	870
22	213	2441	882
Derived from flow monitoring data in 2010			
81325	79	2240	488
80577	70	1743	383
128449	279	5720	562
141552	134	3253	716

*Trent University and other residential areas contribute to sanitary flow at monitoring location 17 and 17B. As the population at Trent University varies throughout the year, the population data provided from the 2006 census would not be representative. Therefore, per capita sanitary flow contributions should not be determined from the population data exclusively. In order to determine the DWF to monitoring locations 17 and 17B, the City's design criteria of 450 l/cap/d was assigned to the residential portion of the contributing area and the measured flow prior to the storm event at the monitoring location was assigned to the remaining area (i.e. Trent University). Further details are found in **Appendix D**.

Trent University is also a major contributor of sanitary flow at monitoring location 17A. Similarly to station 17, the population data from the 2006 census would not be representative. Therefore per capita sanitary flow contributions should not be determined from the population data. The DWF was determined using the measured data from the flow monitor just prior to a given storm event. The details regarding the DWF for a given event can in found in **Appendix D.

Figure 6-2 shows the estimated DWF rates. Most of the tributary areas exceed the City's DWF design criteria of 450 l/cap/d. A higher DWF appears to occur in and around the Otonabee River. This is likely due to the high water table near the river.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University Rd
Water St
Cumberland Av
Hilliard St
Chemong Rd
Fairbairn St
Lily Lake Rd
Television Rd
Armour Rd
Parkhill Rd W
Brealey Dr
Sherbrooke St
Monaghan Rd
The Parkway
Lansdowne St W
Sir Sandford Fleming Dr
7 & 115 Hwy
123443 (#17A)
123455 (#17)
RG Trent University (Env Canada)
81633 (#17B)
RG3(Northwest Community Centre)
81616 (#17C)
141552
PARKHILL EAST PS
128449
81325
VALLEYVIEW PS
RG City Hall (City)
RG6(City Hall)
PARKHILL WEST PS
RG2(Parkhill West PS)
SIMCOE STREET PS
ENGLEBURN PS
123429 (#12)
BURNHAM POINT PS
ASHBURNHAM PS
RG4(PUC)
RG5(Kinsmen Civic Centre)
83266(#9)
80577
80499(#6)
141588 (#7)
RG WWTP (City)
MONAGHAN ROAD PS
80641 (#1)
RG1(Peterborough Sports Wellness Centre)
124219 (#22)
Legend
Historical Monitoring Locations
Current Monitoring Locations
Historical Rain Gauge Locations
Current Rain Gauge Locations
Note : Only historical and new flow station with reliable data shown
Pumping Station
WWTP
Forcemain
Sanitary Sewers
Sanitary Trunk Sewers (Diameter > 375 mm)
River
Parcels
City Boundary
Monitoring DWF (L/c/d)
< 450
450 - 600
600 - 700
700 - 800
800 - 900
> 900
Notes :
1. L/c/d = Liters per capita per day
2. City Design Criteria = 450 L/c/d
City of Peterborough
COLE ENGINEERING
Detailed Sanitary Sewer EA
Figure 6-2: Dry Weather Flow
Drawn By: J.H.
Date: Feb 27, 2012
0 250 500 1,000
km

6.3.2. Wet Weather Flow

The wet weather flows in the sanitary sewer system were calibrated wtih MIKE URBAN, using two hydrologic methods:

1. Time-Area (TA); and,
2. Rainfall Dependent Infiltration (RDI).

The TA Method is a surface runoff model where runoff is a function of hydrological losses and runoff routing is achieved by the TA curve. The TA curve represents time and proportion of the catchment which contributes flow at the outlet.

RDI provides detailed, continuous modelling of the complete land phase of the hydrological cycle providing support for urban, rural, and mixed catchments analysis. Excess precipitation is routed through three different types of storage:

1. Surface;
2. Unsaturated zone (i.e. root zone); and,
3. Ground water.

This enables continuous modelling of the runoff processes with long term routing effects.

The total I-I into the sanitary sewer system is determined by two components of flow:

1. Rapid inflow (i.e. TA): short term response – e.g., directly connected downspouts, foundation drains, or illegal connections; and,
2. Moderate and slow infiltration (RDI): medium to long term response – e.g., inflow through sanitary manhole lids and GWI.

Table 6-2 below summarizes the calibration parameters used in the model at each of the flow monitoring stations used for model calibration and for the analysis of alternatives.

Table 6-2 – Model Calibration Parameters

Flow Meter	TA-Initial Loss	TA-Reduction Factor	TA-Concentration (min)	RDI-Overland Coefficient	RDI-Contribution Area (%)	RDI-Root Storage (mm)	RDI-Lower Zone Moisture (mm)
81325	0.0009	0.02	60	0.2	17.5	35	10
19	0.0009	0.02	60	0.2	17.5	35	10
12	0.0009	0.04	60	0.3	20	35	10
17	0.0009	0.008	60	0.15	25	35	10
17A	0.0009	0.015	60	0.2	40	35	10
17B	0.0009	0.008	60	0.2	25	35	10
17C	0.0009	0.007	60	0.18	25	35	10
9	0.0009	0.02	180	0.1	10	35	10
7	0.0009	0.015	180	0.1	10	35	10
1	0.0009	0.01	60	0.2	10	35	10
22	0.0009	0.01	60	0.1	10	35	10
141552	0.0009	0.02	60	0.3	17.5	35	10
128449	0.0009	0.02	60	0.2	17.5	35	10
80577	0.0009	0.008	60	0.2	10	35	10
6	0.0009	0.02	60	0.2	11	35	10

The fast responding TA parameters and the slower responding RDI parameters were adjusted to yield a "best fit" between the modeled and measured flow. The RDI – Contribution Area and RDI – Root Storage parameters varied depending on the previous day's antecedent moisture condition for a particular calibration event. Antecedent moisture conditions relate wetness or dryness of a watershed to the response during a storm event. Antecedent moisture conditions change continuously and impact the flow response in the sanitary sewer system during wet weather. The values for the slow responding RDI parameters, contributing area, and root storage represent moderate soil moisture conditions. These parameters were kept constant as they represent "typical" root storage and lower zone moisture. Detailed calibration results for each flow monitor can found in **Appendix D**.

7.0 Existing Conditions Results

The existing sanitary sewer network was evaluated for the flow rates corresponding to the City's sanitary sewer design criteria of 450 L/cap/d and I-I of 0.25 l/s/ha, and various design storm events representing increasing return periods of 2 years, 5 years, 10 years, 25 years, 50 years, and 100 years. The City's IDF parameters were used together with a 4 hour Chicago distribution to generate the 'design' events. **Table 7-1** summarises the storm volume's correspondence to each design event. The sanitary sewer network was also evaluated for the Regional Timmins Storm as well as the July 14 – 15, 2004 historical storm event. These storm distributions are shown in **Appendix F**.

Table 7-1 – Storm Events

Storm	Depth (mm)
2 year	33.1
5 year	44.8
10 year	52.7
25 year*	62.1
50 year	69.6
100 year**	76.8
Regional (Timmins)	106
July 14-15, 2004	124.5

Notes: Volumes for 2-100 year storm events correspond to maximum 4 hour storm durations.
*Assumed sanitary sewer system level of protection against flooding.
**Assumed storm drainage system design criteria.

Typical level of protection for I-I in South-western Ontario (unless otherwise specified) is 1 in 25 year storm protection.

Figure 7-1 illustrates the system performance under the design criteria DWF of 450 l/cal/d and I-I of 0.25 l/s/ha. The existing sanitary sewer system has approximately 20 critical surcharged sewer locations where the HGL is within 1.8 m of the ground surface. **Figure 7-2** to **Figure 7-9** illustrate the sanitary sewer system performance for the 2 year, 5 year, 10 year, 25 year, 50 year, 100 year design storms, the regional (Timmins) storm, and the July 14 / 15 2004 historic storm. The red lines show the locations with high potential for flooding due to capacity constraints resulting in the HGL rising to within 1.8 m of the ground surface. The orange lines show surcharging below 1.8 m from the ground surface.

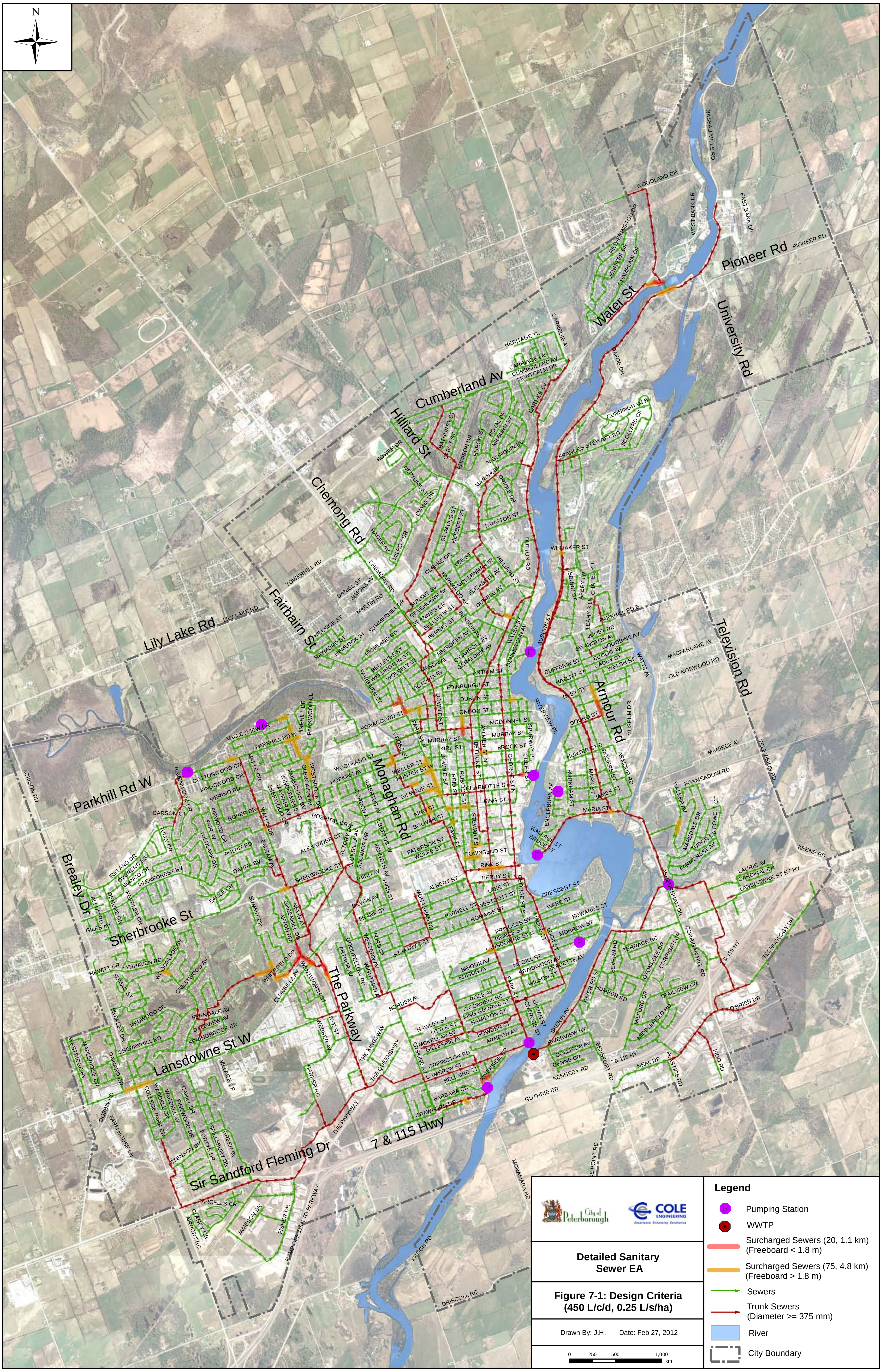
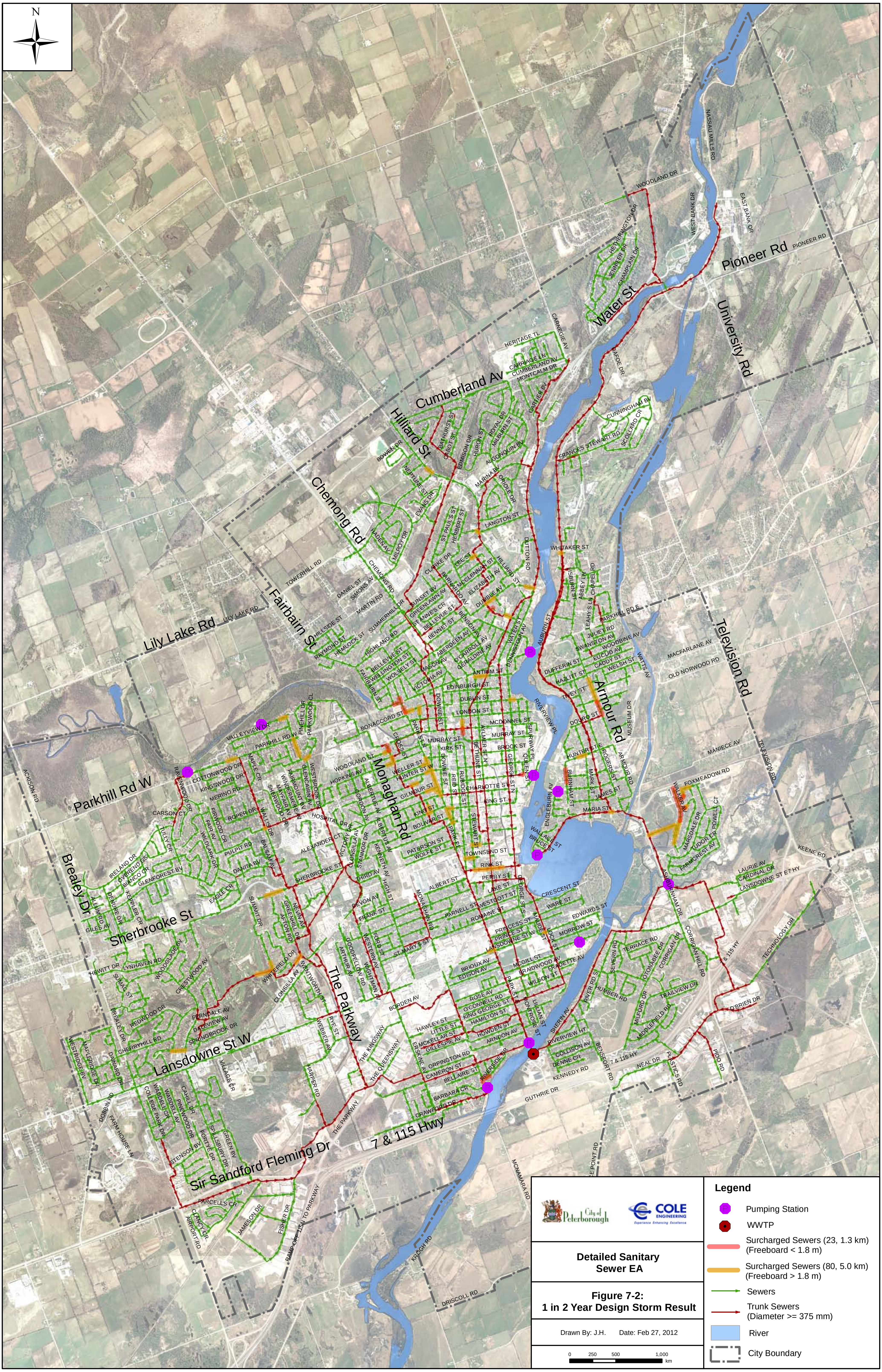


Figure 7-1: Design Criteria
(450 L/c/d, 0.25 L/s/ha)



Detailed Sanitary Sewer EA

Figure 7-2:
1 in 2 Year Design Storm Result

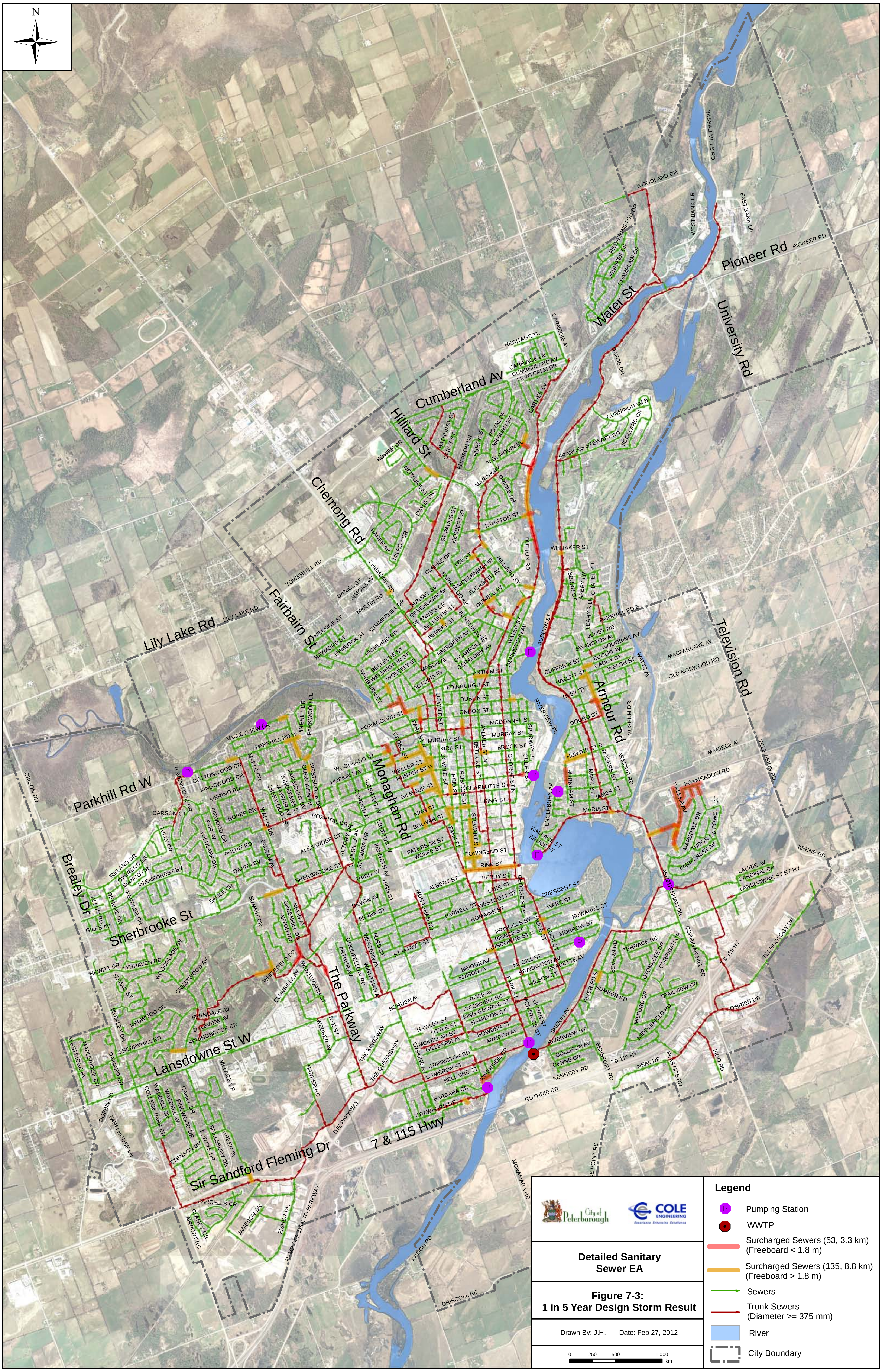
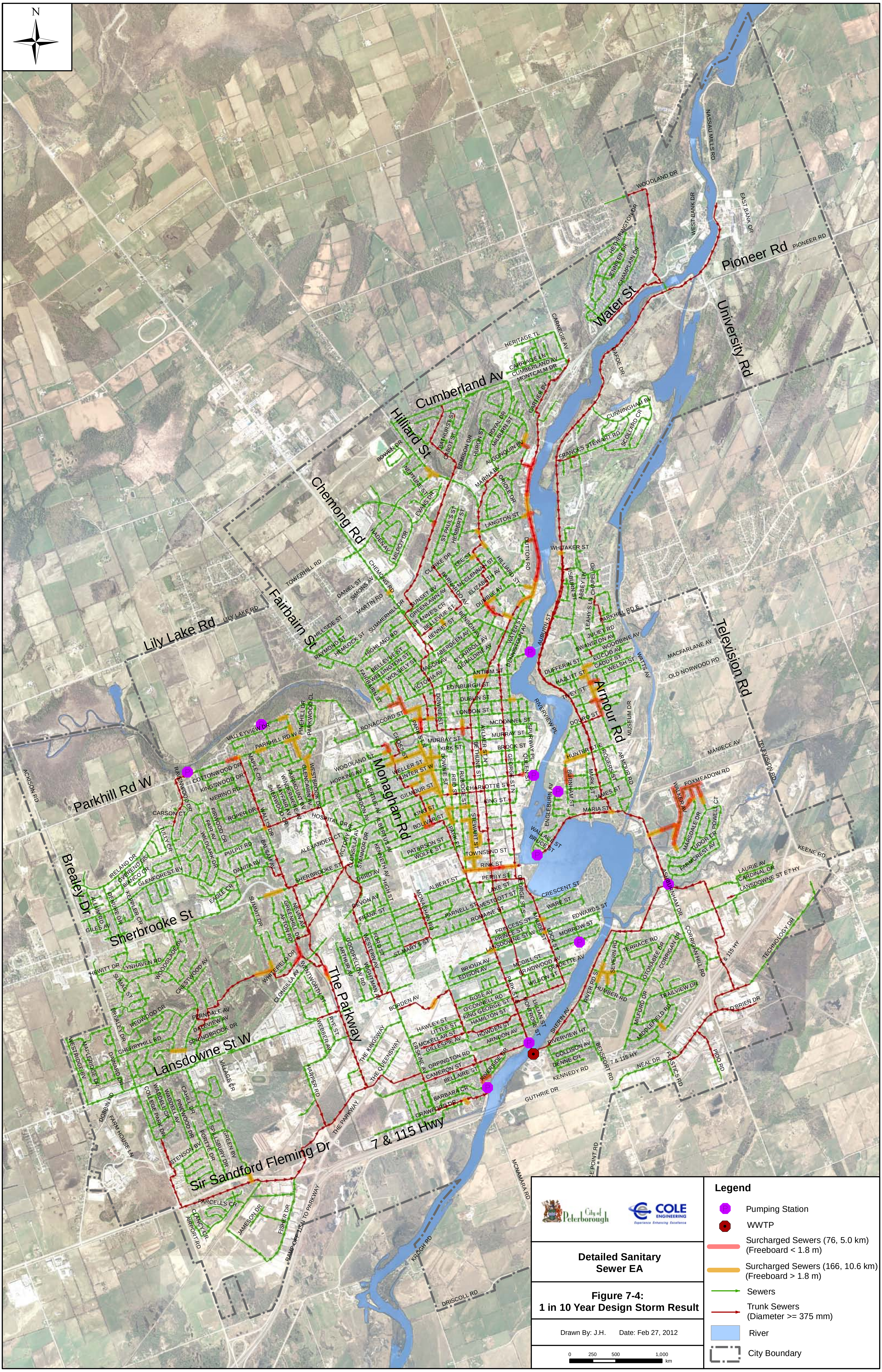


Figure 7-3: 1 in 5 Year Design Storm Result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Monaghan Rd
Armour Rd
Water St
Pioneer Rd
University Rd
Television Rd
Brealey Dr
Sherbrooke St
Lansdowne St W
The Parkway
Sir Sandford Fleming Dr
7 & 115 Hwy
City of Peterborough
COLE ENGINEERING
Experience Enhancing Excellence
Detailed Sanitary Sewer EA
Figure 7-4:
1 in 10 Year Design Storm Result
Drawn By: J.H.
Date: Feb 27, 2012
0 250 500 1,000 km
Legend
Pumping Station
WWTP
Surcharged Sewers (76, 5.0 km) (Freeboard < 1.8 m)
Surcharged Sewers (166, 10.6 km) (Freeboard > 1.8 m)
Sewers
Trunk Sewers (Diameter >= 375 mm)
River
City Boundary

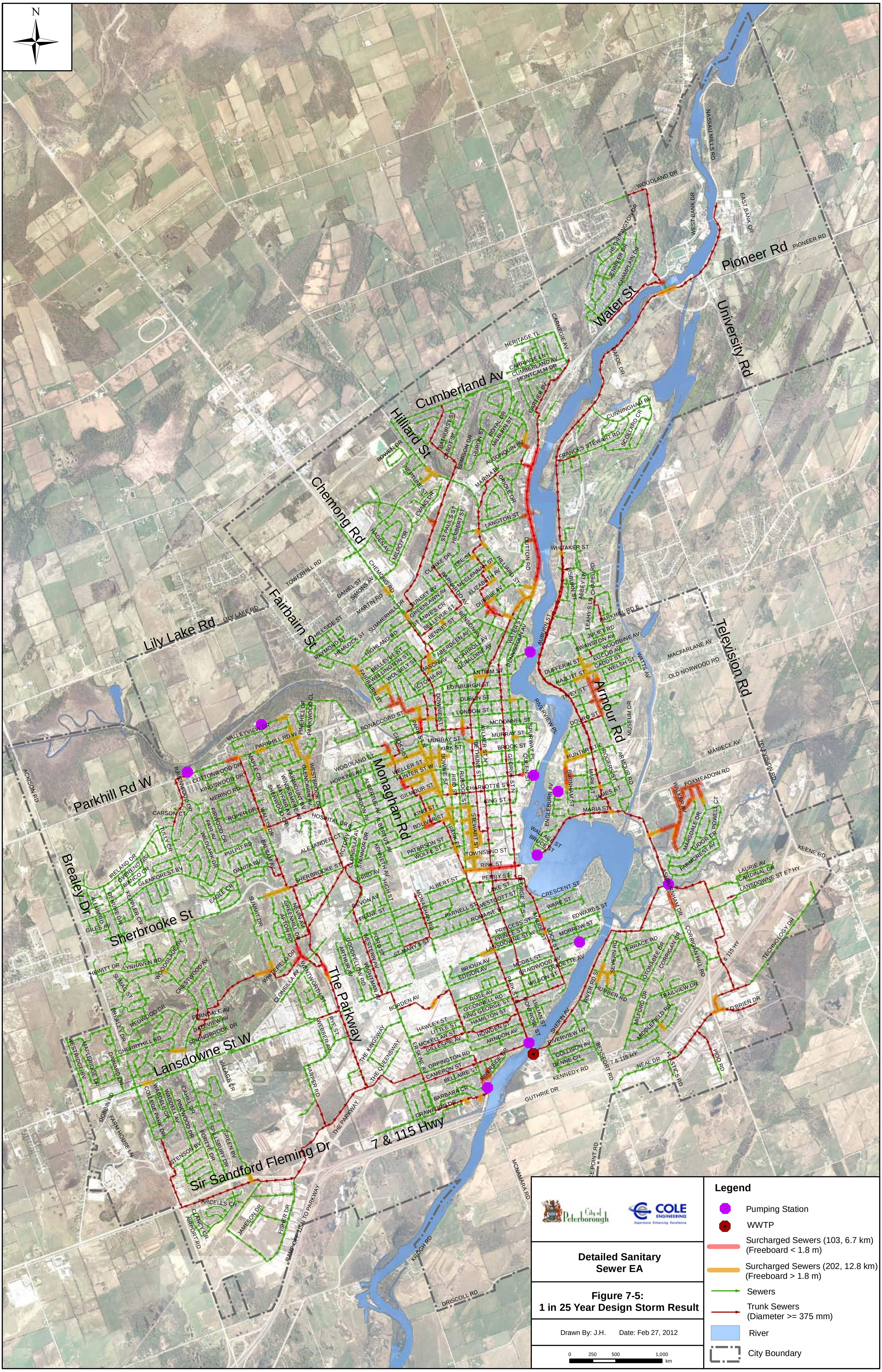
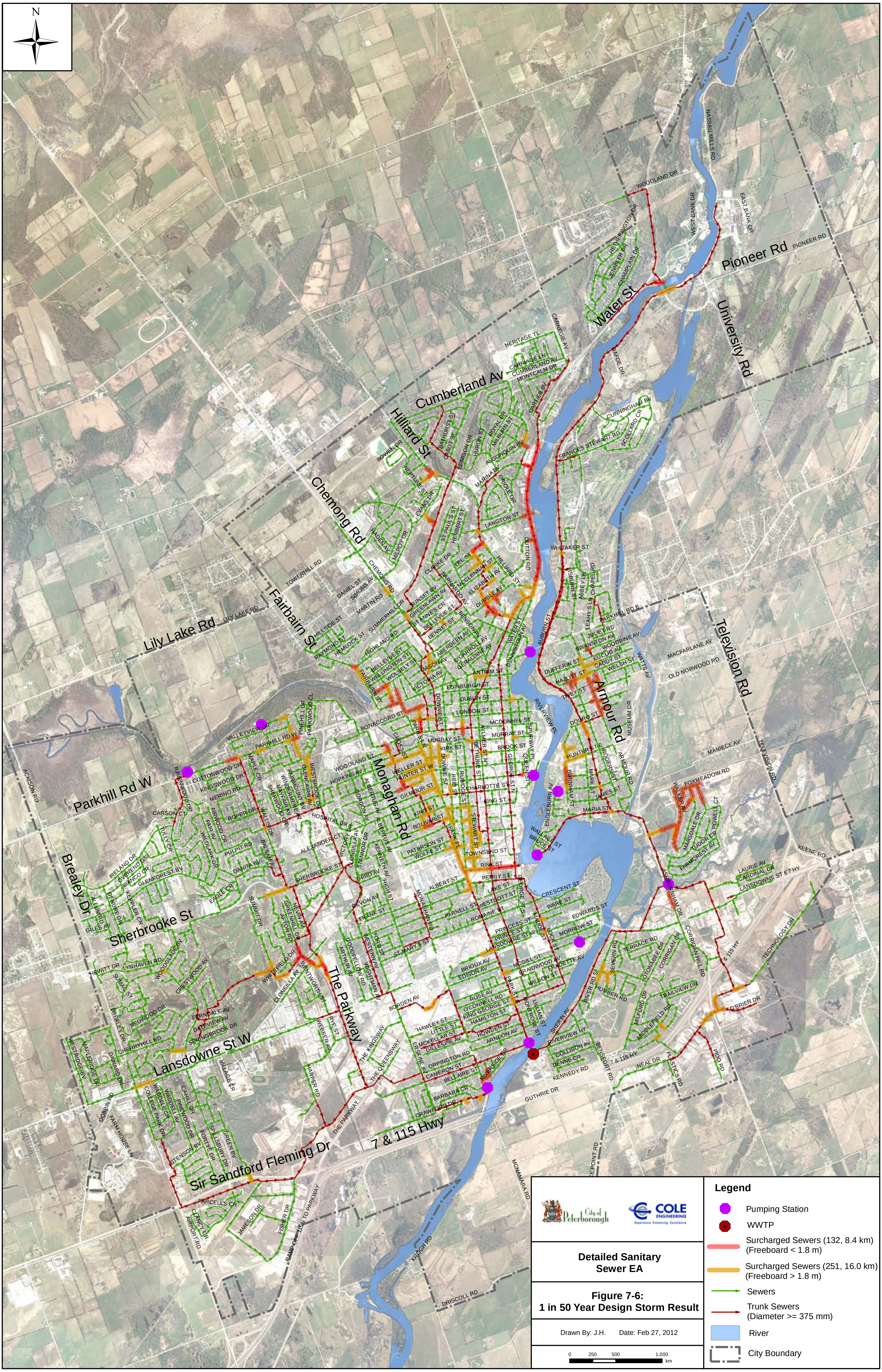


Figure 7-5: 1 in 25 Year Design Storm Result



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Lily Lake Rd
Parkhill Rd W
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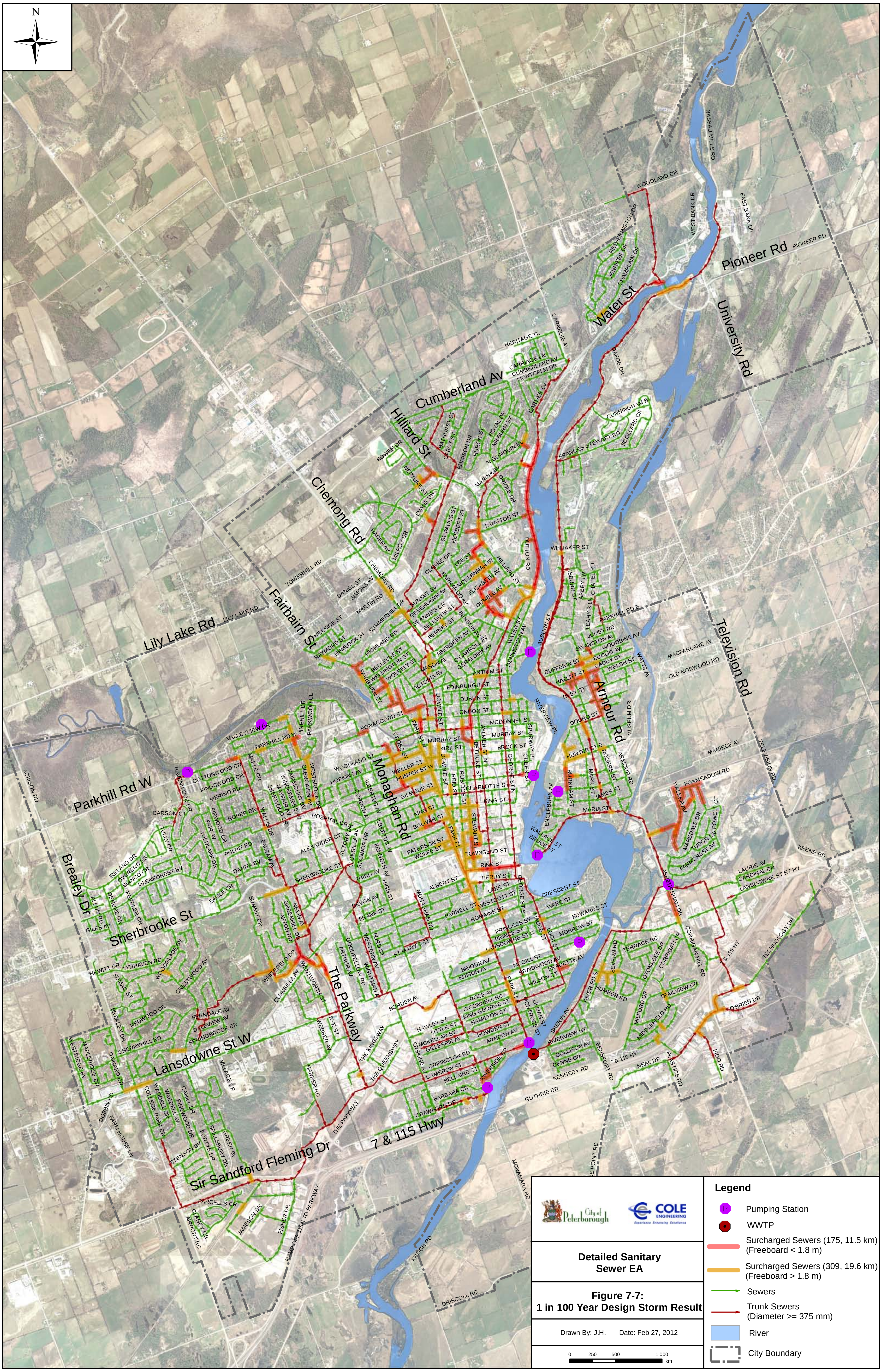
Sherbrooke St
Monaghan Rd
The Parkway
Lansdowne St W
Sir Sandford Fleming Dr
7 & 115 Hwy
Water St
Pioneer Rd
University Rd
Television Rd
Armour Rd
City of Peterborough
COLE ENGINEERING
Experience Enhancing Excellence
Detailed Sanitary Sewer EA
Figure 7-6:
1 in 50 Year Design Storm Result
Drawn By: J.H.
Date: Feb 27, 2012
0 250 500 1,000 km
Legend
Pumping Station
WWTP
Surcharged Sewers (132, 8.4 km) (Freeboard < 1.8 m)
Surcharged Sewers (251, 16.0 km) (Freeboard > 1.8 m)
Sewers
Trunk Sewers (Diameter >= 375 mm)
River
City Boundary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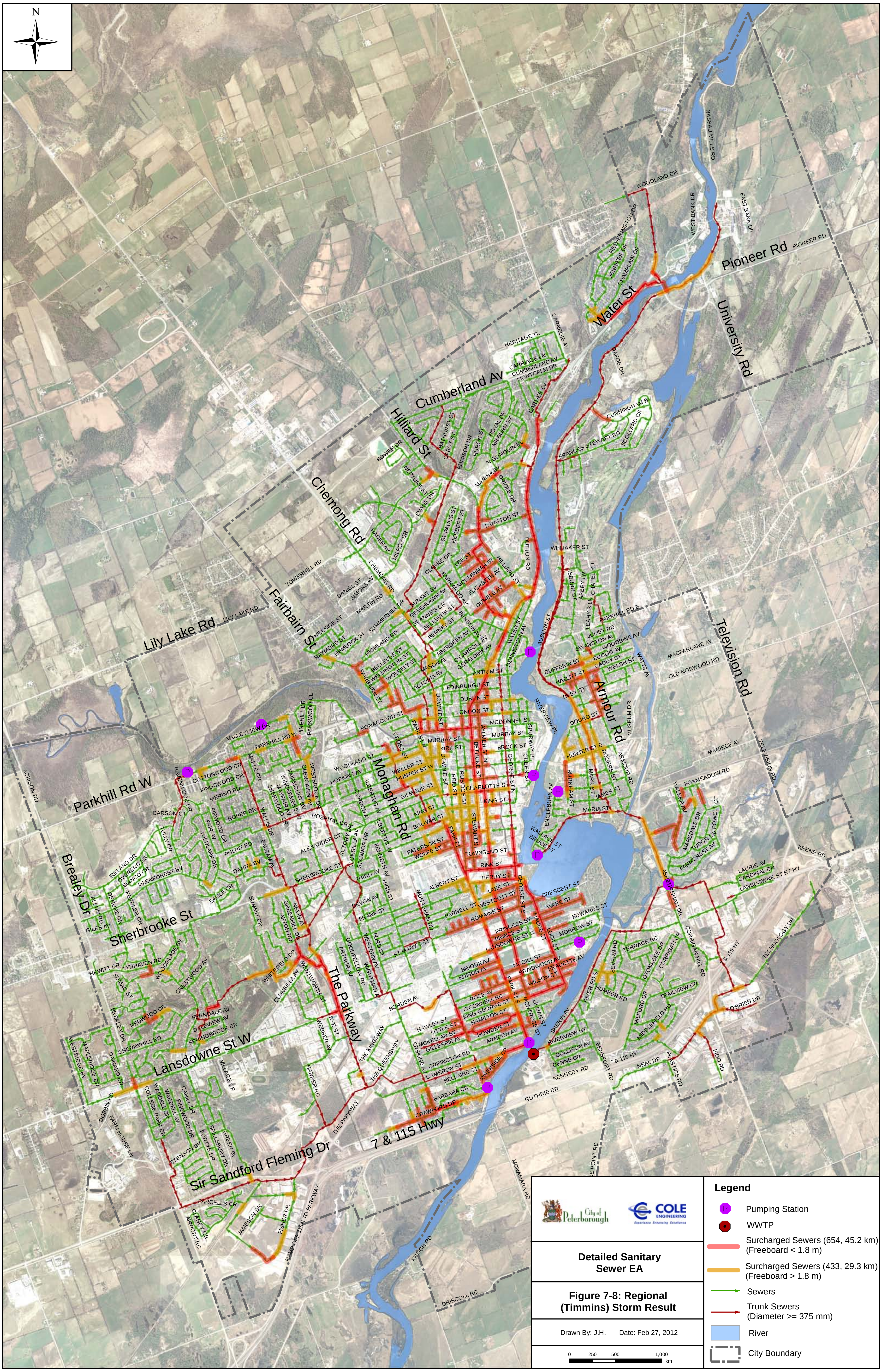
Lily Lake Rd
Television Rd
Armour Rd
Parkhill Rd W
Monaghan Rd
Brealey Dr
Sherbrooke St
The Parkway
Lansdowne St W
Sir Sandford Fleming Dr
7 & 115 Hwy
City of Peterborough
COLE ENGINEERING
Experience Enhancing Excellence
Detailed Sanitary Sewer EA
Figure 7-7:
1 in 100 Year Design Storm Result
Drawn By: J.H.
Date: Feb 27, 2012
0 250 500 1,000 km
Legend
Pumping Station
WWTP
Surcharged Sewers (175, 11.5 km) (Freeboard < 1.8 m)
Surcharged Sewers (309, 19.6 km) (Freeboard > 1.8 m)
Sewers
Trunk Sewers (Diameter >= 375 mm)
River
City Boundary



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Hilliard St
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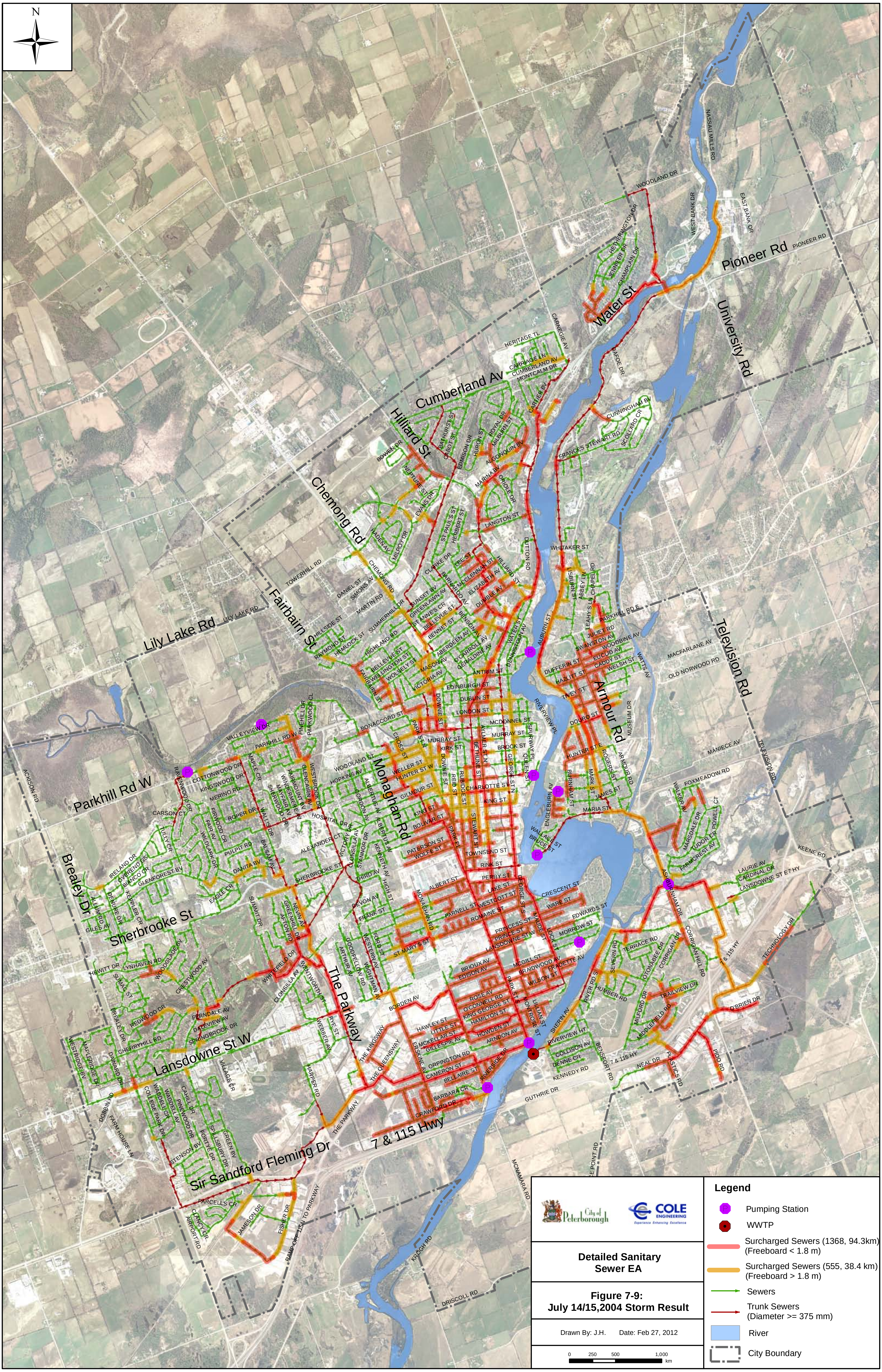
Fairbairn St
Lily Lake Rd
Parkhill Rd W
Monaghan Rd
The Parkway
Sherbrooke St
Brealey Dr
Lansdowne St W
Sir Sandford Fleming Dr
7 & 115 Hwy
Water St
Pioneer Rd
University Rd
Television Rd
Armour Rd
City of Peterborough
COLE ENGINEERING
Experience Enhancing Excellence
Detailed Sanitary Sewer EA
Figure 7-8: Regional (Timmins) Storm Result
Drawn By: J.H.
Date: Feb 27, 2012
0
250
500
1,000
km
Legend
Pumping Station
WWTP
Surcharged Sewers (654, 45.2 km) (Freeboard < 1.8 m)
Surcharged Sewers (433, 29.3 km) (Freeboard > 1.8 m)
Sewers
Trunk Sewers (Diameter >= 375 mm)
River
City Boundary



Detailed Sanitary Sewer EA

Figure 7-9: July 14/15,2004 Storm Result

7.1. I-I Characterisation

As previously mentioned in **Section 5.4.2**, I-I rates determined from measured storm events vary significantly throughout the City. The variability is due to either: (1) sewershed and sewer conditions; or (2) the size of the storm event. Therefore, in order to objectively compare I-I between areas, a "normalised" I-I rate must be obtained by determining the quantity of I-I produced during a constant storm event, which in this case is the 1 in 25 year storm event. As previously stated, this may be considered a typical level of protection used in Ontario.

Table 7-2 below shows the normalised I-I rates in the monitored areas in the City. **Figure 7-10** illustrates the normalised I-I for the 1 in 25 year design storm event.

Table 7-2 – Normalised I-I for 1 in 25 Year Design Storm

Flow Gauge	Incremental Drainage Area (ha)	Modeled Wet Weather Flow (L/s)	Normalised Infiltration and Inflow (L/s/ha)
Derived from previous flow monitoring in 2005			
1	591	385.9	0.37
6	216	872.3	0.39
7	266	95.8	0.36
9	147	67.8	0.46
Derived from previous flow monitoring in 2006			
12	31	48.2	1.19
17	117	77.0	0.42
17A	24	28.0	1.17
17B	10	81.2	0.44
17C	62	99.7	0.30
19	363	405.1	0.36
22	213	123.5	0.58
Derived from flow monitoring in 2010			
81325	79	78.4	0.99
80577	70	28.8	0.42
128449	279	310.9	1.11
141552	134	229.6	0.91

As shown in **Table 7-2** and **Figure 7-10**, I-I at all flow monitoring locations exceed the City's design criteria of 0.25 l/s/ha for the 1 in 25 year design storm event.

These results help determine the flow monitoring relocation strategy as previously described in **Section 5.4.3**.

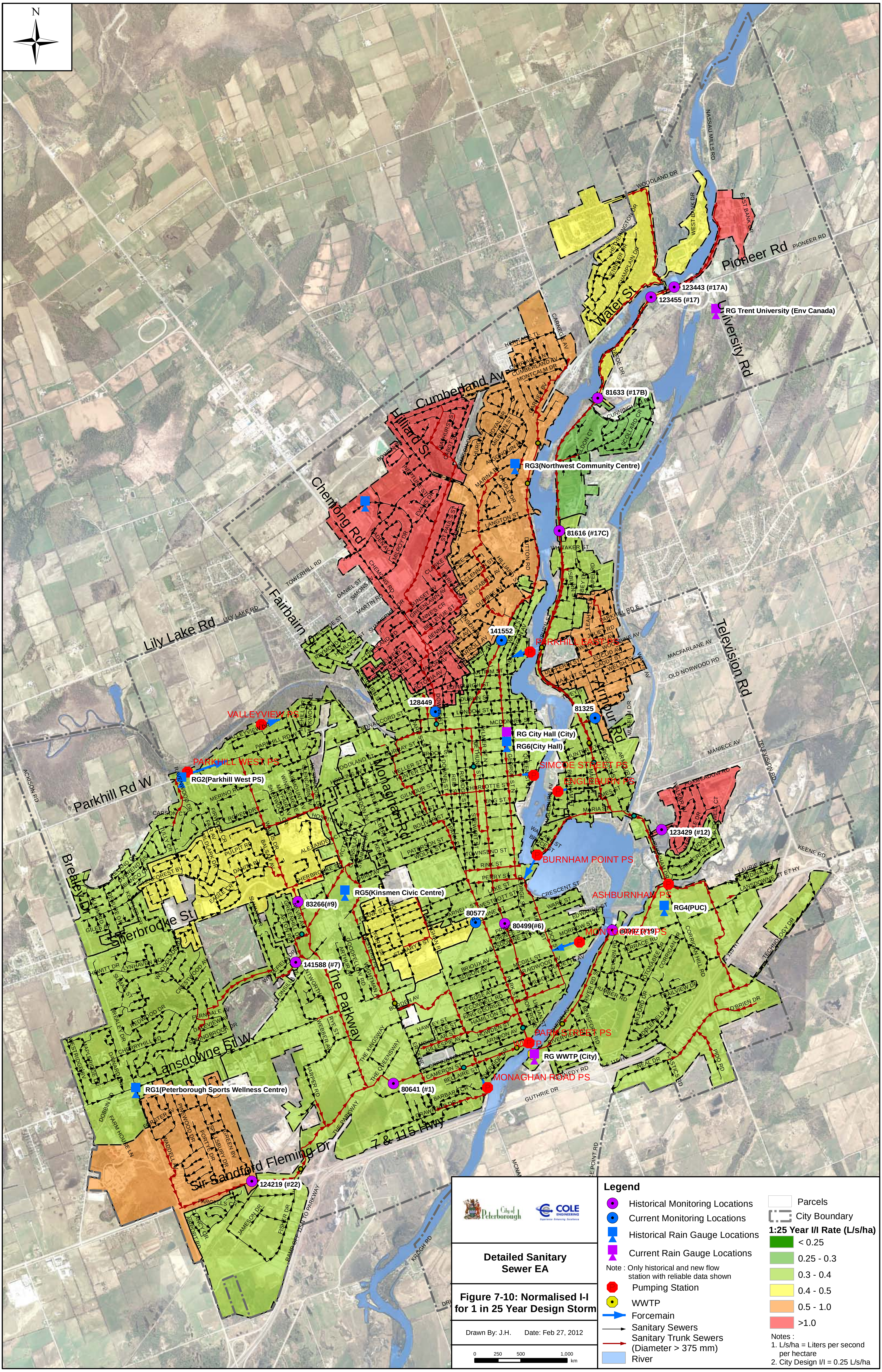


Figure 7-10: Normalised I-I for 1 in 25 Year Design Storm

7.2. Dry and Wet Weather I-I Analysis

The DWF results indicate that the per capita generation rates had substantially higher generation rates compared to that of the City's design criteria of 450 l/cap/d (the City's design criteria is found in **Appendix B**). High DWF could be attributed to:

- High GWI;
- Significant industrial, commercial, or institutional flows; and,
- Unaccounted population.

As noted earlier by others, the GWI rates have been found to be generally high, especially in areas near to the Otonabee River.

High DWF limits the sewer capacity available during wet-weather and adds significant inflow volumes to the treatment plant. With respect to WWF, higher I-I responses are likely due to directly connected inflows to the sanitary sewer system via downspouts or other direct connections.

7.3. Potential Flooding

Figure 7-1 to **Figure 7-9** show the locations at risk of flooding under various storm conditions. It should be noted that historical flooding reports provided by the City were considered for verification but these do not specify the nature of flooding (i.e. surface, basement, etc.). **Appendix I** shows the reported flooding locations in the City as well as flooding locations based on the various design storms.

The main cause of high flooding for the sanitary sewer system are generally attributed to surcharge of the sanitary sewer caused by excessive I-I.

Other causes of flooding associated with storm drainage in general have been identified in other similar studies as:

- Accumulation of surface runoff in low-lying areas and poor or no overland flow routes;
- Reverse-sloped driveways leading to surface flooding problems;
- High overland flow depth above street right-of-way elevation;
- Undersized storm sewer or undersized catchbasins, resulting in high overland flow;
- Blocked or broken sanitary sewers and manholes; and/or,
- Blocked catchbasins.

Other basement flooding can be attributed to one or more of the following conditions:

- Poor lot grading;
- Structural problems in the house sewer connection;
- Blockage in the house connection;
- Cracks in the basement walls or floor resulting in storm water leakage; and/or,
- Possibility of roof downspout connected to the sanitary drain.

7.4. Flood Criteria

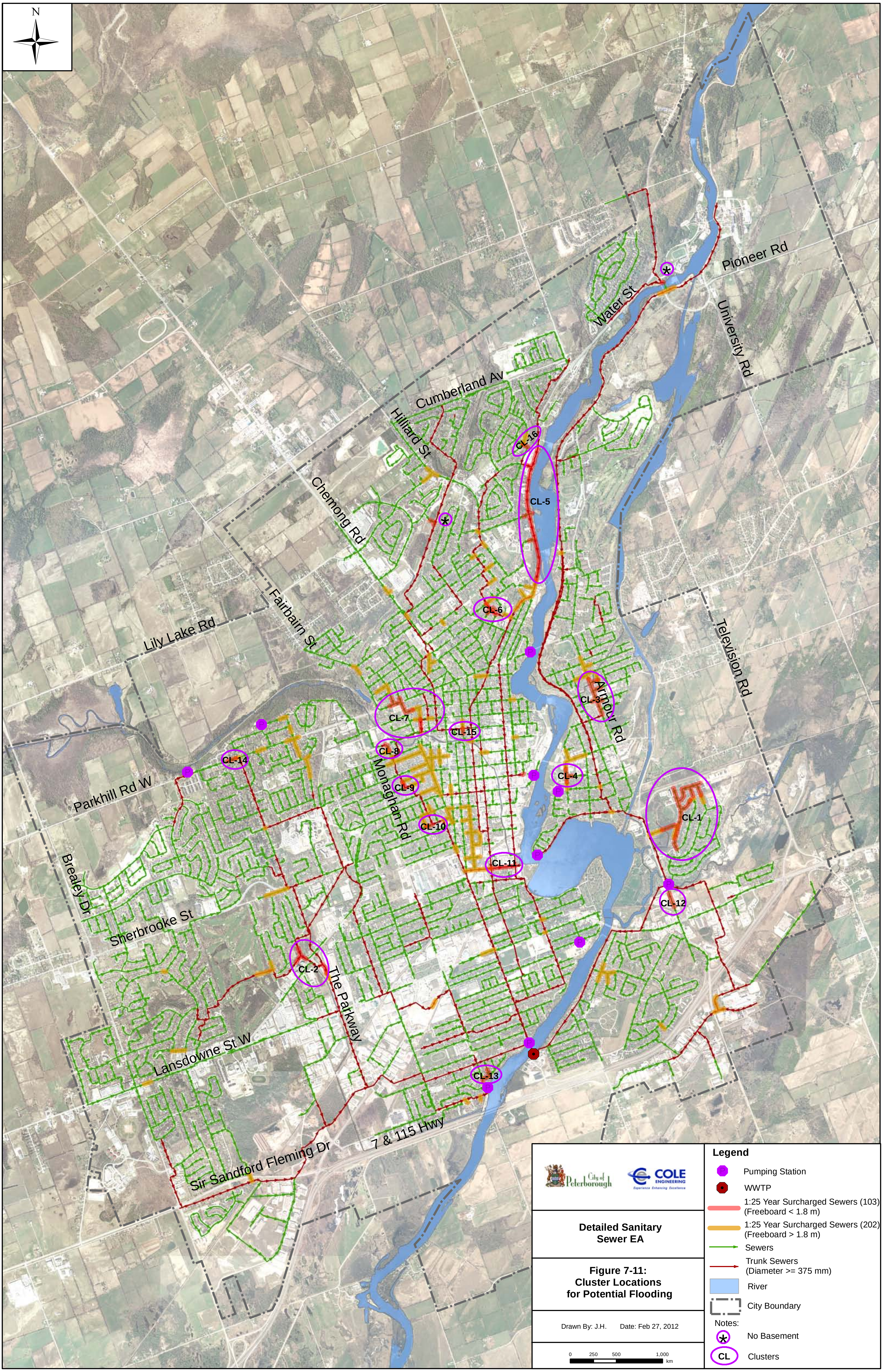
The flood potential methodology was developed for evaluating the capacity of the sanitary sewer system. The flood potential was quantified based on the HGL elevation in the sewers. The flood potential quantifies the likeliness of flooding at specific locations based on whether or not the maximum allowable or HGL elevation is reached. The model provides the best predictive tool based on assumed building elevations relative to sewer and street elevations. Potential flooding occurs when HGL levels in surcharged sewers reach estimated basement elevations.

This EA considered a level of service where the maximum HGL of the sanitary system is maintained at an elevation of at least 1.8 m below the ground elevation (considered to be the basement elevation) during a storm event equivalent to the 1 in 25 year design storm. This storm has a 10 minute peak of 123 mm/hr and a total duration of 24 hours. The 1 in 25 year design storm is a typical design criterion for municipalities in Ontario. As the City does not have a defined flooding criteria level of service, the 1 in 25 year design storm event was used. The distribution of all storm events used in this study is provided in **Appendix F**. It should also be noted that if a pipe segment is within 1.8 m of the ground surface elevation and the HGL is within the pipe (ie. not surcharged), it is not considered to be a flooding risk.

The City is also interested in the possibility of providing a potential solution for the 1 in 100 year event due to the nature of pervious historical events. This will be discussed further in **Section 10.4**.

7.5. Clusters with High Flood Potential

The model results identified sanitary sewer reaches that are susceptible to high flood potential due to elevated hydraulic gradelines. These reaches have been grouped into “clusters” reflecting the local connectivity and potentially common cause of flooding and common alternative solutions. A total of 16 clusters have been identified based on the 1 in 25 year storm event results. **Figure 7-11** shows the cluster locations for potential flooding in the City.



Detailed Sanitary Sewer EA

Figure 7-11: Cluster Locations for Potential Flooding

8.0 Remediation Alternatives

8.1. Development and Analysis of Alternative Remedial Measures

Several alternatives have been considered and evaluated to minimize extraneous flows entering the sanitary sewer. These are divided into five categories:

1. Do Nothing;
2. I-I Reduction – source control measures;
3. Conveyance Improvements – sewer twinning or replacement;
4. Adding Storage – in-line or off-line storage; and,
5. Hybrid Solution – possible combinations I-I reduction with either conveyance or storage.

All the measures proposed at the street level were considered, for every cluster area where applicable, and specifically defined as discussed in **Table 8-1**.

Table 8-1 provides general descriptions for each type of control measure, listing advantages and disadvantages of each as well as general applicability. More detailed assessments will be required during detail design.

8.1.1. Alternative 1 – Do Nothing

This alternative does not require any action from the City. This alternatives will have no immediate financial impacts to the City. Not providing any form of remediation, costs to the City and the public will be incurred in the case of a sever storm event. The "Do Nothing" alternative must be considered as part of the Class EA process.

8.1.2. Alternative 2 – I-I Reduction

This alternative will reduce storm and ground water ("clear water") entering the sanitary sewers. Some of the measures would be applied within private lots subject to landowner approval, while others would occur on public properties including the public right-of-way.

Sources of I-I include the following:

- Typical direct connections:
  - Downspout (inflow);
  - Catchbasin (inflow);
  - Cross-connection within storm and sanitary sewers (inflow);
  - Cleanout (inflow); and,
  - Manhole cover (inflow).
- Typical indirect connections:
  - Foundation drain via gravity or sump pumps (infiltration or inflow);
  - Lateral and joints (infiltration or inflow depending on degree of crack);
  - Sewer and joints (infiltration or inflow depending on degree of crack);
  - Manhole structure and joints (infiltration or inflow depending on degree of crack); and,
  - Sump pumps (inflow).

Remedial measures considered in this alternative consist of the following:

- Source control (at lot level):
  - Roof leader disconnection;
  - Cap cleanout and replacement;
  - Storm trap cleanout;
  - Homeowner participation in the Sanitary Backflow Prevention Subsidy Program (as previously discussed in **Section 5.1.2**);
  - Disconnect foundation drains from sanitary sewers and install sump pit and pump to storm or surface;
  - Lot regrading;
  - Lining, grouting, replacement, or bursting of faulty laterals, joints or sewers; and,
  - Sealing sanitary manhole covers in low lying areas to reduce overland storm flows entering the sanitary sewer system.
- Source control (at street): Indirect through improved storm drainage:
  - Increasing storm sewer system capture by installing additional catchbasins or trench drains (large inlet with grating across the street) to relieve surface flooding.

The main advantages of most of these measures are that they reduce peak flows and volumes within the sewer system and at the plant. Subject to finding significant direct inflow soruces, I-I reduction can be implemented at a lower cost than other alternatives. I-I reduction provides additional sewer capacity for existing or future development.

The main disadvantages are that I-I investigations can be intensive, time consuming, typically provide partial results, and do not completely eliminate the potential for flooding to the desired level of protection. The lot level measures are subject to the homeowner's initiative. Some types of I-I sources, such as foundation drain disconnections, can be disruptive to private owners and expensive to implement.

The above measures are recommended for consideration in the entire study area. Their implementation will reduce the storm flows to the sanitary sewer system and will result in further reduction in the HGL than what would be expected after implementation of other relief measures. For example, downspout disconnection or roof leader disconnection would reduce the storm flow entering the santiary sewer system.

I-I reduction can target sources of direct inflows (i.e. roof downspouts, illegal connections, and cross connections) or infiltration. Through previous experience in I-I reduction projects in the Greater Toronto Area (GTA), it has been estimated that these direct inflow sources can be practically reduced by approximately 25%. I-I reduction is an ongoing solution that extends beyond infrastructure related solutions such as conveyance and storage.

Figure 8-1 illustrates the estimated impact of I-I reduction during a 1 in 25 year design storm.

8.1.3. Alternative 3 – Increased Conveyance Capacity

This alternative involves increasing the sewer system conveyance capacity by adding new sewers (twinning) or replacing existing sewers with larger size sewers. The conveyance alternative is identified as:

- Sewer twinning, where the proposed sewer is interconnected with the existing sewer at manholes;
- Sewer diversion where the new sewer is used to divert the flow from existing sewer; and,
- Sewer replacement, where the new sewer replaces the existing sewer.

The main advantage of adding additional conveyance capacity is that it provides an effective, predictable, and timely relief against potential basement flooding. For the purposes of this study, all alternatives incorporating the conveyance alternative have used the “twinning” method.

Some disadvantages include the potential increase in the flows downstream, no decrease in flow volumes, potential impact on the downstream conveyance and treatment systems, requirement of available space in existing streets which in some cases are constrained by existing utilities and services, the inconvenience associated with construction activities, and the potentially higher costs as compared to I-I Reduction. Unless sewer oversizing is considered, this alternative also does not free up capacity in the sanitary sewer system for new development.

Figure 8-2 illustrates the impact of implementing the conveyance alternative during the 1 in 25 year storm event.

8.1.4. Alternative 4 – Storage

This alternative provides system storage in key locations within the sanitary sewer system. Storage facilities generally attenuate flows by holding and releasing at a reduced rate, alleviating the downstream conveyance system. Storage is provided in-line or off-line in subsurface tanks or conduits. For the purposes of this study, all alternatives which incorporate the storage alternative have used the in-line method.

The main advantage of this alternative is that it provides basement flooding protection and reduces flow rates downstream. It is most effective in cases where the downstream system does not have conveyance capacity and space is readily available.

A disadvantage of this alternative includes difficulty in acquiring land in urban environments and costs. Storage alternatives typically require relatively more expensive capital and operation / maintenance costs compared to other alternatives. They also do not free up capacity in the sanitary sewer system for new development or existing capacity at the WWTP.

Figure 8-3 illustrates the impact of implementing the storage alternative during the 1 in 25 year storm event.

8.1.5. Alternative 5 – Hybrid Solution

This alternative is a combination of Alternative 2 – I-I Reduction along with either Alternatives 3 – Conveyance or Alternative 4 – Storage. In Alternative 5 – Hybrid solution, remedial measures from the first three alternatives were selected to form Alternative 5.

The selection is based on the ability to reduce potential flooding, provide additional capacity in the sanitary sewer system, and cost effectiveness. Considerations were also given to minimizing downstream impact and minimizing potential stormwater inflow to the sanitary system in low lying areas.

Reduction of I-I to the sanitary system is recommended for the entire study area. Recommended measures to reduce I-I include but are not limited to sealing of sanitary manhole covers in low lying areas, conducting dye testing in the homes of the areas showing higher than normal inflow (to identify possibility of interconnection between the storm drain and the sanitary drain), and identifying and eliminating connection of roof leaders to the sanitary sewer system.

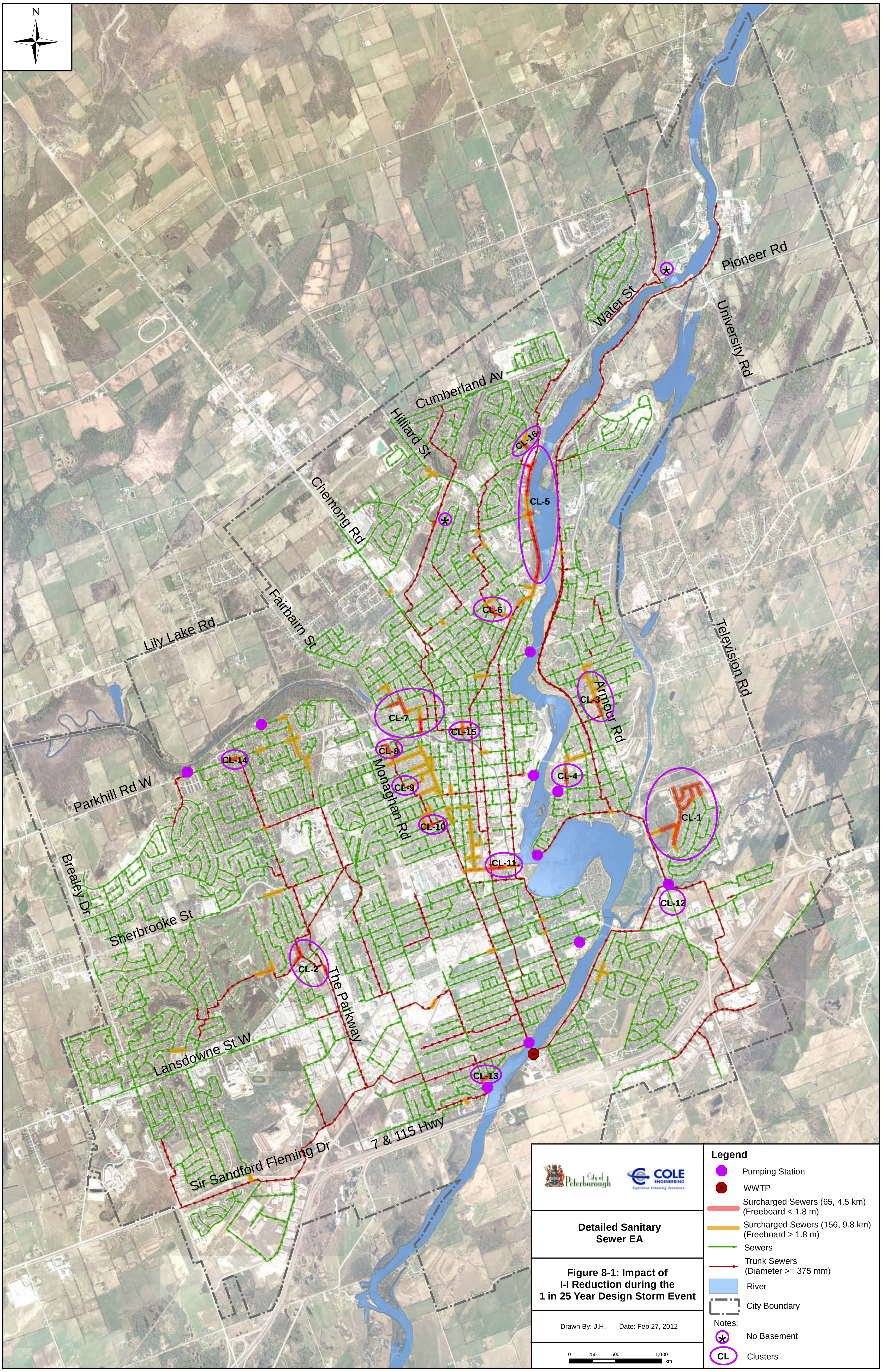
Figure 8-4 illustrates the hybrid solution for the 1 in 25 year design storm event. Through this alternative, the HGL in all clusters is below 1.8 m from the ground surface which reduces the risk of potential basement flooding. Although surcharging may still occur, there is no flood risk as the HGL is not within 1.8 of the ground surface elevation.

Table 8-1 – Evaluation of Remedial Measures

Alternative	Control Measure	Advantage	Disadvantage	Applicability
1. Do Nothing	None	No short term or direct costs to the City.	Does not reduce extraneous flows entering the sanitary sewer system. Does not reduce potential of flooding. Does not reduce the risk of sewer bypass to river.	None
2. I-I Reduction (Flow Reduction)	Roof leader disconnection	Divert roof runoff from sanitary sewers thereby reducing the peak flows and volume of runoff.	Requires proper soil conditions (sandy) and proper grading to be effective.	Applicable in areas where suitable soil conditions exist. To be assessed on a sewershed basis.
	Backflow prevention with sump pump	Effective in preventing stormwater from entering foundation drains and roof leader from entering the sanitary system.	Implementation costs will be considerably high due to disruption, damage and restoration of property.	Applied in situations where basement flooding exists. A government incentive program may increase interest of homeowners. It should be noted that there currently is a backflow prevention subsidy program in the City which is explained in **Section 5.1.2**.
	Sump pump for foundation drains	Effective in reducing inflow into the sanitary sewer from foundation drains.	Implementation costs will be considerably high due to disruption, damage and restoration of property.	Applied in situations where basement flooding exists. A government incentive program may increase interest of homeowners. It should be noted that there currently is a backflow prevention subsidy program in the City which is explained in **Section 5.1.2**.
	Foundation drain disconnect / reconnect	Effective in reducing inflow into the sanitary sewer from foundation drains.	Implementation costs will be considerably high due to disruption, damage and restoration of property.	Applied in situations where basement flooding exists. A government incentive program may increase interest of homeowners. It should be noted that there currently is a backflow prevention subsidy program in the City which is explained in **Section 5.1.2**.

Alternative	Control Measure	Advantage	Disadvantage	Applicability
	Lot regrading	Effective in reducing storm runoff by promoting recharge and natural infiltration.	Difficult to implement	This control measure is not feasible for this project since the study area is developed and lot regrading will be very costly.
	Rain barrel	Effective in reducing storm runoff by promoting re-use of roof runoff.	In order for it to operate effectively proper installation and modification must be made. Requires the initiative of homeowners.	Applicable in low-medium residential developments. A public awareness / outreach program would help education the public on potential benefits and cost savings.
	Sealing or improving sanitary sewer manhole covers	Effective in preventing stormwater from entering the sanitary sewer.	Gas built up due to the decomposition of sewage.	Applied in situations where sanitary manholes are in a depressed area subjected to overland flow flooding.
	Pipe and manhole rehabilitation	Effective in reducing I-I into the sanitary sewer.	High capital cost due to the length of sanitary sewer present in the area.	Applicable in areas where high I-I is discovered.
3. Conveyance Improvements	Additional sewer capacity (twinning)	Creates a relief for existing sewers reducing the possibility of basement flooding.	Costs can vary significantly depending on length of pipe to be installed. Potentially increases peak flows downstream.	Applied in situations where basement flooding exists. Underground space can limit the application of additional pipes to be installed.
	Sewer replacement	New infrastructure allows for sewers reducing the possibility of basement flooding.	Costs can vary significantly depending on length of pipe to be installed. Potentially increases peak flows downstream.	Applied in situations where basement flooding exists. Underground space can limit the application of additional pipes to be installed.

Alternative	Control Measure	Advantage	Disadvantage	Applicability
4. Adding Storage	Underground storage tank	Well suited for sanitary flow control in urbanized areas since they can be buried and hence not restrict use of beaches, parkland etc. Applicable in retrofit conditions where the application of source and conveyance control are limited. Low operation and maintenance cost if the cleaning system is automated.	High capital cost due to size of facility and potential construction constraints.	Applicable where open space (parkland, school yard, etc) is available.
	System Storage – in-line or off-line	Effective in relieving undersize pipes.	Costs can vary significantly depending on sewer depth and the presence of bedrock.	Applied in situations where basement flooding exists due to sanitary sewer surcharge. Land / space requirements in right-of-way can limit the application of the in-line / off-line storage. Most efficient where downstream pipe system does not have adequate capacity to convey the peak WWF.
5. Hybrid Solution	Combination of I-I reduction, increased conveyance capacity, and storage.	Effective in reducing I-I into the sanitary sewer, provides increased conveyance capacity and provides flow attenuation through storage.	Costs can vary significantly depending on the infrastructure requirement beyond I-I reduction.	Applicable in areas where basement flood exists. Further investigations will need to be conducted to determine land requirements and soil conditions/



Detailed Sanitary Sewer EA

Figure 8-1: Impact of I-I Reduction during the 1 in 25 Year Design Storm Event

Drawn By: J.H. Date: Feb 27, 2012

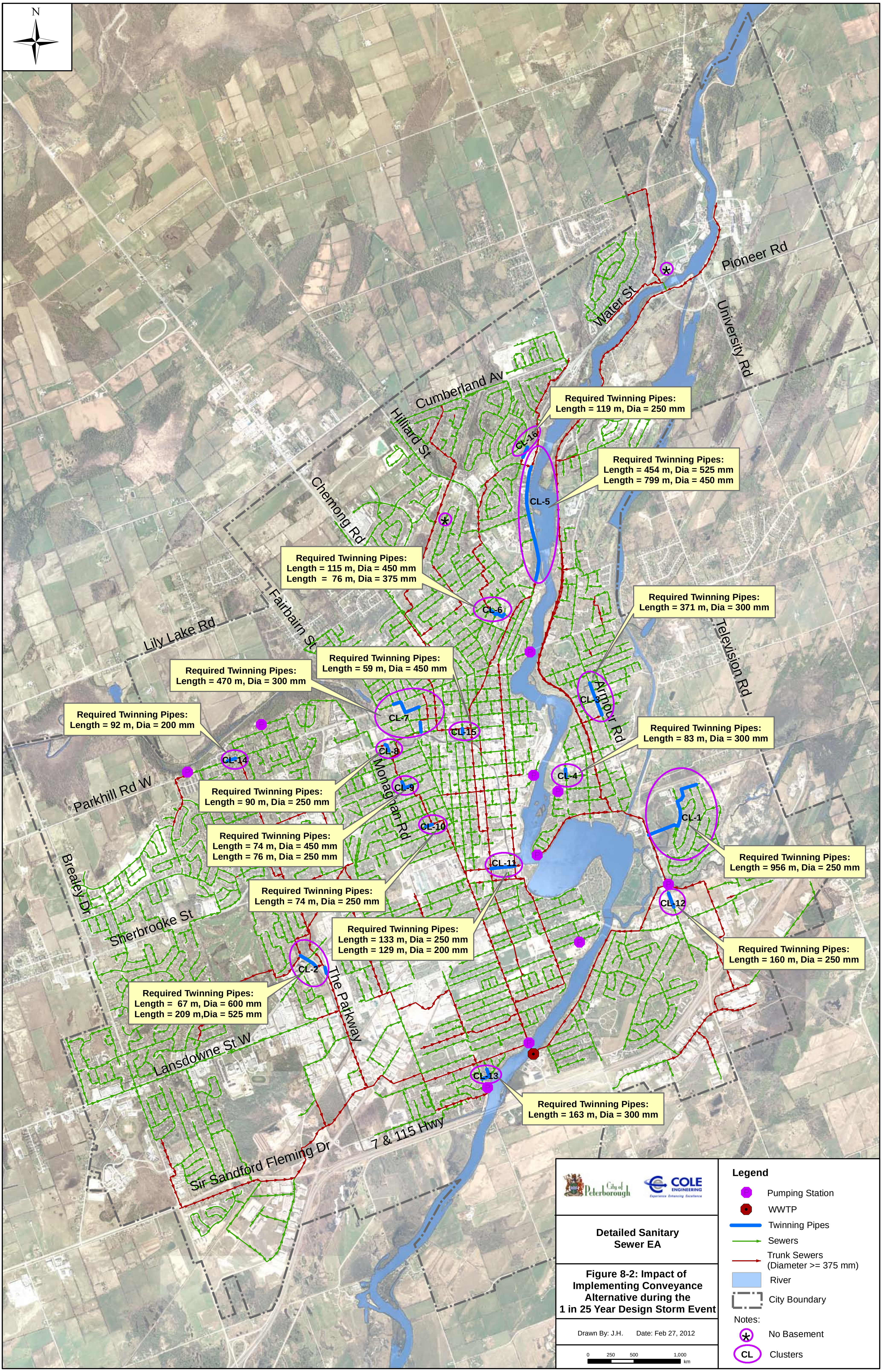


Figure 8-2: Impact of Implementing Conveyance Alternative during the 1 in 25 Year Design Storm Event

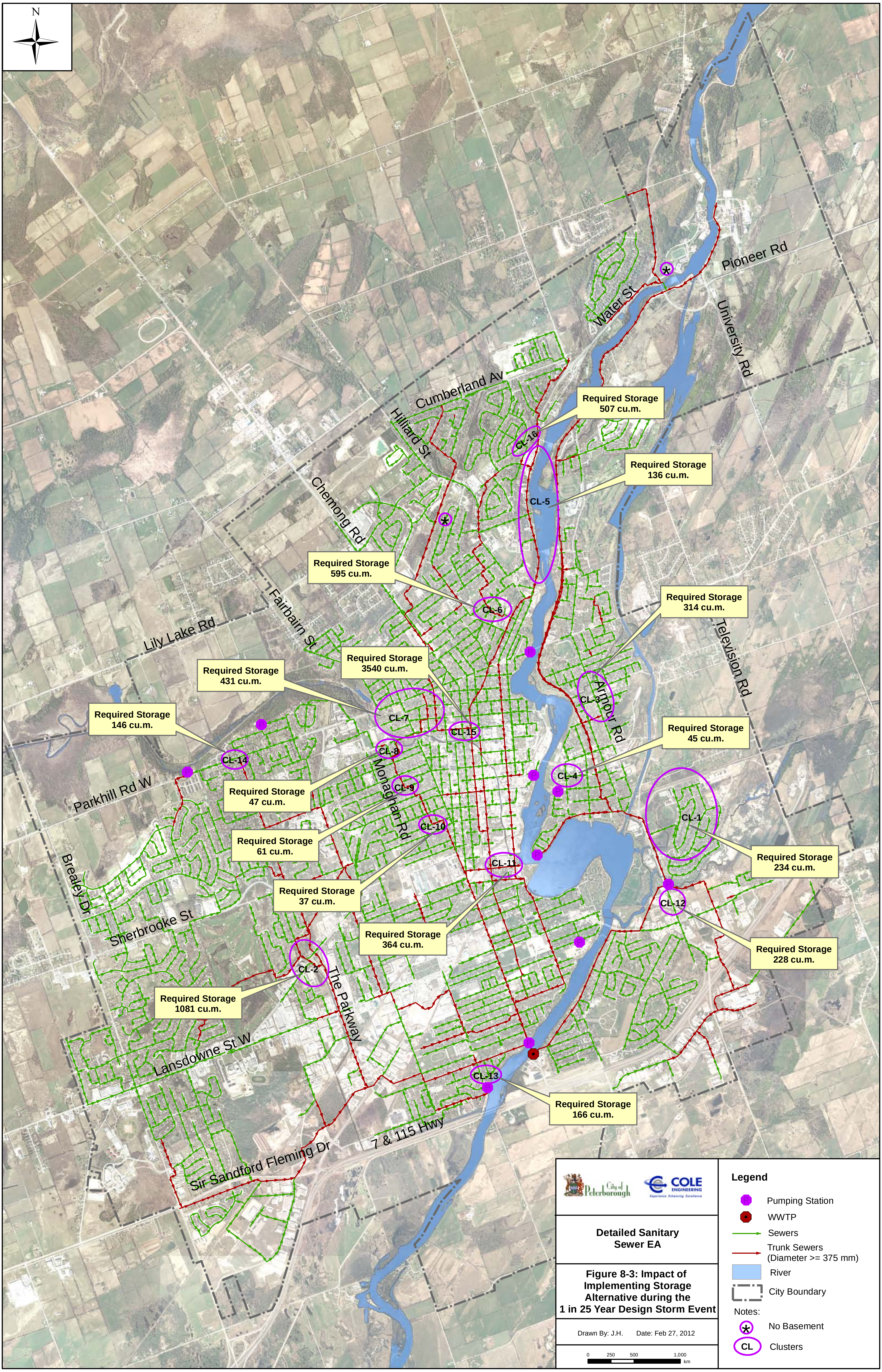


Figure 8-3: Impact of Implementing Storage Alternative during the 1 in 25 Year Design Storm Event

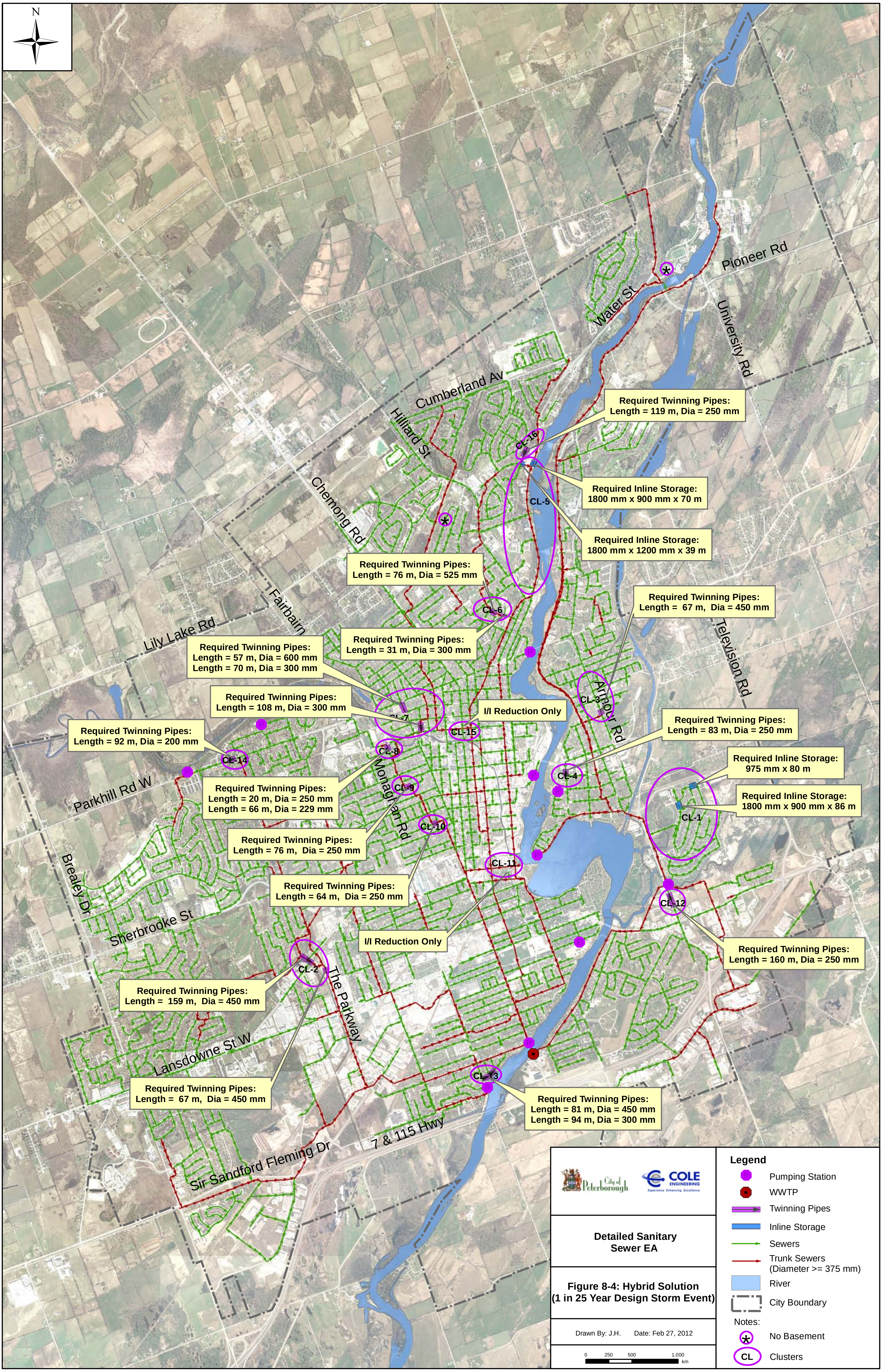


Figure 8-4: Hybrid Solution (1 in 25 Year Design Storm Event)

8.2. Sizing of Alternatives

Alternative measures were considered and developed individually for each cluster area. Sizing for the different elements was determined through modelling. Conveyance or storage elements were added and sizes and/or lengths were adjusted until the model showed acceptable results achieving the target level of protection. Elements were located in the street right-of-way. The availability of space in the right-of-way to place the proposed facility was considered but not assessed in detail at this stage.

Based on the above analysis, the following sections describe the alternatives and summarises the sizing required for every cluster area.

8.2.1. Alternative 1 – Do Nothing

There are no I-I reduction, conveyance, or storage options associated with this alternative.

8.2.2. Alternative 2 – I-I Reduction

I-I reduction lowers the peak flow and volume of extraneous flows in the sanitary sewer system and at the WWTP. I-I reduction also decreases the occurrence of raw or secondary sewage bypass at the WWTP. By reducing flow, additional capacity becomes available in the sanitary sewer system. Note that depending on the level of I-I the potential of flooding is not eliminated. Approximately 25% of direct sources of inflow (downspouts, cross connections, and illegal connections) have been assumed to be removed. This is based on typical rates achieved in similar studies in the GTA. Direct sources of inflow are represented as "TA" parameters in the model, as previously discussed. The I-I reduction alternative was modelled by reducing the "TA – Reduction Factor" parameter by 25% for the 1 in 25 year design event.

Table 8-2 below shows the I-I flow reduction that can be achieved by identifying and eliminating approximately 25% of the direct inflow sources. **Figure 8-1**, as previously shown, illustrates the impact of implementing I-I reduction during the 1 in 25 year storm event.

Table 8-2 – Peak Flow Reduction through I-I Remediation

Cluster ID	Existing Flow Rate (l/s)	I-I Reduced Flow Rate (l/s)	Estimated Net Flow Reduction (l/s)
CL1	57.0	50.2	6.8 (12%)
CL2	297.5	225.1	72.4 (24%)
CL3	81.5	66.4	15.1 (19%)
CL4	17.0	14.8	2.2 (13%)
CL5	115.3	99.0	16.3 (14%)
CL6	115.0	88.0	27.0 (23%)
CL7	47.8	36.7	11.1 (23%)
CL8	36.7	28.0	8.7 (24%)
CL9	63.1	47.1	16.0 (25%)
CL10	82.2	59.1	23.1 (28%)
CL11	81.1	60.2	20.9 (26%)
CL12	40.9	31.5	9.4 (23%)
CL13	18.9	14.9	4.0 (21%)
CL14	59.4	56.2	3.2 (5%)
CL15	5.5	0.3	5.2 (95%)
CL16	37.3	28.3	9.0 (24%)

Note that the net reduction is not a constant 25% due to flow routing and sewer capacity effects from the sources.

8.2.3. Alternative 3 – Conveyance (Twinning)

The conveyance alternative eliminates the flood potential by reducing the HGL in the sanitary sewer system below 1.8 m from the surface. However, this alternative does not reduce the peak flow or volume of extraneous flow entering the system. The peak flow can increase leading to higher flood potential downstream and likelihood for raw sewage bypasses at the WWTP. **Table 8-3** shows the length and diameter of sewer required in each of the 16 clusters which eliminates the risk of flooding during a 1 in 25 year event. **Figure 8-2**, as previously discussed, shows the conveyance alternative during the 1 in 25 year storm event.

Twinning was modelled by adding a new pipe at the capacity bottleneck location. The proposed pipe is assumed to have the same inverts and length as the existing sewer. The diameter of the new sewer is selected to reduce the HGL below 1.8 m from the ground surface during the 1 in 25 year design storm event.

Table 8-3 – Alternative 3 – Conveyance

Cluster ID	Proposed Diameter (m)	Length (m)	Increase in Flow Rate due to Increased Conveyance Capacity (l/s)
CL1	0.250	956	34.4
CL2	0.525	209	9.0
	0.600	67	
CL3	0.250	10	13.9
	0.300	261	
	0.450	67	
CL4	0.375	83	1.0
CL5	0.450	799	0.2
	0.525	454	
CL6	0.375	76	3.6
	0.450	115	
CL7	0.250	67	3.5
	0.300	275	
	0.375	62	
	0.525	57	
CL8	0.250	90	0.0
CL9	0.250	76	2.1
CL10	0.250	64	1.4
CL11	0.250	133	8.8
CL12	0.250	160	0.0
CL13	0.250	134	13.1
	0.300	81	
	0.375	94	
CL14	0.250	92	0.0
CL15	0.450	59	8.6
CL16	0.250	119	0.0

8.2.4. Alternative 4 – Storage

Storage eliminates flooding potential by temporarily holding and releasing the additional wet weather at a reduced rate to match the available capacity downstream. This method does not reduce the overall volume of flows but does reduce the peak flows and the possible risk of bypasses and/or flooding.

The storage alternative was modeled adding storage at the upstream node of the constraining sewer segment. Flow is allowed to accumulate in the storage node limiting the increase in the HGL upstream and downstream of the node during the 1 in 25 year event. The actual configuration of the storage units will be determined at the detailed design stage.

Table 8-4 shows total storage volume required in each of the 16 clusters to eliminate high flooding potential by maintaining the HGL below 1.8 m from the surface. **Figure 8-3**, shown previously, illustrates the impact of storage for the 1 in 25 year event.

Table 8-4 – Alternative 4 – Storage

Cluster ID	Total Storage Requirement (m^3)	Decrease in flow rate due to storage (l/s)
CL1	230	12.9
CL2	1282	113.7
CL3	307	40.9
CL4	40	8.8
CL5	126	33.2
CL6	141	72.6
CL7	265	36.0
CL8	25	9.2
CL9	71	26.8
CL10	125	48.6
CL11	326	44.5
CL12	238	22.7
CL13	305	126.9
CL14	145	31.6
CL15	3429	13.5
CL16	512	28.6

8.2.5. Alternative 5 – Hybrid Solution

This alternative reduces I-I upstream of all flood clusters in combination with either conveyance or storage alternatives to reduce the potential of flooding at each cluster. I-I reduction and conveyance alternatives were modeled as previously discussed. The storage component in the hybrid solution was assumed to be in-line with the existing sewer. A new pipe was located upstream of the constraiing sewer segment. Flow is allowed to accumulate in the new pipe, limiting the increase in the HGL upstream and downstream of the effected segment. The configuration of the storage units should be determined at the detailed design stage. Further details are found in **Appendix I**.

The hybrid alternative yields an overall net decrease in flow rate and volume downstream from each cluster. **Table 8-5** presents I-I reduction in combination with either conveyance or storage to eliminate the flooding risk in each of the 16 clusters. **Figure 8-4** illustrates the impact of the hybrid alternative for the 1 in 25 year event.

Table 8-5 – Alternative 5 – Hybrid Solution

Cluster ID	I-I Flow Reduction (l/s)	Conveyance (Twinning)		Storage (m^3)	Decrease in Flow Rate (l/s)
		Diameter (m)	Length (m)		
CL1	6.8	NA		60	15.0
				139	
CL2	72.4	0.450	226	NA	63.9
CL3	15.2	0.450	67	NA	8.2
CL4	2.2	0.250	83	NA	1.5
CL5	16.3	NA		62	28.7
				152	
CL6	27.0	0.300	31	NA	21.5
		0.525	76		
CL7	11.1	0.300	178	NA	6.9
		0.600	57		
CL8	8.7	0.250	86	NA	10.9
CL9	16.0	0.250	76	NA	18.1
CL10	23.1	0.250	64	NA	28.7
CL11	20.9	NA		NA	3.6
CL12	9.5	0.250	160	NA	9.5
CL13	4.0	0.300	94	NA	106.2
		0.450	81		
CL14	3.3	0.200	92	NA	3.1
CL15	5.2	NA		NA	8.0
CL16	9.0	0.250	119	NA	8.4

NA – Not Applicable

8.2.6. Impacts on Wastewater Treatment Plant (WWTP)

Table 8-6 below summarises the peak flows at the Peterborough WWTP for each of the five alternatives under the 1 in 25 year design event.

Table 8-6 – Peak Flows at the Peterborough WWTP (1 in 25 year design storm)

Storm Event	Existing Peak Pumping Capacity at WWTP (m^3/d)	Alternative 1 Do Nothing (Existing Conditions) (m^3/d)	Alternative 2 I-I Reduction (m^3/d)	Alternative 3 Conveyance (m^3/d)	Alternative 4 Storage (m^3/d)	Alternative 5 Hybrid (m^3/d)
1 in 25	190,900	203,314	173,981	205,506	180,050	173,226

Table 8-6 shows that Alternatives 1 and 3 increase the peak flow at the Peterborough WWTP and exceed the WWTP's existing pumping capacity. Both increase the risk of bypass to the Otonabee River.

Alternatives 2, 4 and 5 all result in lower peak flows than the pump capacity at the Peterborough WWTP. Although Alternative 2 frees up capacity in the sanitary sewer system, it does not completely eliminate the risk of basement flooding.

9.0 Preliminary Costing

This section presents preliminary cost estimates associated with each of the five collection system alternatives. It should be noted that the costs include construction plus 30% for engineering and contingency.

9.1. Alternative 1 – Do Nothing

There are no costs incurred by the City. However in the long-term, if no mitigative measures are implemented there may be significant costs to the City and the public through property damage, loss of business, loss of income, Insurance claims, etc.

9.2. Alternative 2 – I-I Reduction

The cost of identifying and mitigating I-I sources can vary significantly depending on the effort required to identify the sources and works to remediate. An approximate unit cost of $20,000 l/s of reduction has been assumed based on recent studies in the GTA. This unit cost refers to the lot level identification and mitigation of I-I sources. **Table 9-1** presents the cost estimates for I-I reduction in each of the 16 clusters.

Table 9-1 – Alternative 2 – I-I Reduction

Cluster ID	Flow Reduction (l/s)	Unit Cost ($/l/s)	Sub-Total Cost	Total Cost (incl. 30% eng. and contingency)
CL1	6.8	20,000	$136,040	$176,852
CL2	72.4		$1,448,780	$1,883,414
CL3	15.2		$303,220	$394,186
CL4	2.2		$43,060	$55,978
CL5	16.3		$326,060	$423,878
CL6	27.0		$540,580	$702,754
CL7	11.1		$222,380	$289,094
CL8	8.7		$174,300	$226,590
CL9	16.0		$319,800	$415,740
CL10	23.1		$461,680	$600,184
CL11	20.9		$417,060	$542,178
CL12	9.5		$189,000	$245,700
CL13	4.0		$80,400	$104,520
CL14	3.3		$65,520	$85,176
CL15	5.2		$104,420	$135,746
CL16	9.0		$180,300	$234,390
Total	250.7		**$5,012,600**	**$6,516,380**

9.3. Alternative 3 – Conveyance

Unit costs for storage, twinning, replacement, and diversion was used to estimate the cost of the conveyance alternative. The unit cost table is found in **Appendix G**. **Table 9-2** below shows the required pipe size and length for a given pipe segment to alleviate flood risk in all 16 clusters.

Table 9-2 – Alternative 3 – Conveyance

Cluster ID	Diameter (m)	Length (m)	Unit Cost ($/m)	Sub-Total Cost	Total Cost (incl. 30% eng. and contingency)
CL1	0.250	956	883	$844,132	$1,097,372
CL2	0.525	209	1,300	$368,913	$479,587
	0.600	67	1,460		
CL3	0.250	10	883	$349,703	$454,614
	0.300	261	1,010		
	0.450	67	1,166		
CL4	0.375	83	1,100	$91,000	$118,300
CL5	0.450	799	1,166	$1,520,921	$1,977,197
	0.525	454	1,300		
CL6	0.375	76	1,100	$218,407	$283,929
	0.450	115	1,166		
CL7	0.250	67	883	$479,740	$623,662
	0.300	275	1,010		
	0.375	62	1,100		
	0.525	57	1,300		
CL8	0.250	90	883	$79,223	$102,990
CL9	0.250	76	883	$66,724	$86,741
CL10	0.250	64	883	$56,510	$73,463
CL11	0.250	133	883	$117,734	$153,054
CL12	0.250	160	883	$141,195	$183,554
CL13	0.250	134	883	$303,547	$394,611
	0.300	81	1,010		
	0.375	94	1,100		
CL14	0.250	92	883	$81,151	$105,496
CL15	0.450	59	1,166	$69,116	$89,851
CL16	0.250	119	883	$104,862	$136,321
Total				**$4,892,878**	**$6,360,741**

9.4. Alternative 4 – Storage

A unit cost of $2,000/m^3 was used to determine the total cost of implementing storage units in all 16 clusters in the study area, as seen below in **Table 9-3**.

Table 9-3 – Alternative 4 – Storage

Cluster ID	Total Storage Requirement (m^3)	Sub-Total Cost	Total Cost (incl. 30% eng. and contingency)
CL1	230	$459,933	$597,913
CL2	1282	$2,564,360	$3,333,668
CL3	307	$613,434	$797,464
CL4	40	$79,427	$103,255
CL5	126	$252,102	$327,733
CL6	141	$1,114,959	$1,449,447
CL7	265	$1,333,478	$1,733,521
CL8	25	$49,375	$64,188
CL9	71	$142,678	$185,481
CL10	125	$249,929	$324,908
CL11	326	$651,231	$846,600
CL12	238	$476,579	$619,553
CL13	305	$610,823	$794,070
CL14	145	$290,104	$377,135
CL15	3429	$6,857,017	$8,914,122
CL16	512	$1,023,588	$1,330,664
Total		**$16,769,019**	**$21,799,725**

9.5. Alternative 5 – Hybrid Solution

Table 9-4 summarises the costs of the hybrid alternative in each cluster. Costs are based on the unit rates described in **Appendix G**. The hybrid solution is not the most inexpensive alternative in a given cluster; but, it reduces potential flooding and provides additional capacity in the sanitary sewer system.

Table 9-4 – Alternative 5 – Hybrid Solution

Cluster ID	I-I Flow Reduction (l/s)	Conveyance (Twinning)		Storage Provided (m^3)	Sub-Total Cost	Total Cost (incl. 30% eng. and contingency)
		Diameter (m)	Length (m)			
CL1	6.8	NA		60	$605,205	$786,767
				139		
CL2	72.4	0.450	226	NA	$1,712,177	$2,225,830
CL3	15.2	0.450	67	NA	$380,999	$495,299
CL4	2.2	0.250	83	NA	$116,012	$150,816
CL5	16.3	NA		62	$728,136	$946,577
				152		
CL6	27.0	0.300	31	NA	$670,783	$872,018
		0.525	76			
CL7	11.1	0.300	178	NA	$484,751	$630,176
		0.600	57			
CL8	8.7	0.250	86	NA	$250,013	$325,017
CL9	16.0	0.250	76	NA	$386,524	$502,481
CL10	23.1	0.250	64	NA	$518,190	$673,647
CL11	20.9	NA		NA	$417,060	$542,178
CL12	9.5	0.250	160	NA	$330,195	$429,254
CL13	4.0	0.300	94	NA	$269,544	$350,407
		0.450	81			
CL14	3.3	0.200	92	NA	$146,671	$190,672
CL15	5.2	NA		NA	$104,420	$135,746
CL16	9.0	0.250	119	NA	$285,159	$370,707
Total					**$7,405,837**	**$9,627,588**

Table 9-5 following shows a summary of costs for each of the five alternatives.

Table 9-5 – Summary of Total Costs

Cluster ID	Alternative 1: Do Nothing	Alternative 2: I-I Reduction	Alternative 3: Conveyance	Alternative 4: Storage	Alternative 5: Hybrid
CL1	$0	$176,852	$1,097,372	$597,913	$786,767
CL2	$0	$1,883,414	$479,587	$3,333,668	$2,225,830
CL3	$0	$394,186	$454,614	$797,464	$495,299
CL4	$0	$55,978	$118,300	$103,255	$150,816
CL5	$0	$423,878	$1,977,197	$327,733	$946,577
CL6	$0	$702,754	$283,929	$1,449,447	$872,018
CL7	$0	$289,094	$623,662	$1,733,521	$630,176
CL8	$0	$226,590	$102,990	$64,188	$325,017
CL9	$0	$415,740	$86,741	$185,481	$502,481
CL10	$0	$600,184	$73,463	$324,908	$673,647
CL11	$0	$542,178	$153,054	$846,600	$542,178
CL12	$0	$245,700	$183,554	$619,553	$429,254
CL13	$0	$104,520	$394,611	$794,070	$350,407
CL14	$0	$85,176	$105,496	$377,135	$190,672
CL15	$0	$135,746	$89,851	$8,914,122	$135,746
CL16	$0	$234,390	$136,321	$1,330,664	$370,707
Total	**$0**	**$6,516,380**	**$6,360,741**	**$21,799,725**	**$9,627,588**

10.0 Alternative Evaluation

10.1. Evaluation Criteria and Scoring System

The five alternatives were compared considering the following evaluation criteria:

1. Functional (technical effectiveness);
2. Natural heritage features;
3. Social environment;
4. Cultural environment heritage;
5. Economic environment;
6. First Nations / Aboriginal peoples, and,
7. Constructability.

Table 10-1 – Alternative Evaluation Criteria for the Sanitary Sewer System

Functional
Opportunity to reduce extraneous flows into the sanitary sewer system
Opportunity to eliminate high flood potential
Natural Heritage Features
Impacts to terrestrial habitat
Impacts to aquatic habitat
Impacts on water quality
Social Environment
Ability to improve public safety
Long term impacts to private properties
Long term impacts to public properties
Expected disturbance to some roads during construction
Cultural Environment Heritage
Potential impacts to areas of archeological importance
Potential impacts to built heritage resources and cultural heritage landscapes
Economic Environment
Capital costs
Maintenance costs
First Nations / Aboriginal Peoples
Impacts to identified First Nations resources
Potential impacts to First Nations land claims
Constructability
Ease of construction and accessibility

A preferred alternative was selected based on the following scoring:

1. Positive performance or low / no cost. Score 3
2. Moderate performance or medium cost. Score 2
3. Poor performance or high cost. Score 1

The score was applied to the four alternatives for each criterion and the total score for each alternative was calculated. The alternative with the highest score was selected as the preferred alternative for a given cluster. The measure for evaluating each criterion was established as presented below in **Table 10-2**.

Table 10-2 – Evaluation Criteria

Comparative Criteria	Description	Measures for Evaluating
Functional		
Extraneous Flows	Effectiveness in the reduction of extraneous flows from the sanitary sewer system in the cluster area.	▪ Alternative is effective in achieving extraneous flow reduction – score 3. ▪ Alternative is moderately effective in achieving extraneous flow reduction – score 2. ▪ Alternative has minimal or no effectiveness in achieving extraneous flow reduction – score 1.
High Flood Potential	Effectiveness in reducing the potential of flooding by maintaining the HGL below 1.8 m from the surface.	▪ Alternative is effective in reducing the potential of flooding – score 3. ▪ Alternative is moderately effective in reducing the potential of flooding – score 2. ▪ Alternative is minimally effective reducing the potential of flooding – score 1.
Natural Heritage Features		
Terrestrial Habitat	Potential to impact terrestrial habitats or systems, including terrestrial features / functions (ANSIs, ESAs), unique vegetation species, mature trees, existing park / open spaces linkages or wildlife.	▪ Alternative has a positive/no negative impact on terrestrial system – score 3. ▪ Alternative has minor impact on terrestrial system – score 2. ▪ Alternative has a negative impact on terrestrial system – score 1.
Aquatic Habitat	Potential to impact aquatic habitats or systems, including possible impacts on aquatic life, features / functions or groundwater.	▪ Alternative has a positive/no negative impact on aquatic system – score 3. ▪ Alternative has minor impact on aquatic system – score 2. ▪ Alternative has a negative impact on aquatic system – score 1.
Water Quality	Potential to impact water quality.	▪ Alternative has a positive/no negative impact on water quality – score 3. ▪ Alternative has minor impact on water quality – score 2. ▪ Alternative has a negative impact on water quality – score 1.

Comparative Criteria	Description	Measures for Evaluating
Social Environment		
Public Safety	Potential impact to public safety.	▪ Alternative has a positive/no negative impact on public safety – score 3. ▪ Alternative has a moderate impact on public safety – score 2. ▪ Alternative has negative impact on public safety – score 1.
Impacts to private properties	Potential impact on private properties.	▪ Alternative has a positive/no negative impact on private properties – score 3. ▪ Alternative has minor impact on private properties – score 2. ▪ Alternative has a negative impact on private properties – score 1.
Impacts to public properties	Potential impact on public properties.	▪ Alternative has a positive/no negative impact on public properties – score 3. ▪ Alternative has minor impact on public properties – score 2. ▪ Alternative has a negative impact on public properties – score 1.
Disturbances to roads during construction	The extent to which alternatives impact roads and transportation within the area related to visibility, noise, air emissions, traffic congestions and regulatory requirements.	▪ Alternative demonstrates minimal road disturbances during construction – score 3. ▪ Alternative demonstrates moderate disturbances during road construction – score 2. ▪ Alternative demonstrates several disturbances during road construction – score 1.
Cultural Environment Heritage		
Archaeological Significance	Impact on archaeological significance.	▪ Alternative does not have significant archaeological impacts – score 3. ▪ Alternative has moderate archaeological impact – score 2. ▪ Alternative has major archaeological impact – score 1.
Built Heritage Resources and Cultural Heritage Landscapes	Impact on built heritage resources and cultural heritage landscapes.	▪ Alternative does not impact built heritage resources and cultural heritage landscapes – score 3. ▪ Alternative has minor impact on built heritage resources and cultural heritage landscapes – score 2. ▪ Alternative has major impact on built heritage resources and cultural heritage landscapes – score 1.
Economic Environment		
Capital Cost	The capital cost associated with the construction of the alternative including labour, material and equipment.	▪ Capital cost of alternative is low– score 3. ▪ Capital cost of alternative is medium – score 2. ▪ Capital cost of alternative is high – score 1.

Comparative Criteria	Description	Measures for Evaluating
Maintenance Cost	Post-construction operation and maintenance costs associated with the alternative.	▪ Maintenance cost of alternative is low – score 3. ▪ Maintenance cost of alternative is moderate – score 2. ▪ Maintenance cost of alternative is high – score 1.
First Nations / Aboriginal Peoples		
Impacts to Identified First Nations Resources	Potential impacts to identified First Nations resources.	▪ Alternative has a positive/no negative impact on First Nations Resources – score 3. ▪ Alternative has a moderate impact on First Nations Resources– score 2. ▪ Alternative has a negative impact on First Nations Resources – score 1.
Potential Impacts to First Nations Land Claims	Potential impacts to First Nations land claims.	▪ Alternative has a positive/ no negative impact on First Nations Land Claims – score 3. ▪ Alternative has minor impact on First Nations Land Claims – score 2. ▪ Alternative has a negative impact on First Nations Land Claims – score 1.
Constructability		
Construction and Accessibility	Potential impacts to construction and accessibility.	▪ Alternative does not have a negative impact on construction and accessibility – score 3. ▪ Alternative has minor impact on construction and accessibility – score 2. ▪ Alternative has a negative impact on construction and accessibility – score 1.

10.2. Evaluation of Alternatives

The alternatives were evaluated and scored for each cluster area and the results are discussed below.

10.2.1. Extraneous Flows

Alternatives 2 and 5 reduce the amount of extraneous flows entering the sanitary sewer system. Clearwater is removed allowing for increased sewer security and/or future development. Alternatives 1, 3, and 4 do not reduce extraneous flows in the sanitary sewer system; therefore, they are rated as poor performers.

10.2.2. High Flood Potential

Alternative 1 is not preferred as it does not eliminate the potential of flooding. Alternatives 3, 4, and 5 all minimize the flood potential as the HGL in the targeted clusters will be lowered to below 1.8 m from the surface through design considerations. In clusters 11 and 15, Alternative 2 minimizes the potential of flooding and provides additional capacity in the sewer system without any additional infrastructure construction.

10.2.3. Terrestrial Habitat

The terrestrial habitat should not be affected as environmental protection measures should be implemented during construction for Alternatives 3, 4, and 5. Alternative 2 will not have any effect on terrestrial habitat. Note that Alternative 1 may result in possible impacts to the terrestrial habitat if a severe weather event is experienced and no remedial measures are implemented.

10.2.4. Aquatic Habitat

Alternative 1 may result in possible impacts to the aquatic habitat under a severe weather event. Alternative 2 should not have negative impacts on aquatic habitats. Environmental protection measures should be implemented during construction for Alternatives 3, 4, and 5. Alternative 3 may increase peak flows downstream, which has the potential to lead to possible bypasses to the Otonabee River.

10.2.5. Water Quality

Raw sewage bypasses may also occur if no remedial measures are implemented as is the case with Alternative 1. Alternative 2 would improve the water quality in the river through reduced overflows. Environmental protection measures should be implemented during construction for Alternatives 3, 4, and 5. Alternative 3 may increase peak flows downstream, which has the potential to lead to possible raw sewage bypasses.

10.2.6. Public Safety

Alternative 1 may have a negative impact on public safety as it does not implement any of the proposed recommendations (i.e. "Do Nothing"). This may still lead to flooding and potential bypasses. The remaining alternatives all improve public safety.

10.2.7. Impacts to Private Properties

Alternative 1 may have a negative impact to private properties as a flood risk will still exist if no remediation measures are implemented. With Alternatives 2 and 5, some I-I reduction measures will have to be incorporated on private properties depending on the source and nature of the I-I. Alternatives 3 and 4 should not have any impacts to private properties.

10.2.8. Impacts to Public Properties

Alternative 1 may have a negative impact to public properties as there will still exist a flood risk if no remediation measures are implemented. Alternatives 3, 4, and 5 will require infrastructure related works to be implemented in or on public lands. As such, there may be some impacts to public properties with the exception of normal construction activity.

10.2.9. Disturbances to Roads during Construction

Alternatives 1 and 2 do not involve construction activities which would result in road disturbances; however, there may be road occupancy during inspections and sewer testing for Alternative 2. Alternatives 3, 4, and 5 have construction related activities associated with the remedial measures.

Road disturbances will exist in several clusters. The extent of this disturbance will be based on the specific remedial measure recommended.

10.2.10. Archaeological Significance

Alternatives 2 to 5 should be constrained to existing developed areas and should have no impact on archaeological resources. Potential works considered would be completed in existing built-up urban areas, in private lots, or the existing right-of-way.

10.2.11. Built Heritage Resources and Cultural Heritage Landscapes

None of the alternatives will have an impact on built heritage resources and cultural heritage landscapes.

10.2.12. Capital Costs

There is no capital costs associated with Alternative 1. However, it should be noted that by doing nothing the risk of flooding and bypasses increase. Flooding in 2004, although in excess of a 1 in 100 year event, led to damages in excess of $100 million to the public and private sectors. Alternatives 3 and 4 will require significant capital works. Alternative 5 may be the most expensive alternative for a given cluster; however, it is generally preferred as it reduces the amount of extraneous flow entering the sanitary sewer system, reduces the risk of sewage bypasses, and may provide sewer capacity for future development.

10.2.13. Maintenance Costs

There are minimal maintenance costs associated with Alternatives 1, 2, and 3. Alternative 4, and in some instances Alternative 5, will have maintenance costs associated with underground storage facilities. These will require maintenance based on the frequency of wet weather events. Alternative 4 would require the highest maintenance and therefore is not preferred.

10.2.14. Impacts to identified First Nations Resources

Alternative 1 and 3 may have a negative impact on identified First Nations resources due to continued and possible increases of bypasses. Alternatives 2, 4 and 5 may reduce the occurrence of bypasses by reducing the amount of WWF entering the sanitary sewer system and lower peak flows downstream

10.2.15. Potential Impacts to First Nations Land-Claims

None of the alternatives will have an effect on First Nations land claims.

10.2.16. Construction and Accessibility

There are no construction related activities with Alternative 1. There may be some minor construction activities with Alternative 2. Alternatives 3, 4, and 5 may have impacts on public and private properties and there may be some road disturbances during construction.

Table 10-3 – Impacts and Mitigation

Cluster	Alternatives	Functional		Natural Heritage Features			Social Environment				Cultural Environment Heritage		Economic Environment		First Nations / Aboriginal Peoples		Constructability	Total Score
		Extraneous Flows	High Flood Potential	Terrestrial Habitat	Aquatic Habitat	Water Quality	Public Safety	Impacts to private properties	Impacts to public properties	Disturbances to roads during construction	Archeological Significance	Built Heritage Resources and Cultural Heritage Landscapes	Capital Costs	Maintenance Costs	Impacts to identified First Nations Resources	Potential impacts to First Nations land claims	Construction and Accessibility	
CL-1	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	2	2	3	2	2	3	2	2	2	3	3	2	2	3	3	2	38
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	1	2	2	3	2	35
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	39
	Alternative 5	3	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	**41**
CL-2	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	2	2	3	2	2	3	2	2	2	3	3	1	2	3	3	2	37
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	2	2	2	3	2	36
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	39
	Alternative 5	3	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	**41**
CL-3	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	2	2	3	2	2	3	2	2	2	3	3	2	2	3	3	2	38
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	2	2	3	3	2	36
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	39
	Alternative 5	3	3	3	3	3	3	2	2	2	3	3	2	2	3	3	2	**42**
CL-4	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	2	2	3	2	2	3	2	2	2	3	3	2	2	3	3	2	38
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	1	2	3	3	2	35
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	39
	Alternative 5	3	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	**41**
CL-5	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	2	2	3	2	2	3	2	2	2	3	3	2	2	3	3	2	38
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	1	2	2	3	2	35
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	2	2	3	3	2	40
	Alternative 5	3	3	3	3	3	3	2	2	2	3	3	2	2	3	3	2	**42**
CL-6	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	2	2	3	2	2	3	2	2	2	3	3	2	2	3	3	2	38

Cluster	Alternatives	Functional		Natural Heritage Features			Social Environment				Cultural Environment Heritage		Economic Environment		First Nations / Aboriginal Peoples		Constructability	Total Score
		Extraneous Flows	High Flood Potential	Terrestrial Habitat	Aquatic Habitat	Water Quality	Public Safety	Impacts to private properties	Impacts to public properties	Disturbances to roads during construction	Archeological Significance	Built Heritage Resources and Cultural Heritage Landscapes	Capital Costs	Maintenance Costs	Impacts to identified First Nations Resources	Potential impacts to First Nations land claims	Construction and Accessibility	
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	2	2	2	3	2	36
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	39
	Alternative 5	3	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	**41**
CL-7	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	2	2	3	2	2	3	2	2	2	3	3	3	2	3	3	2	39
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	2	2	2	3	2	36
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	39
	Alternative 5	3	3	3	3	3	3	2	2	2	3	3	2	2	3	3	2	**42**
CL-8	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	2	2	3	2	2	3	2	2	2	3	3	2	2	3	3	2	38
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	1	2	2	3	2	35
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	39
	Alternative 5	3	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	**41**
CL-9	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	2	2	3	2	2	3	2	2	2	3	3	1	2	3	3	2	37
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	3	2	2	3	2	37
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	2	2	3	3	2	40
	Alternative 5	3	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	**41**
CL-10	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	2	2	3	2	2	3	2	2	2	3	3	1	2	3	3	2	37
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	3	2	2	3	2	37
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	2	2	3	3	2	40
	Alternative 5	3	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	**41**
CL-11	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	3	3	3	2	2	3	2	2	2	3	3	2	2	3	3	2	**40**
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	3	2	2	3	2	37
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	39
	Alternative 5	3	3	3	2	2	3	2	2	2	3	3	2	2	3	3	2	**40**

Cluster	Alternatives	Functional		Natural Heritage Features			Social Environment				Cultural Environment Heritage		Economic Environment		First Nations / Aboriginal Peoples		Constructability	Total Score
		Extraneous Flows	High Flood Potential	Terrestrial Habitat	Aquatic Habitat	Water Quality	Public Safety	Impacts to private properties	Impacts to public properties	Disturbances to roads during construction	Archeological Significance	Built Heritage Resources and Cultural Heritage Landscapes	Capital Costs	Maintenance Costs	Impacts to identified First Nations Resources	Potential impacts to First Nations land claims	Construction and Accessibility	
CL-12	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	2	2	3	2	2	3	2	2	2	3	3	2	2	3	3	2	38
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	2	2	2	3	2	36
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	39
	Alternative 5	3	3	3	3	3	3	2	2	2	3	3	2	2	3	3	2	**42**
CL-13	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	2	2	3	2	2	3	2	2	2	3	3	3	2	3	3	2	39
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	2	2	2	3	2	36
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	39
	Alternative 5	3	3	3	3	3	3	2	2	2	3	3	2	2	3	3	2	**42**
CL-14	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	2	2	3	2	2	3	2	2	2	3	3	3	2	3	3	2	39
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	2	2	2	3	2	36
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	39
	Alternative 5	3	3	3	3	3	3	2	2	2	3	3	2	2	3	3	2	**42**
CL-15	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	3	3	3	2	2	3	2	2	2	3	3	2	2	3	3	2	**40**
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	3	2	2	3	2	37
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	39
	Alternative 5	3	3	3	2	2	3	2	2	2	3	3	2	2	3	3	2	**40**
CL-16	Alternative 1	1	1	2	2	1	1	1	1	3	3	3	2	3	2	3	3	32
	Alternative 2	2	2	3	2	2	3	2	2	2	3	3	2	2	3	3	2	38
	Alternative 3	1	2	3	2	2	3	2	2	2	3	3	3	2	2	3	2	37
	Alternative 4	1	3	3	3	3	3	2	2	2	3	3	1	2	3	3	2	39
	Alternative 5	3	3	3	3	3	3	2	2	2	3	3	2	2	3	3	2	**42**

10.3. Summary Results of Evaluation Criteria

As shown in **Table 10-3**, the hybrid alternative is preferred for each cluster area, except for cluster 11 and cluster 15, where Alternative 2 is preferred. The preferred alternative requires I-I reduction throughout the City. Additional conveyance or storage would be implemented in selected locations to minimize flood potential and to ensure the HGL is reduced below 1.8 m of the surface.

In clusters 11 and 15, a 25% reduction in I-I will also reduce the flood potential, provided the works for other clusters upstream are also implemented. (No additional storage or conveyance capacity required). The hybrid alternative (Alternative 2) has been selected as the preferred alternative as it meets all the functional requirements and does not require additional infrastructure and construction related activity. Detailed evaluation for each cluster can be found under **Appendix H**.

10.4. Enhanced 100 Year Alternative

Due to the large intensity and volume of historical storm events recently experienced in the City which resulted in significant extraneous flows entering the sanitary sewer system, flooding, and sewage bypasses, an “enhanced” solution was analyzed to assess the resources required to provide potential solutions for the 1 in 100 year event. As is the case for the 1 in 25 year storm event, I-I reduction will be applied throughout the system in combination with conveyance or storage options. The enhanced solution would be considered in areas where there are other future capital works planned. The total cost of implementing the enhanced hybrid solution to provide a 1 in 100 year level of protection is approximately $13,000,000. This will protect against basement flooding.

During the 1 in 100 year design storm event, the peak flow to the WWTP under existing conditions exceeds the existing pumping capacity of 190,000 m^3/day (note: this is also the case for the 1 in 25 year design storm event under existing conditions). Historically when this has occurred, raw sewage has bypassed the treatment plant and discharged directly into the Otonabee River. Therefore, although there may be the possibility to provide potential solutions for flooding during the 1 in 100 year design event, there still exists the possibility of raw sewage bypasses. Details of this enhanced hybrid alternative are found in **Appendix I.**

It should be noted that the I-I reduction corresponds to approximately 25% of direct inflows as calculated during the 1 in 25 year event.

11.0 Preferred Alternative

11.1. Preferred Remedial Measures

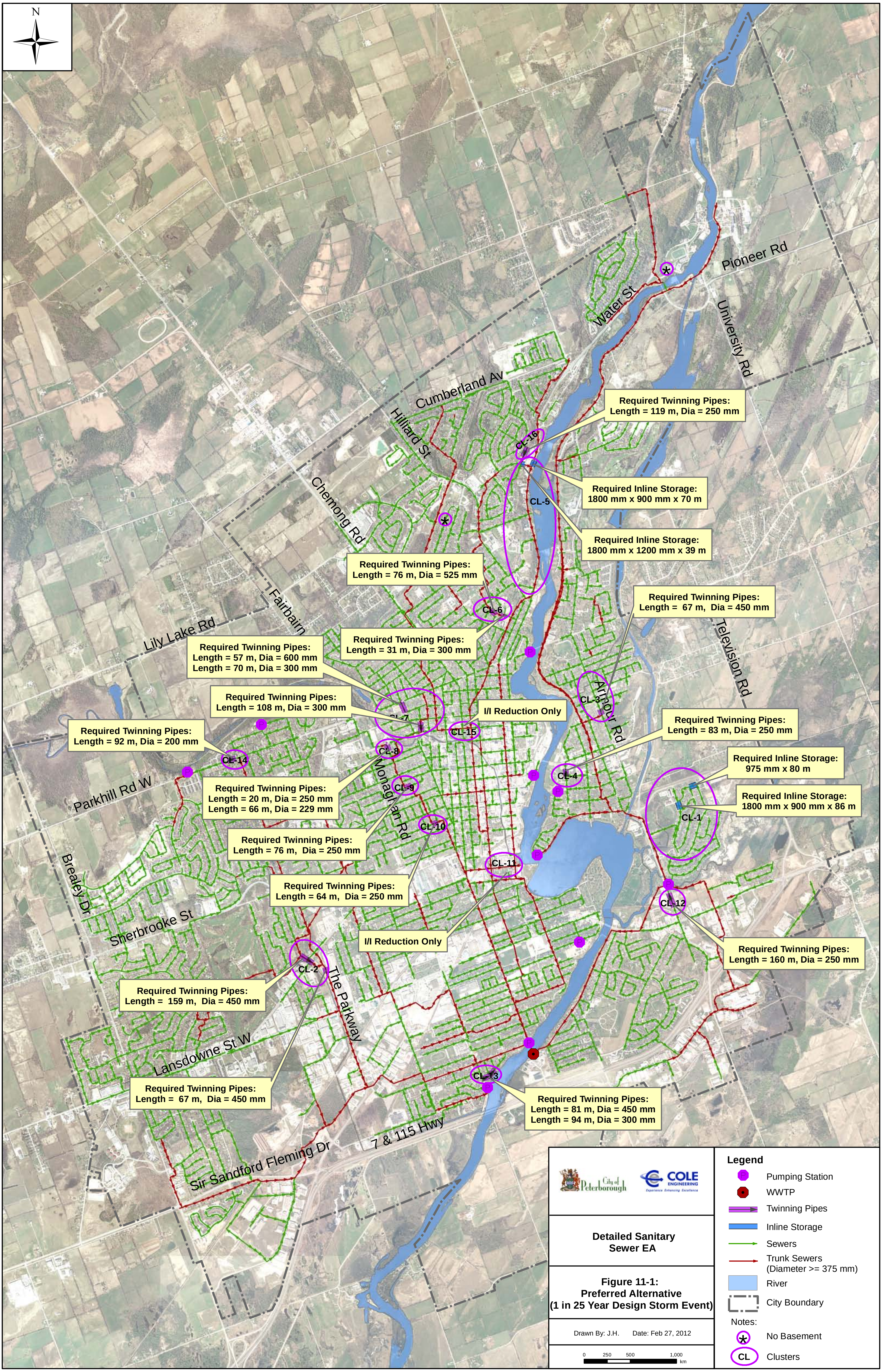
Table 11-1 summarizes the preferred alternative solution in each cluster, listing the target I-I reduction during a 1 in 25 year storm event, the length of required conveyance, and proposed additional storage volume for peak flow attenuation.

Table 11-1 – Summary of Preferred Alternative for each Cluster

Cluster ID	I-I Flow Reduction (l/s)	Additional Conveyance Capacity		Additional Storage Attenuation (m^3)
		Diameter (m)	Length (m)	
CL1	6.8	NA		60
				139
CL2	72.4	0.450	226	NA
CL3	15.2	0.450	67	NA
CL4	2.2	0.250	83	NA
CL5	16.3	NA		62
				152
CL6	27.0	0.300	31	NA
		0.525	76	
CL7	11.1	0.300	178	NA
		0.600	57	
CL8	8.7	0.250	86	NA
CL9	16.0	0.250	76	NA
CL10	23.1	0.250	64	NA
CL11	20.9	NA		NA
CL12	9.5	0.250	160	NA
CL13	4.0	0.300	94	NA
		0.450	81	
CL14	3.3	0.200	92	NA
CL15	5.2	NA		NA
CL16	9.0	0.250	119	NA

NA – Not Applicable

Figure 11-1 shows the location of each of the 16 clusters and the preferred alternative. The remedial measures included in the preferred alternative are explained in the following sections. A map for every cluster showing all remedial measures are provided in **Appendix I**. A profile of the HGL, for the sanitary sewers before and after remediation, is also provided in **Appendix I**.



Detailed Sanitary Sewer EA

Figure 11-1: Preferred Alternative (1 in 25 Year Design Storm Event)

Drawn By: J.H. Date: Feb 27, 2012

It should be noted that the results under this scenario implement the preferred alternative in all 16 identified clusters under the 1 in 25 year design storm event. The preferred solution in upstream clusters will impact the preferred alternative in downstream clusters. For example, in the preferred alternative, clusters 11 and 15 require I-I reduction only to reduce the risk of potential flooding. However, in Alternative 2 where I-I reduction alone is applied across the entire network with no additional conveyance or storage solutions, there still exists flooding risk in clusters 11 and 15. The reason for the difference is that in the preferred alternative, solutions upstream of clusters 11 and 15 reduce peak flows downstream (through I-I reduction, conveyance and storage) to a point where only I-I reduction is required in clusters 11 and 15 to provide the 1 in 25 year level of service. I-I reduction alone does not reduce the risk of flooding in any cluster to the 1 in 25 year design storm event unless the preferred alternative is implemented in upstream clusters.

11.2. General Recommendations

During detail design, construction, and implementation of the recommended works, it is recommended that the City undertake the following at key locations:

- Confirm existing sewer network geometry such as inverts, lengths, and diameters in each cluster area and immediately downstream. As previously noted, the model development required assumptions throughout most of the sewer network. An extensive data gap infilling process was undertaken to complete the sanitary sewer system hydraulic model. The assumptions are listed in **Appendix G**. It is important that the sewer geometry is represented accurately in the model to ensure that flood vulnerable areas are verified and the solutions confirmed;
- Conduct a survey of existing basement elevations in each cluster area. For the purposes of this study, basement elevations have been assumed to be 1.8 m from the ground surface elevation. A given area may have variable basement elevations or no basements. Verifying the locations of existing basements and their elevations will help refine the risk for potential flooding ;
- Flow monitoring in each cluster would be beneficial in order to accurately quantify the existing flows discharged from that specific tributary area. The flow monitoring results should be used to further calibrate the model and provide a site-specific representation of existing conditions and flows for a given area of concern;
- As part of the preferred alternative, 12 of the 16 clusters have sewer twinning as a component of the overall preferred solution. Details regarding new sewer connections should be based on local conditions (e.g. locates) which should be determined prior to the detailed design phase;
- As part of the preferred alternative, 2 of the 16 clusters in the City have in-line storage as a component of the overall preferred alternative. In-line storage is proposed as sewer pipes. The availability and effectiveness of other in-line or off-line configurations should be examined prior to detailed design;
- There are several areas in the City that have limited access to sanitary manholes. It is recommended that access be identified for all sanitary manholes for efficient and effective maintenance of the sewer system;

Future works in the same locations where works ill take place under this program should be considered and combined during planning of the preferred alternative. This is captured under **Section 13.0** of this report. The City should consider the implementation of the 1 in 100 year enhanced alternative if there are other planned capital projects in the same area.

11.3. Details of Cluster Specific Recommendations

The following section outlines the specific recommendations for each cluster area. All of the projects mentioned in this section are considered Schedule B projects and can proceed to detail design. Details can be found under **Appendix I**.

11.3.1. Cluster 1

The preferred alternative consists of:

- I-I reduction at the cluster and upstream; and,
- Two in-line storage units along Foxmeadow Road and Walker Avenue.

Table 11-2 – Preferred Alternative: Cluster 1

Remedial Measure	Location	Size (mm)	Length (m)	Volume of Storage provided (m^3)
In-Line Storage	Foxmeadow Road	975	80	60
	Walker Avenue	1800 x 900	86	139

Through discussions with the City, it has been noted that a sanitary sewer along Walker Avenue is currently in the design phase. This presents an opportunity to incorporate I-I reduction, as well as review the need for in-line storage work.

11.3.2. Cluster 2

The preferred alternative consists of:

- I-I reduction at the cluster and upstream; and,
- Two twinned sewer lengths near the intersection of Consilla Avenue and The Parkway.

Table 11-3 – Preferred Alternative: Cluster 2

Remedial Measure	Location	Size (mm)	Length (m)
Sewer Twinning	Near the intersection of Consilla Avenue and The Parkway	450	159
	Near the intersection of Consilla Avenue and The Parkway	450	67

Portions of the proposed twinned pipes are located outside of the road right-of-way. Access to sanitary sewer infrastructure and land ownership should be confirmed prior to the detailed design phase.

11.3.3. Cluster 3

The preferred alternative consists of:

- I-I reduction at the cluster and upstream; and,
- Twinned sewer on Armour Road between Munroe Avenue and Douro Street.

Table 11-4 – Preferred Alternative: Cluster 3

Remedial Measure	Location	Size (mm)	Length (m):
Sewer Twinning	Armour Road	450	67

Cluster 3 is located adjacent to Rube Brady Memorial Park where access to sanitary infrastructure may be limited. It is recommended that the City define and implement clear access points to all sanitary manholes prior to detailed design. It is also recommended that any potential adverse impacts to the park be assessed prior to detailed design.

11.3.4. Cluster 4

The preferred alternative consists of:

- I-I reduction at the cluster and upstream; and,
- Twinned sewer on Burnham Street north of Robinson Street.

Table 11-5 – Preferred Alternative: Cluster 4

Remedial Measure	Location	Size (mm)	Length (m)
Sewer Twinning	Burnham Street	250	83

Cluster 4 is located adjacent to James Stevenson Park where access to sanitary infrastructure may be limited. It is recommended that the City define and implement clear access points to all sanitary manholes prior to detailed design. It is also recommended that all potential adverse impacts to the park be assessed prior to detailed design.

11.3.5. Cluster 5

The preferred alternative consists of:

- I-I reduction at the cluster and upstream; and,
- Two in-line storage units along Water Street and Marina Boulevard.

Table 11-6 – Preferred Alternative: Cluster 5

Remedial Measure	Location	Size (mm)	Length (m)	Volume of Storage provided (m^3)
In-Line Storage	Water Street	1800 x 1200	70	152
	Marina Boulevard	1800 x 900	39	62

Through discussions with the City, it has been noted that a trunk sewer along Water Street has recently been reconstructed. The updated information for the new Water Street trunk sewer was not available during this study. As such, it is recommended that prior to detail design the model should be updated to include the new Water Street trunk sewer data, to determine if the cluster is still considered at risk of flooding.

The proposed storage units are located near the Northcrest Community Centre. Potential impacts to the community centre should be assessed prior to the detailed design phase.

11.3.6. Cluster 6

The preferred alternative consists of:

- I-I reduction at the cluster and upstream; and,
- One twinned sewer off Argyle Street and one twinned sewer off Nicholls Street.

Table 11-7 – Preferred Alternative: Cluster 6

Remedial Measure	Location	Size (mm)	Length (m)
Sewer Twinning	Argyle Street	300	31
	Nicholls Street	525	76

The proposed twinned pipes are not located in the road right-of-way. It is recommended that land ownership and access to the sanitary sewers be confirmed prior to detail design.

11.3.7. Cluster 7

The preferred alternative consists of:

- I-I reduction at the cluster and upstream; and,
- Two twinned pipes on Park Street North south of Parkhill Road West, and one twinned pipe on Gilchrist Street south of London Street.

Table 11-8 – Preferred Alternative: Cluster 7

Remedial Measure	Location	Size (mm)	Length (m)
Sewer Twinning	Gilchrist Street	300	108
	Park Street North	300	70
	Park Street North	600	57

The cluster is located in the proximity to the Trans Canada Trail. It is recommended that prior to detail design any adverse impacts be identified and mitigated.

11.3.8. Cluster 8

The preferred alternative consists of:

- I-I reduction at the cluster and upstream; and,
- Two twinned pipes on near the intersection of McDonnel Street and Cambridge Street.

Table 11-9 – Preferred Alternative: Cluster 8

Remedial Measure	Location	Size (mm)	Length (m)
Sewer Twinning	Intersection of McDonnel Street and Cambridge Street	250	20
	Cambridge Street	229	66

The cluster is located just west of the Trans Canada Trail. It is recommended that prior to detail design that any potential impacts to the Trans Canada Trail be identified and mitigated.

11.3.9. Cluster 9

The preferred alternative consists of:

- I-I reduction at the cluster and upstream; and,
- One twinned pipe along Homewood Avenue between Walton Street and Leslie Avenue.

Table 11-10 – Preferred Alternative: Cluster 9

Remedial Measure	Location	Size (mm)	Length (m)
Sewer Twinning	Homewood Avenue	250	76

11.3.10. Cluster 10

The preferred alternative consists of:

- I-I reduction at the cluster and upstream; and,
- One twinned pipe on Bolivar Street between Thomas Street and William Street.

Table 11-11 – Preferred Alternative: Cluster 10

Remedial Measure	Location	Size (mm)	Length (m)
Sewer Twinning	Bolivar Street	250	64

11.3.11. Cluster 11

The preferred alternative consists of:

- I-I reduction at the cluster and upstream will reduce the risk of basement flooding (provided other works upstream are completed).

As there no recommendations for major infrastructure works in this cluster, it is recommended that the City undertake an I-I reduction program to mitigate the effects of extraneous flows entering the sanitary sewer system.

11.3.12. Cluster 12

The preferred alternative consists of:

- I-I reduction at the cluster and upstream; and,
- One twinned pipe on Ashburnham Drive north of Lansdowne Street East.

Table 11-12 – Preferred Alternative: Cluster 12

Remedial Measure	Location	Size (mm)	Length (m)
Sewer Twinning	Ashburnham Drive	250	160

The cluster is located west of the Trans Canada Trail. It is recommended that prior to detail design that potential impacts to the Trans Canada Trail be identified and mitigated.

11.3.13. Cluster 13

The preferred alternative consists of:

- I-I reduction at the cluster and upstream; and,
- Two twinned pipes on Riverside Drive between Spruce Avenue and Steele Avenue.

Table 11-13 – Preferred Alternative: Cluster 13

Remedial Measure	Location	Size (mm)	Length (m)
Sewer Twinning	Riverside Drive	300	94
		450	81

11.3.14. Cluster 14

The preferred alternative consists of:

- I-I reduction at the cluster and upstream; and,
- One twinned pipe on Parkhill Road West just west of Wallis Drive.

Table 11-14 – Preferred Alternative: Cluster 14

Remedial Measure	Location	Size (mm)	Length (m)
Sewer Twinning	Parkhill Road West	200	92

Through discussions with the City at the time of this study, it is noted that the Parkhill West Pump Station is being upgraded to accommodate future growth. As such, it is recommended that prior to detail design of the preferred solution, the model be new to include the updated pump station specifications.

The cluster is located west of the Trans Canada Trail. It is recommended that prior to detail design any potential impacts to the Trans Canada Trail be identified and mitigated.

11.3.15. Cluster 15

The preferred alternative consists of:

- I-I reduction in the cluster and upstream will reduce the risk of basement flooding (provided other proposed works upstream are completed).

As there no recommendations for major infrastructure works in this cluster, it is recommended that the City undertake an I-I reduction program to mitigate the effects of extraneous flows entering the sanitary sewer system.

11.3.16. Cluster 16

The preferred alternative consists of:

- I-I reduction in the cluster and upstream; and,
- One twinned pipe near intersection of Marina Boulevard and Water Street.

Table 11-15 – Preferred Alternative: Cluster 16

Remedial Measure	Location	Size (mm)	Length (m)
Sewer Twinning	Near intersection of Marina Drive and Water Street	250	119

As is the case in cluster 5, through discussions with the City at the time of this study, it has been noted that a truck sewer along Water Street has been recently reconstructed. This cluster is located to the west of Water Street. The data used at the time of this analysis did not include the updated information for the Water Street trunk sewer. As such, it is recommended that prior to detail design, the model be updated to include the new sewer data and geometry for the Water Street trunk sewer.

The proposed storage units are located near the Northcrest Community Centre. Any potential impacts to the community centre should be assessed prior to the detailed design phase.

The proposed twinned pipe is not located in the road right-of-way. It is recommended that land ownership and access to the sanitary sewers be confirmed prior to detail design.

11.4. Other Ongoing Initiatives and Recommendations

In addition to the cluster specific recommendations, there are ongoing initiatives that the City should undertake to address extraneous flows from entering the sanitary sewer system.

11.4.1. Groundwater Infiltration

Due to the vicinity of Clusters 1, 3, 4, 5, 6 11, 12, 13, and 16 to the Otonabee River, specific measures to minimize GWI, such as sewer relining and grouting, should be investigated. Field investigation should be conducted to determine possible sources of direct inflow into the sanitary sewer system. Furthermore, the City would benefit from further baseflow analysis of the monitored data to prioritize future GWI mitigation measures, such as sewer lining and grouting.

11.4.2. Pump Stations

Pump station flow rates have an impact on downstream sewers. As part of this study, a pump station assessment was conducted at the ten pump stations located in the City to determine maximum pumping capacity. It is recommended that all future upgrades to pump stations be accounted for in the model.

It is also recommended that the City identify the pump stations where bypasses may occur and that these bypasses should be quantified. Furthermore, it is recommend to undertake tests of the standby generator at all pump stations to determine the pump station’s firm and maximum pumping rates.

11.4.3. Flow and Rainfall Monitoring

Ongoing flow monitoring in the sanitary sewer and rainfall monitoring is recommended at each cluster location and at other key areas in the system. Monitoring should be carried out to subdivide areas with high I-I to identify the sources and locations where extraneous flows occur into the sanitary sewer system. The City should consider monitoring downstream of locations where sewer remediation will be completed, as well as after completion.

11.4.4. Future Development

As development occurs throughout the City, information such as sanitary infrastructure and census data should be updated. This includes external areas being added into the City's sanitary sewer system. The City should also consider partnering with the development industry to finance ongoing I-I reduction efforts that will facilitate accommodating new development flows in the existing system.

11.4.5. Ongoing Field Work

The recommended solutions are highly dependent on the accuracy of the sanitary sewer network information. It is important that the sewer attributes, pump station information, and all other sanitary infrastructure are kept up-to-date to increase the reliability of the model. Confirmation of the sewer network information is recommended as part of the ongoing maintenance and other field investigations. This information includes sewers, manholes, siphons, and overflows.

11.4.6. New Sewer Infrastructure Information / Model Update

It is recommended to keep the model maintained and updated as infrastructure is added or changed and development progresses throughout the City.

11.4.7. Implementation of Recommendations from Other Studies

The clusters identified in this study are distributed throughout the City. Alternatives and recommendations presented in the other studies may impact, directly or indirectly, some of the clusters. For example, a reduction in surface flooding may significantly reduce the amount of I-I entering the sanitary sewer system. It is recommended to review previous studies to assess potential impacts and consider concurrent implementation of remediation works.

11.4.8. Staffing and Resources

Addressing data gaps within the sanitary sewer network, conducting flow monitoring to isolate areas of high GWI and I-I, updating the sanitary model to reflect existing and future conditions, etc. are all critical tasks of a comprehensive I-I reduction program. As such, staffing resources and funding will be required. It is recommended that the City considers funding to address the general recommendations and ongoing initiatives. A general work plan outlining the requirements for I-I reduction and mitigation are described in **Section 12.0**.

12.0 I-I Reduction Work Plan

Identification and remediation of I-I requires a coordinated effort. The following section outlines typical components of I-I reduction programs to identify and remove sources of I-I in the sanitary sewer system.

12.1. General Approach

An integrated approach involving systematic coordination of field investigations, modelling, and field implementation is recommended in order to identify and mitigate I-I. This is known as the I-I management system and consists of the following:

- Identify specific sources of I-I;
- Quantify their contributions in terms of rates and volumes;
- Prioritize and undertake remediation / construction activities; and,
- Verify the I-I reduction.

12.1.1. Work Plan Development and Customization

The first step is to develop an area-specific work plan using background data, previous studies, and knowledge of the system.

12.1.2. Area Selection

The area selection identifies the areas proposed for investigation based on I-I generation potential. The potential would be assessed using information from previous studies, operations staff recommendations, and sanitary sewer delineation. Generally, areas with known high I-I are given the highest priority. Areas selected for monitoring and testing are referred to as Sanitary Sewer Evaluation Survey (SSES) areas. The criteria to screen for SSES areas include subdivision and sewer age, size of area, locations with potential high groundwater table relative to sewers, and recommendations from local municipal staff. Areas with high I-I within the City have been previously identified through flow and rainfall monitoring.

12.1.3. Initial Monitoring, Bracket Monitoring

Area selection is followed by an enhanced monitoring program, involving installation of flow meters (with primary devices) and a high density of rain gauges from which distributed rainfall analysis can be performed. This methodology includes an enhanced monitoring approach to increase the reliability of the measurements and develop a relationship between rainfall over the tributary area and the I-I rate generated from the same area. Additional bracket monitoring is often necessary within the original areas to isolate sub-areas and high I-I sources prior to SSES testing.

12.1.4. SSES Area Testing

Detailed field testing within each SSES area should identify direct inflow sources such as surface inflows, roof downspouts that are directly connected, and other cross connected drains. The testing includes fog and dye investigation and enhanced CCTV inspection (wet inspections and dye 'plug' CCTV when necessary). Testing is performed after monitoring sufficient wet weather events and confirming that the area generates significant I-I. This minimizes costs and potential impacts to traffic and residents. Fog testing, dye testing, or onsite property evaluations are coordinated with the local municipality and property owners through a comprehensive communication plan.

12.1.5. I-I Source Identification and Documentation

The field results from the flow monitoring and SSES area testing are used to update a GIS I-I source list and location map. The I-I sources are organized by categories (e.g. surface inlet sources, direct roof leader connections, direct commercial drain connections, gushers from manholes, etc.) for further I-I evaluation and prioritization.

12.1.6. I-I Source Evaluation

Source evaluation involves quantification of I-I generated. Each source is evaluated based on the quantity of I-I generated, property ownership and accessibility, constraints, and downstream impacts (e.g. local impacts or roof leader disconnected from sanitary sewers). Field data collection and analysis is normally conducted to verify the contributing tributary area of I-I. As part of the I-I source evaluation, the pre and post remediation volumes and rates of I-I should be calculated.

12.1.7. Detailed Modelling of SSES Areas

The detailed hydrodynamic model developed should be used for each SSES area for further calibration and prediction of the normalized 1 in 25 year I-I rate. Model calibration prior to estimating the 1 in 25 year peak I-I rate must be performed using accurate rainfall and flow monitoring collected during the largest events captured. Note that the normalized I-I rate using a 1 in 25 year design storm assumes average Antecedent Moisture Condition (AMC) with respect to soil parameters in the model. Thus, the calibration must account for the AMC prior to the monitored events by adjusting the appropriate moisture storage parameters. These parameters must then be set to the equivalent average AMC conditions of the catchment when analyzing the 1 in 25 year I-I.

12.1.8. I-I Remedial Option Evaluation

With the existing 1 in 25 year I-I rate calculated for each source, potential remediation alternatives are developed and evaluated. The overall effectiveness of the remedial options will be quantified based onsite conditions. For example, roof downspout disconnection from the sanitary sewer will be quantified by establishing the roof area draining to the roof leader, accounting for potential inlet control effects that occur due to limited hydraulic capacity in the connecting system.

All potential solutions will be identified and assessed for effectiveness of removing I-I, cost to complete the work, construction difficulties and impacts to local traffic, residents, as well as timing for remediation and verification.

12.1.9. Cost / Time Evaluation

Once specific solutions have been determined for the various areas identified as contributing to I-I, these solutions need to be evaluated to determine their effectiveness of reducing I-I, cost, and time required for implementation.

12.1.10. Design and Implementation Phase

Detailed plans should be drafted for the preferred remediation measures and submitted for review and approval by agencies, as necessary (e.g. MOE or Conservation Authority if working in regulated areas).

12.1.11. Construction

Construction should proceed in sequence after securing permits and approvals, confirming notices, and obtaining sign-backs for work commencement from local property owners.

12.1.12. Post Construction Monitoring and Modelling for I-I Reduction Verification

Successful removal of I-I from the system should be verified through monitoring. As per the baseline I-I rates established from the initial monitoring program, verification monitoring data can be used to re-calibrate the detailed hydrodynamic model prior to estimating the 1 in 25 year post-remediation I-I rate.

Subsequent I-I removal effectiveness assumptions may be modified subject to I-I reduction verification results. These should be based on local I-I rates (verified through modelling). Net improvements within the sanitary sewer flows should be verified by the City.

13.0 Staging and Implementation

The recommended staging and implementation of the preferred alternative for each cluster is summarised below. The staging does not consider funding factors. The rationale for staging and implementation should account for the following general considerations:

- Areas which have been identified to have sewer surcharging within 1.8 m of the ground surface for events less intense than the 1 in 25 year design (i.e. Design Criteria, 1 in 2 year, 1 in 5 year, and 1 in 10 year design events) have been assigned a priority group based on the frequency of potential flood risks;
- Clusters where I-I reduction alone can reduce risk of flooding and free up capacity in the sanitary sewer network. I-I reduction does not require the detail design of conveyance or storage components; therefore, it can be implemented at the earliest possible timeline;
- Clusters in the vicinity of construction projects currently being undertaken in the City should have the preferred alternative implemented. Combining construction projects would reduce mobilization resources and costs. The City should confirm short, medium, and long-term construction initiatives across the City and determine which clusters are practical for implementing the preferred alternative; and,
- As all the preferred solutions effectively reduce the amount of flow leaving a cluster (as per **Table 8-5**), clusters should be phased from upstream to downstream so that the flow reduction can be taken into account at the detailed design phase of clusters located downstream.Based on the general considerations noted, **Table 13-1** below summarises the implementation and staging of the preferred alternative

Table 13-1 – Implementation and Staging of the Preferred Alternative

Priority Group	Cluster	Solution	Recommended Order of Implementation	Rationale
1	CL-15-	I-I reduction	1	▪ Flood Risk under Design Criteria Conditions (450 L/cap/d, I-I = 0.25 L/s/ha); and, ▪ Can be mitigated through I-I alone.
	CL-3	I-I reduction and conveyance (twinning)	2	▪ Flood Risk under Design Criteria Conditions (450 L/cap/d, I-I = 0.25 L/s/ha); and, ▪ Located furthest upstream east of river.
	CL-7	I-I reduction and conveyance (twinning)	3	▪ Flood Risk under Design Criteria Conditions (450 L/cap/d, I-I = 0.25 L/s/ha); and, ▪ Located furthest upstream west of river.
	CL-13	I-I reduction and conveyance (twinning)	4	▪ Flood Risk under Design Criteria Conditions (450 L/cap/d, I-I = 0.25 L/s/ha); and, ▪ Located furthest downstream west of river.
	CL-2	I-I reduction and conveyance (twinning)	5	▪ Flood Risk under Design Criteria Conditions (450 L/cap/d, I-I = 0.25 L/s/ha); and, ▪ Isolated cluster and does not impact other clusters downstream.

Priority Group	Cluster	Solution	Recommended Order of Implementation	Rationale
2	CL-1	I-I reduction and storage (in-line)	1	▪ Flood Risk under the 1 in 2 year design storm event; and, ▪ Can be implemented in combination with Walker Avenue Trunk Sewer Design.
	CL-4	I-I reduction and conveyance (twinning)	2	▪ Flood Risk under the 1 in 2 year design storm event; and, ▪ Would benefit from recommended works at CL-15.
	CL-6	I-I reduction and conveyance (twinning)	3	▪ Flood Risk under the 1 in 2 year design storm event; and, ▪ Located furthest upstream west of river.
	CL-8	I-I reduction and conveyance (twinning)	4	▪ Flood Risk under the 1 in 2 year design storm event; and, ▪ Located downstream of CL-6.
3	CL-16	I-I reduction and conveyance (twinning)	1	▪ Flood Risk under the 1 in 5 year design storm event; and, ▪ Located furthest upstream west of river.
	CL-5	I-I reduction and storage (in-line)	2	▪ Flood Risk under the 1 in 5 year design storm event; ▪ Update to GIS / model information to include new Water Street trunk sewer; and, ▪ Located downstream of CL-16.
4	CL-11	I-I reduction	1	▪ Flood Risk under the 1 in 10 year design storm event ▪ Can be mitigated through I-I alone
	CL-14	I-I reduction and conveyance (twinning)	2	▪ Flood Risk under the 1 in 10 year design storm event; and, ▪ Can be implemented during proposed upgrade to Parkhill West PS.
	CL-10	I-I reduction and conveyance (twinning)	3	▪ Flood Risk under the 1 in 10 year design storm event; and, ▪ Only one section of surcharged pipe.
5	CL-9	I-I reduction and conveyance (twinning)	1	▪ Flood Risk under the 1 in 25 year design storm event; and, ▪ Located downstream of other higher priority clusters.
	CL-12	I-I reduction and conveyance (twinning)	2	▪ Flood Risk under the 1 in 25 year design storm event; and, ▪ No clusters located upstream.

It should be noted that the sequence of staging is subject to change based on implementation of other capital works throughout the City.

14.0 Cost Estimate for Preferred Alternative

The cost estimate for the preferred conveyance system solution is presented below in **Table 14-1**. These are estimates for implementing the recommended alternative. The unit cost estimates are presented in **Appendix G**. The total estimated cost, excluding applicable taxes, for the preferred conveyance system solution for the City is **$9,627,588**.

Table 14-1 – Cost Estimates for Preferred Alternative

Cluster	Sub-Total Cost	Total Cost (incl. 30% eng. and contingency)
CL-1	$605,205	$786,767
CL-2	$1,712,177	$2,225,830
CL-3	$380,999	$495,299
CL-4	$116,012	$150,816
CL-5	$728,136	$946,577
CL-6	$670,783	$872,018
CL-7	$484,751	$630,176
CL-8	$250,013	$325,017
CL-9	$386,524	$502,481
CL-10	$518,190	$673,647
CL-11	$417,060	$542,178
CL-12	$330,195	$429,254
CL-13	$269,544	$350,407
CL-14	$146,671	$190,672
CL-15	$104,420	$135,746
CL-16	$285,159	$370,707
Total	**$7,405,837**	**$9,627,588**

15.0 Wastewater Treatment Plant Alternatives

15.1. Background and Existing Conditions

The Peterborough WWTP has a capacity to receive up to 190,000 m^3/d (peak flow) providing preliminary and primary treatment and 120,000 m^3/d of secondary treatment. The UV disinfection system has capacity for up to 190,000 m^3/d. A process flow diagram of the existing plant is included in **Appendix J**.

There is an existing 8,000 m^3 peak attenuation facility in the plant, which is used for WWF storage. During periods of high wet weather flows in excess of 120,000 m^3, when secondary treatment capacity is exceeded, the excess flow receives primary treatment but bypasses secondary treatment and is diverted to the storage facility. This flow is stored until the wet weather event has passed and there is sufficient capacity in the secondary treatment system in the plant.

During larger storm events that exceed the storage capacity of the peak attenuation facility (8,000 m^3), flows will go through UV disinfection prior to discharging to the Otonabee River. Since peak flow attenuation tracking started in 2006, there have been five occurrences of secondary bypasses, particularly during the spring months of April and May, as well as one in the month of December. There has also been one raw sewage bypass to the Otonabee River since 2006. A summary of the bypasses at the WWTP can be found in **Appendix J.**

Reduction in the frequency of bypasses to the Ottonabee River, by providing additional storage for peak flow attenuation, has been identified as a short term objective by senior operations staff in the City.

15.2. Level of Service

The calibrated hydrologic / hydraulic model was used to predict peak flow rates to the Peterborough WWTP for various design storms and historical events assuming the same 4 hour Chicago storm distribution. **Table 15-1** below shows the design and historical summer event flow rates predicted by the model.

Table 15-1 – Wastewater Treatment Plant Flows

Design Storm / Historical Event	WWTP peak flow (m^3/d)	Secondary Treatment Capacity (m^3/d)	Potential Secondary Bypass Volume (m^3)
Dry Weather Flow	90,634	120,000	0
2 Year Storm	131,242		340
5 Year Storm	160,445		2,150
10 Year Storm	180,230		3,852
25 Year Storm	202,867		6,166
50 Year Storm	221,098		8,380
100 Year Storm	238,378		11,200
Regional (Timmins) Storm	345,082		106,120
July 14, 2004 Storm	384,653		>150,000

As can be seen in **Table 15-1**, the existing 8,000 m^3 attenuation facility can store the excess volume from a four hour storm even with a 50 year return period. A similar 24 hour storm increases the frequency to less than 25 years. Although the above table suggests that the existing level of service prior to the secondary bypass is approximately 1 in 50 years design storm event, previously discussed there have been five instances of secondary bypasses since 2006.

15.3. Ministry of Environment Policy

Peak DWF plus 90% of the design peak WWF is to be collected and conveyed to the Peterborough WWTP. All overflows and bypasses at the Peterborough WWTP require a minimum of primary treatment equivalent, along with disinfection in order to meet the MOE's CSO effluent E. coli limit. These requirements are based on the MOE's Policy F-5-5 (Procedure F-5-5, Determination of Treatment for Municipal and Private Combined and Partially Separated Sewer Systems).

The MOE's interim effluent quality E. coli limit for disinfection of bypasses during wet weather is a monthly geometric mean of 1,000 organisms per 100 mL (MPN or cfu). The MOE could also issue more stringent limits on a case-by-case basis, where warranted by site-specific conditions.

15.4. Purpose

The objective of this assessment is to reduce the frequency of bypasses at the Peterborough WWTP. Works in the conveyance system alone will help reduce the amount of water entering the sanitary sewer system and reduce the peak flows at the plant but will not eliminate the risk of bypasses. Additional wet weather storage will reduce the frequency of bypasses and increase the volume of wet weather flows receiving secondary treatment prior to discharge.

15.5. Review of Alternatives

Alternative solutions to address the attenuation and treatment of flows can be categorized as either 'Do Nothing' or Peak Flow Attenuation alternatives. Theinclude:

1. **Alternative 1**: Do Nothing;
2. **Alternative 2:** New Peak Flow Attenuation Facility;
3. **Alternative 3:** Convert Sludge Storage Lagoons to Peak Flow Attenuation Facility;
4. **Alternative 4:** New Underground Storage Peak Flow Attenuation Facility; and,
5. **Alternative 5:** Multiple Peak Flow Attenuation Facilities.

Limited space available at the plant site constrains the additional storage that can be provided to approximately 25,000 m^3. This should provide a significant increase in the level of service to the 100 year return period.

The peak flow attenuation alternatives are all based on storage of the peak day bypass flows up to 25,000 m^3.

15.5.1. Screening Facility

Operations staff, have identified the pressing need to upgrade or replace the existing raw sewage screening facility. The existing screening facility is reported to have a rated peak flow capacity of 190,900 m^3/d. However, the facility has on-going operational issues that limit its capacity. The mechanical screens are past their life expectancy and must be replaced. Should the existing system be upgraded or replaced, the costs for upgrading is estimated to be $4.3 million. A layout of a new screening facility is shown in **Appendix J**.

15.5.2. Peak Flow Attenuation Tanks

Peak flow attenuation facilities in the form of lagoons or tanks, upstream of secondary treatment systems, store sewage until the wet weather event has passed and there is sufficient capacity for secondary treatment. Attenuation facilities typically store the wastewater for a 24 hour to 96 hour period. After the storm event, wastewater is slowly conveyed back to the WWTP for full secondary treatment.

Gravity sedimentation (settling) of solids occurs in the attenuation facilities during storage. Most of the solids are removed prior to the wastewater being conveyed back to the WWTP. Typically 10 - 15 cm of solids and debris remain at the bottom of the lagoon or tank. Solids must be washed to a sump after the tank has been drained. Typical cleaning systems include:

- Tipping buckets;
- Flushing gates; and,
- Automatic spray nozzle systems.

Treated plant effluent water, rather than potable water, is normally used for clean-out of the lagoons or tanks. Aeration of the wastewater is not typically provided in attenuation facilities, except for long sewage retention times and as an alternative to cleaning systems to keep the solids in suspension.

Overflow pipes must be provided in the attenuation facilities, in the event that a storm exceeds the capacity of the lagoon or tank. The wastewater retention time in the attenuation facilities, under overflow conditions, typically provides solids removal equivalent to primary treatment. For the Peterborough WWTP, overflows would bypass directly to the UV system for disinfection prior to discharge to the Otonabee River.

15.6. Evaluation of Alternatives

The five alternatives are evaluated below:

Alternative 1 – Do Nothing

This alternative would not meet the MOE's policy for the minimum level of treatment for WWTP bypass flows and is therefore not further considered.

Alternative 2 – New Peak Flow Attenuation Facility

The existing I-I retention tanks would be decommissioned and a new peak flow attenuation facility would be constructed on the same site. This alternative would require an area of about 80 m x 60 m for the new storage tanks, plus piping, valves, cleaning systems, and possibly a separate pump station for conveying flows to either the raw sewage pump station, the primary influent, or bypass to UV disinfection.

A new peak flow attenuation facility with a 15,000 m^3 storage volume could be constructed in the same as the existing I-I retention tanks. However, the available area is not sufficient for 25,000 m^3 of storage volume. Hence, a new site would be required to centralize the peak flow attenuation in one facility.

Alternative 3 – Convert Sludge Storage Lagoons to Peak Flow Attenuation Facility

The two geomembrane-lined sludge storage lagoons, located on the southwest side of the site, were previously used for liquid digested sludge storage. The volume of these two lagoons is approximately 13,500 m^3 (6,750 m^3 each). The lagoons are used on an emergency basis for sludge storage, if the new mechanical sludge dewatering facility is out of operation. Only one lagoon is needed for emergency sludge storage. The second lagoon could be retrofitted to act as a retention lagoon for peak bypass flows. The effective volume for peak flow attenuation ranges from 5,000 m^3 to 6,750 m^3, depending on upgrades to the lagoons to provide for cleanout after storm events.

The upgrades recommended include:

- Excavation of lagoon to increase depth to 6 m and reduce side slope to 2:1;
- Replacement of 60 mil HDPE membrane liner with new liner; and,
- Installation of network of spray nozzles around periphery of lagoon for cleanout of lagoons after storm events.

A liner for the lagoon is required to prevent exfiltration (i.e. leakage) out of the lagoon. Schematics of lagoon upgrades with geomembrane or concrete liners, along with a comparison of the types of lagoon liners, are included in **Appendix J**. Several types of liners are available, including clay, geosynthetic clay liners (GCL) (i.e. bentonite), and concrete or geomembrane (i.e. HDPE, PVC, hypalon, polypropylene, or polyester) liners. For the geomembrane liner, similar to the liner in the existing sludge lagoons, a water cap of 0.9 m would be maintained in the lagoon after storm events to:

- Provide water “ballast” to prevent groundwater uplift pressure on the liner; and,
- Provide naturally re-aerated water layer for facultative oxidation of odours.

The lagoon capacity would also be derated by 15% with a geomembrane liner.

Typically, geomembrane liners are limited to lagoons with side slopes less than 3:1 [horizontal:vertical (H:V)]. Geomembrane liners on the steeper 2:1 (H:V) slopes would require special geotechnical modifications to the base under the liner.

The type of liner used to retrofit the sludge lagoon to a wet weather wastewater storage lagoon would also depend on a subsoil geotechnical investigation, groundwater levels, and the inside berm slope of the lagoon.

Alternative 4 – Build a New Underground Storage Facility

A new underground storage facility, either as an underground off-line reservoir or as an in-line storage tunnels could be constructed in the southeast area of the plant site. One of the main advantages is that the new underground storage facility will provide wet weather storage volume in addition to the existing 8,000 m^3 peak flow attenuation facility. Another advantage is the reduced pumping costs. Disadvantages include high capital costs.

Alternative 5 – Multiple Peak Flow Attenuation Facilities

Multiple peak flow attenuation facilities would use the existing facilities to provide a total of 25,000 m^3 storage capacity. This would require:

- Retrofit of existing I-I retention tanks to a total 15,000 m^3 volume; and,
- Convert one of the existing sludge lagoons to 10,000 m^3 peak flow attenuation facility.

15.7. Comparison of Alternatives

A comparison of the alternatives is provided in **Table 15-2.** Alternative 5 is recommended. The complete works include:

- Convert the existing I-I facility to provide 15,000 m^3 of storage;
- Convert one of two existing sludge lagoons to a deeper-lined peak flow attenuation lagoon; and,
- Replace existing mechanical screening facility.

The proposed layout at the plant is shown in **Appendix J**. The estimated capital cost is $20.5 M, with an approximate yearly operation and maintenance costs of $50,000. A detailed cost breakdown is found in **Appendix J**.

Table 15-2 – Comparison of Alternatives

Factor	Alternative				
	#1 – Do Nothing	#2 – New Attenuation Facility	#3 – Convert Lagoons	#4 – New Underground Facility	#5 – Multiple Facilites (Retrofit Ex. Tanks / Lagoon)
New Facilities					
Screening Facility Replacement		✓	✓	✓	✓
Tanks (m^3)		25,000			15,000
Lagoons (m^3)			< 25,000 m^3		10,000
Reservoir / Tunnel (m^3)				25,000	
Total Storage Volume (m^3)		25,000	5,000 – 6,750	25,000	25,000
Environmental Impacts					
Area (m^2)	N/A	New - 5,000	N/A	New – 5,000	Ex. I-I – 3,000; Ex. lagoons 6,750
Odour Potential			Minor (from lagoons)	Lowest potential	Minor (from lagoons)
Visual	Reduced		Minor (from lagoons)		Minor (from lagoons)
Environmental Impacts					
Groundwater Impacts	✓		Lagoons lined to prevent impact		Lagoons lined to prevent impact
Surface Water Impacts	✓				
Capital Costs					
Capital ($)	$0M	$25M	N/A	$40 M Highest	$20.5M
Capital Costs					
Capital ($)	$0M	$25M	NA	$40 M Highest	$20.5M
Use of Existing Facilities			Use of lagoons		Use of I-I tanks and lagoons
Operation & Maintenance (O&M)					
O&M ($/yr)	$0M	$25,000	NA	$25,000	$50,000
Clean-out Ease			Lagoon cleanout more difficult than tanks		Multiple facilities to maintain; lagoon cleanout more difficult than tanks
Operating Labour			Higher labour for lagoon cleanout		Higher labour for lagoon cleanout

NA – Not Applicable

16.0 Conclusions for Conveyance System and Wastewater Treatment Plant

The following conclusions can be drawn from this study:

- A sanitary sewer model was developed using the City's existing GIS network database. Assumptions were necessary during development of the model.
- Flow monitoring was carried out for model calibration and validation, which showed good agreement with recorded flow data in terms of peak flows and volumes of flow;
- Flow monitoring showed that the average dry weather and wet weather flows generally exceeds the City's design criteria;
- High ground water table in the City contributes to significant infiltration into the sanitary sewer system causing an increase of flow at the Peterborough WWTP, particularly in the months of April through June. A previous assessment recommended: 1) a review of soil types and water table elevations; and 2) repairs to existing sanitary sewers, deepening of storm sewers where possible, disconnection and sealing of roof leaders from foundation drains, and sanitary sewer flow monitoring.
- The events captured during the monitoring period were not very intense. Therefore, further monitoring for a longer duration is recommended to further quantify I-I for storm events of varying intensity;
- Modelling of the sanitary sewer system showed that it does not have sufficient capacity to convey the flow generated from the City's design criteria or during a 1 in 25 year storm event;
- The 1 in 25 year storm event has been used as the typical level of service for the City;
- The 1 in 25 year storm model revealed 16 clusters with high flood risk;
- Five remedial measure alternatives were considered within the sewer system: (1) Do Nothing; (2) I-I Reduction; (3) Increased Conveyance Capacity; (4) Storage at Key Locations; and (5) Hybrid Solution;
- Each alternative was evaluated against a set of criteria prior to selection that included: physical, economic, environmental, social, cultural, and health factors;
- The preferred alternative is Alternative 2 (I-I Reduction) for two clusters with high flood potential and Alternative 5 (Hybrid Solution) for fourteen clusters. The hybrid solution consists of I-I reduction in combination with either conveyance or storage alternatives. The preferred alternative reduces the high flood potential and the flow delivered to the plant;
- The preferred alternative reduces peak flows at the Peterborough WWTP to less than the existing pumping capacity. This reduces the risk of raw sewage bypass to the Otonabee River;
- There is the potential to provide an enhanced solution for the 100 year design storm event, subject to coordination with other planned capital works;

- It is recommended that the City undertakes more detailed analysis and detailed design prior to implementation of the preferred alternative.
- Ongoing initiatives, such as I-I reduction through on-going flow and rainfall monitoring, model updates including future development scenarios, as well as the implementation of recommendations from other studies, should continue to be implemented as the City continues to grow and develop;
- The main cause of bypasses at the plant is the excess I-I entering the sanitary sewer system and the limited pumping capacity of the WWTP. Storage alternatives have been evaluated at the WWTP in an effort to reduce bypasses. The preferred alternative consists of retrofitting the existing I-I tank and converting one of the sludge lagoons in order to provide a total of 25,000 m^3 of storage;
- The combination preferred alternative in the conveyance system (hybrid solution) and at the storage alternative at the Peterborough WWTP reduces the amount of extraneous flows in the sanitary sewer system, reduces the risk of potential basement flooding, frees up capacity in the existing sewer network, and reduces the frequency of raw and secondary sewage bypasses to the Otonabee river;
- The preferred alternatives in the conveyance system will proceed as Schedule B projects and the preferred alternative at the Peterborough WWTP will proceed as a Schedule C project, under the EA process; and,
- The Schedule B Class EA process has been fulfilled through the two PICs, agency consultation, and the submission of this project file document.