AECOM

City of Peterborough

Jackson Creek Flood Reduction Master Plan

Prepared by:

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Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	S. Hollingworth	2009-12-10	Draft Interim Report Issued for City Review
2	S. Hollingworth	2010-02-24	Draft Final Report Issued for City Review
3	S. Hollingworth	2010-04-23	Final Report for Public Review

Executive Summary

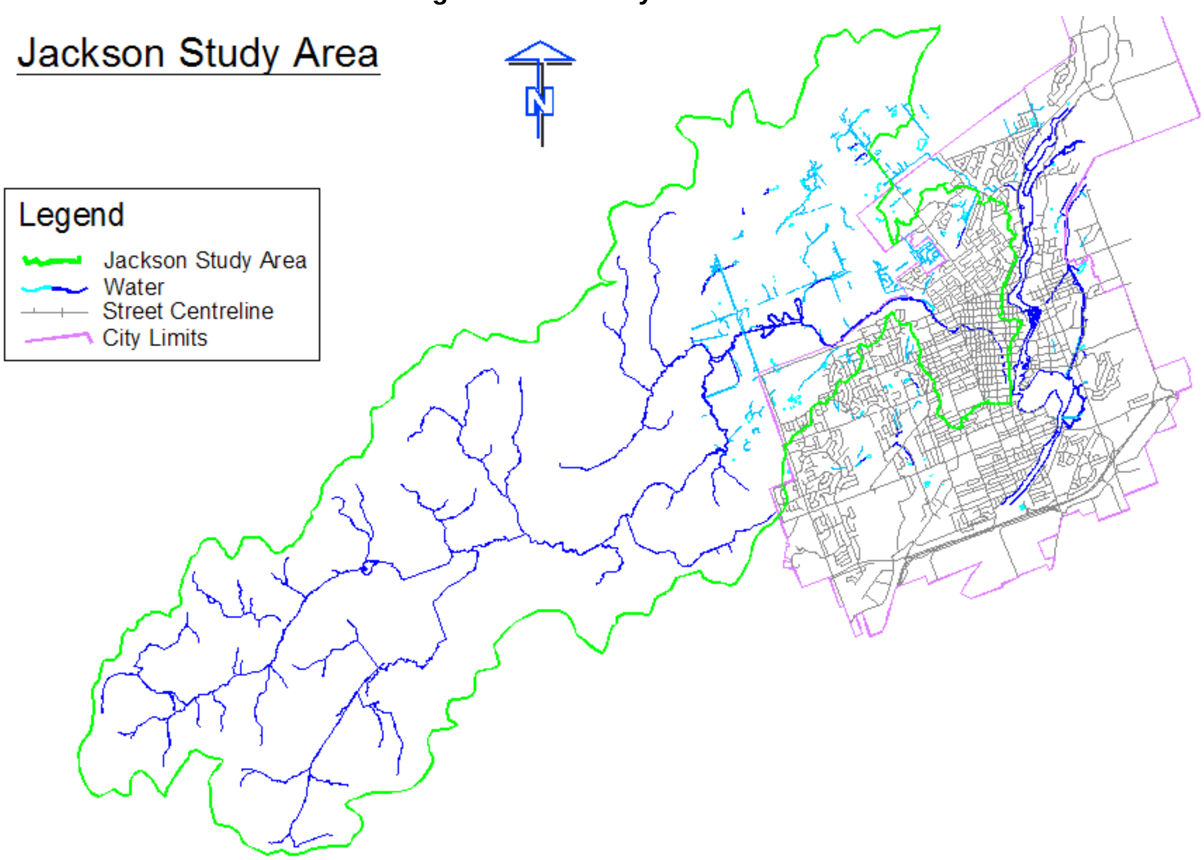
Introduction

In July 2004, the City of Peterborough (the City) was hit by a severe rainfall event that caused significant flood damage. Insured private property damages reportedly exceeded $87 million while Ontario Disaster Relief Assistance Program (ODRAP) infrastructure damages of approximately $25 million were incurred. In addition, insured losses and indirect damages such as disruption in residential living conditions, loss of business, and loss of wages or income, were sustained.

Shortly after the flood, the City retained AECOM (formerly UMA Engineering Ltd.) to investigate the causes and determine remedial measures to improve the operation of the drainage system and reduce the risk of damage from future flooding. AECOM undertook a City-wide Flood Reduction Master Plan Study (the Master Plan) under the Environmental Assessment Act to plan infrastructure improvements as part of the City's overall systems, before dealing with project-specific issues.

Recommendations from the Master Plan included the preparation of detailed flood reduction studies for each of the watersheds flowing through the City. This report constitutes the project file report for the Jackson Creek Flood Reduction Master Plan. The study has been conducted in accordance with the requirements of the Municipal Class Environmental Assessment. The study area is illustrated in Figure ES.1.

Figure ES.1: Study Area



Existing Conditions

Detailed hydrologic and hydraulic models were prepared for Jackson Creek to establish the capacity of the existing creek system, and to determine the extent of flooding and flood damages during extreme storm events. A SWMHYMO hydrology model of the Jackson Creek watershed was developed and calibrated to predict the peak flows in Jackson Creek for a range of storm events. The HEC-GeoRAS program was then used to calculate the corresponding flood levels and extent of flooding in Jackson Creek.

Flood damages were assumed to be 20% of the value of any building within the flood plain for a given storm event. The assessed values of the impacted properties through the Jackson Creek study area were based on the latest property assessments completed by the Municipal Property Assessment Corporation (MPAC), which were provided by the City of Peterborough.

For the Regional (Timmins) storm event, a total of 250 buildings are predicted to be impacted for damages totalling $18.7 Million. Predicted flood damages for the 5 year and 100 year return period events are $4.6 Million (33 buildings) and $ 8.6 Million (118 buildings), respectively. Some of these buildings are also impacted by urban flooding and would continue to be impacted even if the flooding from Jackson Creek were remediated.

More complex hydrologic and hydraulic modelling was undertaken to assess the capacity of the existing storm drainage systems carry runoff from the developed areas of the watershed to Jackson Creek. Urban flood flows were generated with the USEPA SWMM model utilizing the PCSWMM graphic user interface. The SWMM model was then used to separate the runoff hydrographs into minor (piped) flow and major (overland) flow, considering both pipe and catchbasin capacity. Finally, the HEC-GeoRAS hydraulic model was used to determine the depth and extent of flooding and flood damages along the overland flow routes.

A total of 483 buildings are predicted to be impacted by urban flooding during a 5 year return period storm, not including the buildings impacted by the creek flooding. Using 20% of the assessed value of these buildings, damages from the 5 year flood event are estimated to be approximately $26.5 Million. For the 100 year return period storm, a total of 663 buildings are predicted to experience flooding, resulting in estimated damages of $35.8 Million.

Alternative Solutions

A range of alternative solutions to reduce flooding and flood damages through the study area were developed and evaluated.

Alternatives to reduce flooding from Jackson Creek included:

- Retrofitting of the Jackson Weir to reduce flow rates in Jackson Creek
- Constructing a new flood control reservoir in Jackson Park
- Constructing a diversion channel around the City
- Constructing a diversion sewer to carry some of the flow in Jackson Creek directly to the Otonabee River
- Enlarging the existing culverts and bridges over Jackson Creek
- Creating a wide, naturalized creek corridor through the urban area.

During the analyses, it was determined that several of the above alternatives were not feasible.

The diversion sewer to the Otonabee River was determined to be the preferred alternative to mitigate damages from flooding in Jackson Creek. The diversion sewer alternative has been selected as it results in few environmental impacts, can be implemented relatively quickly and is a cost-effective means of reducing flood damages for the 100 year storm event. The design and construction of the sewer may be difficult, but not nearly as difficult as the other alternatives. The diversion sewer was presented as the preferred solution at Public Open House # 2. Based on feedback received at the meeting and on comment forms, the majority of the attendees agreed that the diversion sewer was the preferred solution.

Alternatives to reduce flooding and flood damages from the urban drainage systems included installation of 100 year storm sewers through the entire study area, and applying a combination of 'localized upgrades' specific to each area impacted by flooding. The localized upgrades included replacing storm sewers, adding new storm sewers, adding more catchbasins, re-grading to contain overland flow to road right-of-ways, and creating or upgrading open channel systems leading to Jackson Creek.

The combination of upgrading selected storm sewers, adding catchbasins and relief sewers, and re-grading areas to contain the major system flows was selected as the preferred alternative. It provides flood reduction benefits comparable to the replacement of all storm sewers in the study area at a significantly reduced cost and with less disruption to the community. The preferred solution of selective local upgrades was presented at the Public Open House # 2. While some attendees expressed a preference for 100 year storm sewers throughout the study area, most were in agreement with the preferred solution.

Recommended Action Plan

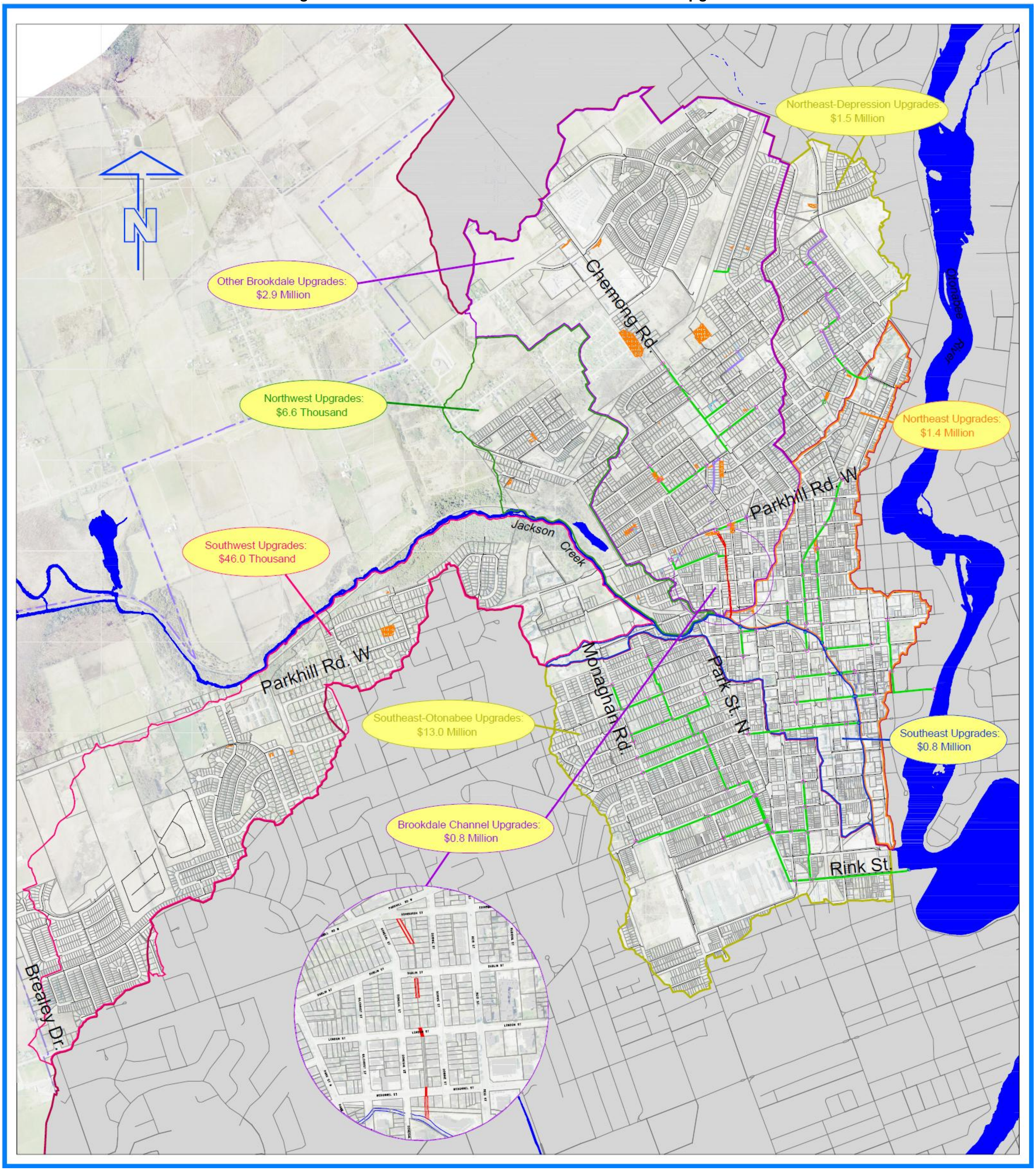
Implementation of the preferred alternative requires a large number of individual construction projects. Funding limitations, the availability of contractors, and the economies achievable by undertaking flood reduction projects in concert with other municipal initiatives, such as road reconstruction, are unlikely to allow all of these projects to be implemented simultaneously. Therefore, further analyses were undertaken to prioritize the individual construction projects. Projects were ranked based on the degree of flood damage reduction that can be achieved relative to the construction cost. Table ES.1 presents the prioritized list of flood reduction projects. The projects and their associated costs are illustrated in Figures ES.2 and ES.3.

Table ES.1: Prioritization of Recommended Works

Priority	Project Name	Project Details	Estimated Cost	Flood Damage Reduction (100 Year Storm)	Benefit-Cost Ratio
1	Brookdale Channel Upgrade	Expand and Extend the existing concrete channel through the south end of the subwatershed	$0.8 Million	$3.0 Million	3.8
2	Northeast Jackson Select Upgrades	Upgrade several storm sewers to 100-year capacity, and construct a relief storm sewer at the north end of the subwatershed	$2.8 Million	$10.4 Million	3.7
3	Jackson Creek Diversion Sewer	Construct a diversion sewer under Murray Street to prevent flood damages for up to the 100 year storm event	$6.5 Million	$8.6 Million	1.3*
4	Southeast Jackson Select Upgrades	Install 100-year storm sewers through the trunk storm sewers in the area	$13.9 Million	$20.3 Million	1.5
5	Remaining Brookdale Select Upgrades	Regrade specified areas, upgrade select storm sewers and add storm sewers	$2.9 Million	$4.2 Million	1.4
6	Northwest Jackson Select Upgrades	Re-grade sections of private property as residential developments occur	$7 Thousand	$135 Thousand	20.5
7	Southwest Jackson Select Upgrades	Re-grade sections of private property as residential developments occur	$46 Thousand	$316 Thousand	6.9

*** *The Jackson Creek Diversion Sewer could replace several of the recommended storm sewer upgrades in NE Jackson*

Figure ES.2. Preferred Urban Alternative – Selective Upgrades



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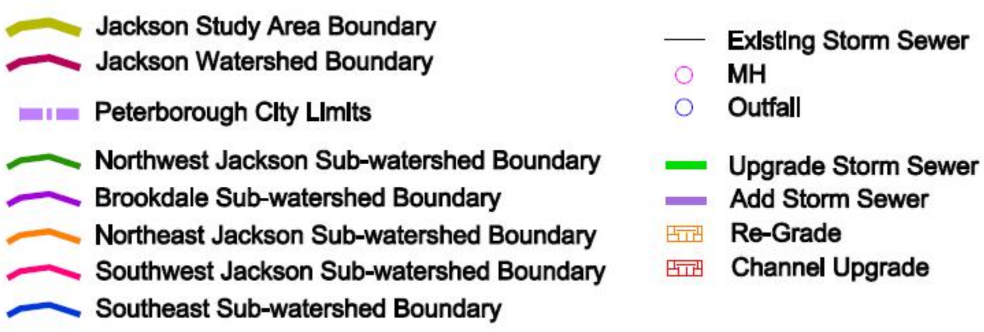
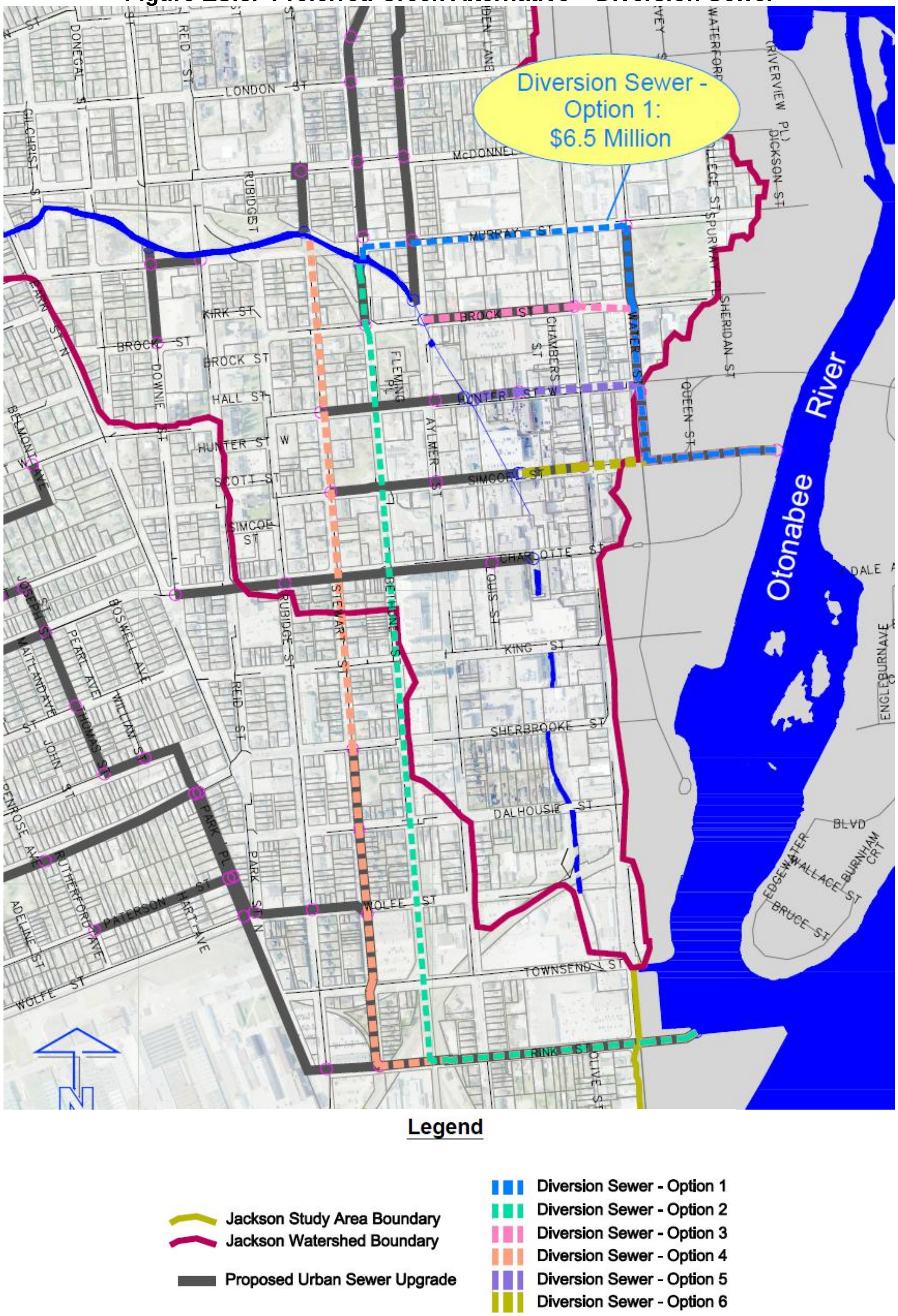


Figure ES.3. Preferred Creek Alternative – Diversion Sewer



Additional Recommendations

In addition to the Recommended Projects set out above, it is also recommended that the City consider the following items which will enhance the success of Flood Damage reduction within the Jackson Creek Study area:

Maintenance: Throughout the study the public consistently expressed a desire/need for increased Jackson Creek and Urban Catchbasin/storm sewer maintenance. Enhanced maintenance of the storm sewer system (catchbasin cleanouts, CCTV inspections, sewer flushing) is recommended to ensure that the capacity of the storm sewer system is fully available.

There were also concerns from the public regarding debris in the watercourse (fallen trees, etc) and deteriorating storm sewer outlets and other structures that could potentially reduce the capacity of the Jackson Creek channel. An inspection and maintenance program is recommended to routinely inspect the channel, remove debris and identify structures (culverts, outlet headwalls, etc) that require rehabilitation.

Streambank Erosion Protection: Through much of the downtown Peterborough area, Jackson Creek flows through culverts and channels with near vertical concrete or armourstone walls. However, upstream of Aylmer Street, there are sections of Jackson Creek where one or both banks are not adequately protected and are actively eroding toward adjacent property and structures. It is recommended that that the City and/or the Otonabee Region Conservation Authority undertake a study to identify erosion prone reaches of Jackson Creek and develop a plan to mitigate further erosion impacts.

Stormwater Management for New Development: At both of the Public Open Houses, attendees were concerned that recent and planned development in the Jackson Creek watershed could worsen flooding along Jackson Creek. Stormwater management controls are recommended for new development to prevent any increases in peak flow rates in Jackson Creek for up to the 100 year storm event. Pre and post development peak flow rates in Jackson Creek should be evaluated both at and downstream of the outlet from the development.

Sanitary Backup: Sanitary sewer back-up risk within the City of Peterborough remains a subject of interest to both the insurance industry and residents. Implementation of the recommendations of this, and the other storm system studies the City has commissioned, will reduce surface water flood damages. However, there will still be some potential for flood damages due to sanitary sewer back-up. The City has initiated a Detailed Sanitary Sewer Environmental Assessment to determine the key causes of sanitary sewer back-up, and to develop a plan to mitigate potential damages from sanitary sewer back-up. This study should be completed and recommendations implemented as soon as possible.

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1. Introduction

1.1 Introduction and Master Plan Process

In July 2004, the City of Peterborough (the City) was hit by a severe rainfall event that caused significant flood damage. Insured private property damages reportedly exceeded $87 million while Ontario Disaster Relief Assistance Program (ODRAP) infrastructure damages of approximately $25 million were incurred. In addition, insured losses and indirect damages such as disruption in residential living conditions, loss of business, and loss of wages or income, were sustained.

Shortly after the flood, the City retained AECOM (formerly UMA Engineering Ltd.) to investigate the causes and determine remedial measures to improve the operation of the drainage system and reduce the risk of damage from future flooding. AECOM undertook a City-wide Flood Reduction Master Plan Study (the Master Plan) under the Environmental Assessment Act to plan infrastructure improvements as part of the City's overall systems, before dealing with project-specific issues. Selected extracts from the Master Plan, as well as additional characterization of the July 2004 extreme rainfall event are contained in Appendix B.

The City-Wide Master Plan recommended a series of actions / studies which were categorized into:

A. Information Gathering & Field Work
B. Detailed Studies & (Municipal Engineers Class) Environmental Assessments
C. Design & Contract Documents (preparation)
D. Construction & Environmental Monitoring
E. Works by Others.

The Group B activities included; Detailed Storm & Watercourse Flood Reduction EA's (Jackson Creek, Curtis Creek, Byersville Harper, Riverview, Thompson, Meade (N&S), and Bears); Watercourse Management Plans; City Wide Policy Review; Sewer Maintenance Program; Emergency Preparedness; Public Awareness Program; Detailed Sanitary Sewer EA.

This report constitutes the project file report for the Jackson Creek Flood Reduction Master Plan. The study has been conducted in accordance with the requirements of the Municipal Class Environmental Assessment, Amended 2007. The study addresses Phases 1 and 2 of the Municipal Class EA planning and design process, and provides a long term strategy for flood damage reduction works within the study area. It is anticipated that the prescribed flood damage reduction projects identified through the course of the Study will be implemented independently of each other.

The problem being addressed was identified in the Master Plan, and verified in this study as:

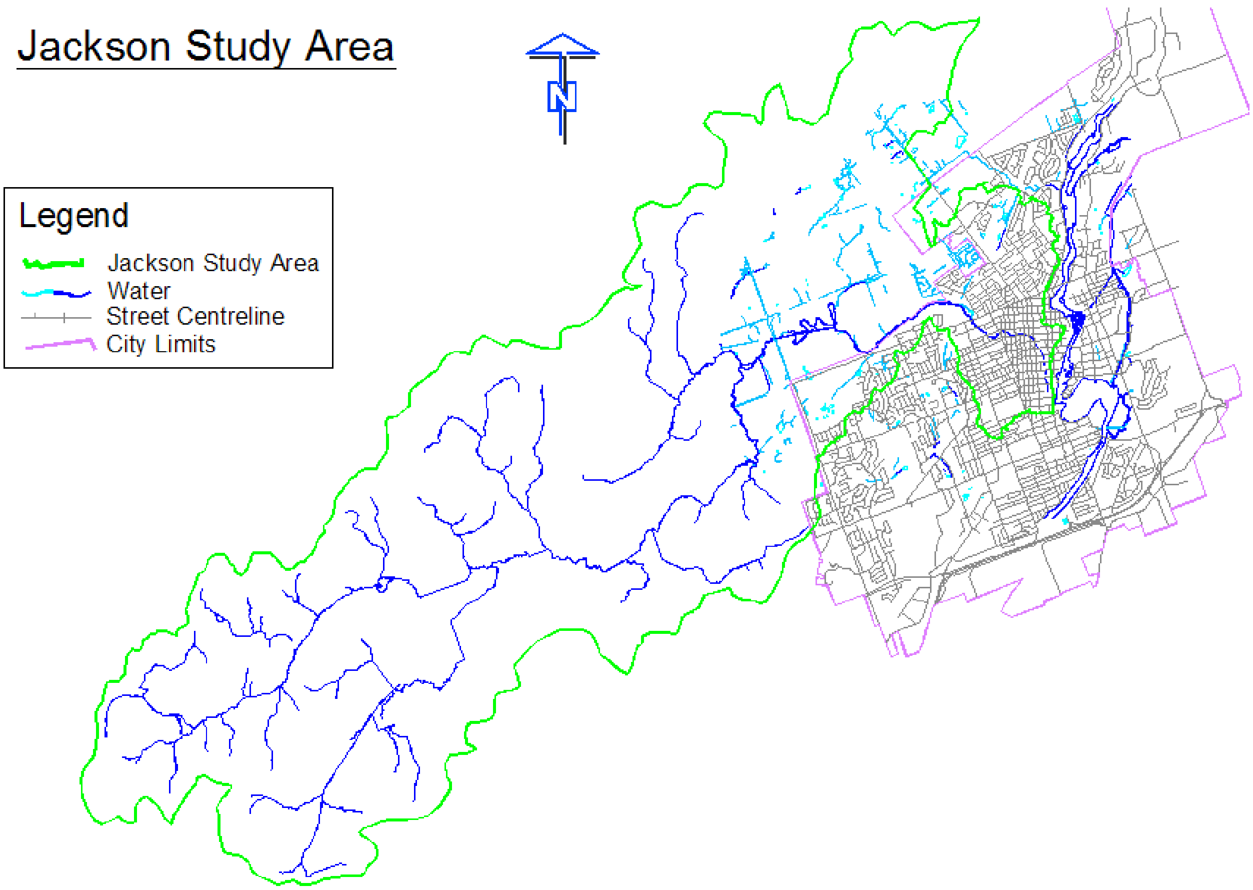
- Excess rainfall
- Insufficient storm sewer capacity
- Poorly defined (uncontrolled) overland flow routes

While issues concerning sanitary sewer flooding and surcharging were not addressed in the study, applicable information (i.e. overland flow routes) has been identified in the report for future action.

In order to resolve the problem, it was determined that improvements are required for existing infrastructure to provide a level of protection for life & property to that provided by current design standards, up to and including a 1:100 year storm.

Figure 1.1 below identifies the Study area

Figure 1.1. Study Area



1.2 Municipal Class EA Master Plan Process

All municipal projects in Ontario require approval under the Environmental Assessment Act (EAA). However, carrying out individual environmental assessments (EAs) and/or seeking exemptions to comply with the requirements of the EAA is onerous, time consuming, and expensive. Since municipalities undertake hundreds of projects, the Municipal Engineers Association (MEA) Municipal Class Environmental Assessment (Municipal Class EA) enables the planning and implementation of municipal infrastructure projects using an approved procedure designed to protect the environment. The Municipal Class EA process provides a decision-making framework that enables the requirements of the EAA to be met in a timely and cost-effective manner.

Given the broad nature of the identified problems and recognizing the need for a coordinated approach to the City's complex urban drainage and sanitary sewer systems, this Study was conducted as a Master Plan under the Ministry of the Environment's definition. Accordingly, the Study will support and provide the framework to facilitate subsequent Municipal Class EA approvals for specific future projects identified with the City of Peterborough, should they be required.

Environmental Assessment or EA is a decision-making process used to promote good environmental planning by assessing the potential effects of certain activities on the environment. The purpose of the EAA is the "betterment of the people of the whole or any part of Ontario by providing for the protection, conservation and wise management in Ontario of the environment", where the broad environment includes the natural, social, cultural, constructed and economic environments. To achieve this, the EAA ensures that environmental problems or opportunities are considered and their effects are planned for before development or building takes place.

The Municipal Class EA provides a streamlined, self-administered framework for EA planning of municipal projects under the provisions of the EAA. The Municipal Class EA enables the planning and execution of municipal projects using an approved procedure, which ensures that potential effects on the natural, social, cultural, technical and economic/financial environment are taken into consideration on a consistent basis. Most importantly, when the Municipal Class EA process is followed, the City is not required to obtain project-specific approval under the EAA.

The Municipal Class EA recognizes that, in many cases, it is better to plan infrastructure improvements as part of an overall system, before dealing with project-specific issues. This allows the proponent to better define the need and justification for individual or specific projects within a broader planning context before proceeding with individual works on a project-by-project basis.

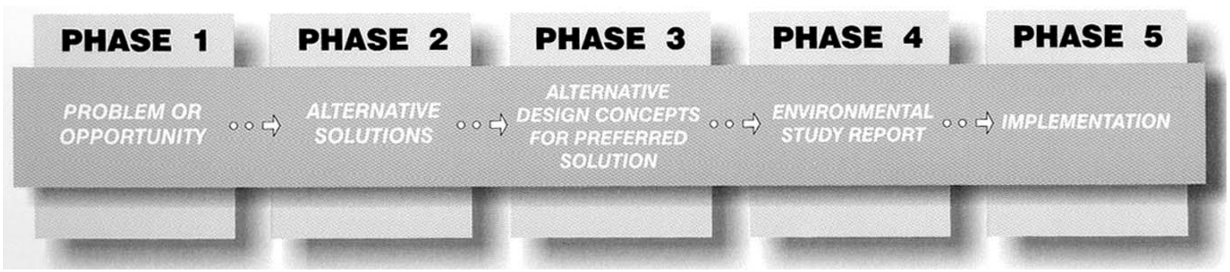
The Master Plan process differs from project specific studies in several aspects. It facilitates long range planning that enables a municipality to identify opportunities and proactively develop strategies for addressing any associated issues. This approach generally yields a framework for planning and implementation of subsequent projects (or a course of action), in combination with a phased implementation plan or program that covers an extended period of time. Though these projects may be implemented as separate works, collectively they form part of the overall management system embodied in the Master Plan.

Prior to the implementation of specific projects recommended within the context of the Master Plan, it is first necessary to determine their level of complexity and potential effects on the environment.

1.3 Study Approach

In keeping with the Master Plan process, this Study has incorporated the key principles of successful environmental assessment planning. Consequently, assessment level undertaken for this Study has addressed the first two phases of the Municipal Class EA process by providing the Problem Statement, regarding the nature and/or extent of the problem including an explanation of the source for the concern, and the need for a solution (Phase 1). This Study also provides a description and assessment of Alternative Solutions, coupled with the decision-making process used to select the Priority Study Areas / Projects (Phase 2) (Figure 1.2).

Figure 1.2. The Municipal Class EA Planning and Design Process



In addition to the Project Team, external regulatory agencies, interested stakeholders and the public have participated throughout the process. As equal partners in the Study, each of the participants has provided input and has therefore played an integral role in the planning and decision-making processes.

1.4 Problem Statement

The problem being addressed was identified in the Flood Reduction Master Plan, and verified in this study as:

- Excess rainfall,
- Insufficient storm sewer capacity,
- Poorly defined (uncontrolled) overland flow routes.

In order to resolve the problem, it was also determined that improvements are required to existing infrastructure to provide a level of protection for life & property to that provided by current design standards, where flood damage protection is provided for events up to and including a 1:100 year storm.

1.5 Ten Year Review Requirements

A time lapse may occur between the filing of the Master Plan and the implementation of each project. In such cases, the proposed project and the environmental mitigation measure approvals may no longer be valid.

If the period of time from filing of the Notice of Completion of the Master Plan in the public record to the proposed commencement of project construction exceeds ten years, the proponents shall review the planning and design process and the current environmental setting to ensure that the project is still valid given the current planning context. The review shall be recorded in an addendum to the Master Plan which shall be placed on the public record.

Notice of Filing of Addendum shall be placed on the public record with the Master Plan Addendum and shall be given to the public the review agencies. A period of 30 calendar days shall be provided for review and response. If no request is received, the proponent is free to proceed with implementation.

1.6 Purpose and Organization of this Report

This Report has been prepared to document and provide a traceable and easily understood record of the planning and decision-making processes. The Report is organized as follows:

- Executive Summary: Provides an overview of why the Study, and summarizes recommendations.
- Section 1 – Introduction: Includes an explanation of the reason why the Study is being conducted under the Municipal Class EA Master Planning process. Provides an overview of the requirement for the Master Plan, and summarizes the recommendations.
- Section 2 – Public and Agency Consultation: Documents the public and regulatory agency consultation activities carried out throughout the Study (e.g., notices, letters, display boards, and public meeting summaries).
- Section 3 – Existing Drainage System Analysis: Provides a description of Jackson Creek and the urban drainage network, and identifies the frequency and severity of flooding within the City
- Section 4 – Existing Environment: Documents the existing natural and socio-economic environment through the study area.
- Section 5 – Alternative Solutions: Documents the development and evaluation of various alternatives to mitigate flooding from Jackson Creek and from the urban drainage systems.
- Section 6 – Recommended Action Plan: Presents and justifies a prioritized list of flood damage reduction projects.
- Section 7 – References – Lists the background reports and studies examined as part of this Study.
- Appendix A: Public Consultation Materials.
- Appendix B: Selected Master Plan & Rainfall Analysis Extracts.
- Appendix C: Jackson Creek Watershed Hydrology Report.
- Appendix D: Jackson Creek Hydraulics Analysis Report.
- Appendix E: Urban Hydrologic & Hydraulic Models & Input Parameters.
- Appendix G: Comparative Construction Cost Estimates.

1.7 Project Team Organization

AECOM led this study, and our inter-disciplinary Project Team consists of specialists in Drainage, Hydrology and Hydraulics, Environmental and Land Use Planning, and Public/Regulatory Agency Consultation. Key staff involved in the Study were:

AECOM Ltd.

- Mr. Brian Worsley, Project Manager
- Mr. Steve Hollingworth, Senior Water Resource Engineer
- Ms. Janelle Weppler, Water Resource Engineer
- Mrs. Emily Cameron, Water Resource Engineer
- Ms. Evelyn Liu, Water Resource Engineer
- Ms. Renata Harry, Project Designer
- Mr. Jeff Atherton, GIS Specialist

Cumming + Company

- Ms. Susan Cumming, Public Facilitator/Mediator

EcoTec Environmental Consultants Inc.

- Mr. Douglas Clark, Environmental Investigations

1.8 Study Schedule

As a Master Plan, the Jackson Creek Flood Reduction Master Plan is subject to approval by the City but does not require formal approval under the EAA. However, at the time of the Studies commencement, it was felt that Schedule B projects might be identified as part of the study; accordingly the MEA Schedule B process has been followed.

The Jackson Creek Flood Reduction Master Plan will be made available for a minimum 30-day public review period. As requests for an order to comply with Part II of the EAA do not apply to Master Plans, the Study is considered approved following the 30-day review period. At this time the City may proceed with its implementation.

It is important to note that more detailed environmental inventories, evaluations and assessments may be required prior to design and construction of any proposed works. The scope and level of analysis is dependent upon the potential complexity and the degree of environmental impact associated with the planned works.

The requirements of Phases 1 and 2 of the Municipal Class EA process will have been satisfied for many of the recommended projects (those considered Schedule A). However, for some Schedule B projects, Phases 1 and 2 will need to be revisited. In addition, for Schedule B projects, it will be necessary to fulfill the consultation and documentation requirements. For any Schedule C projects, the City will need to complete Phases 3 and 4 of the Municipal Class EA process.

2. Public / Agency Consultation

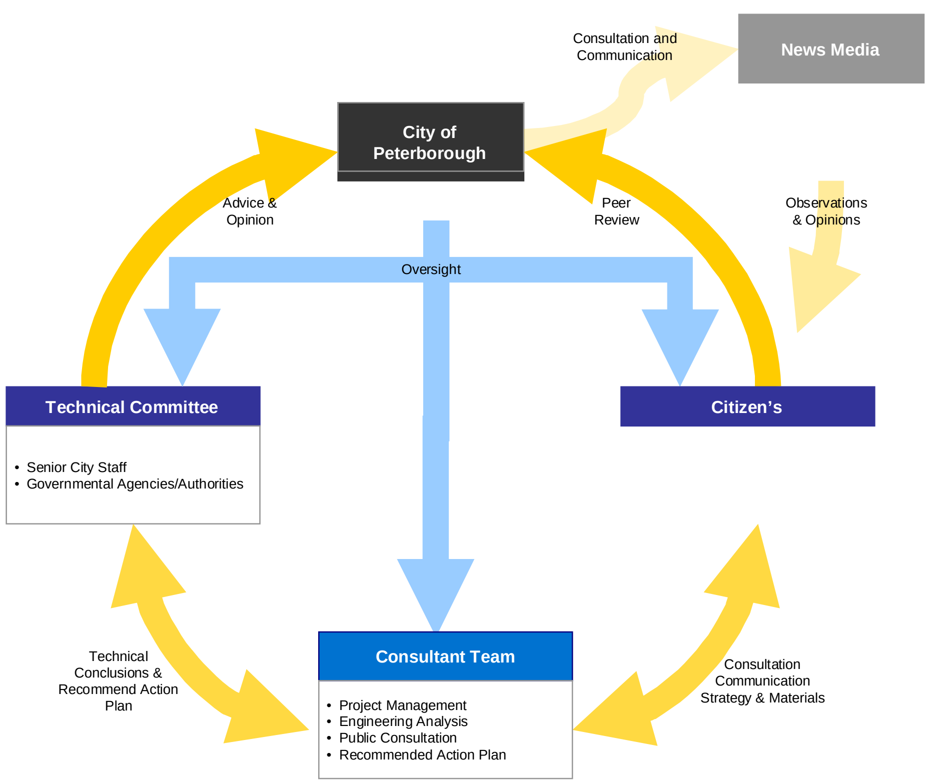
2.1 Consultation Approach

An integral component of the Study was building strong relationships with individuals and groups who are affected by the outcome. It was important to work proactively, collaboratively and candidly with all external agencies and interested stakeholders to meet the City's goal of reducing the risk of future flooding. Our approach was designed to fulfill the following objectives:

- Allow the general public, City Council, stakeholders and external agencies (both federal and provincial) to have an opportunity to participate in the study process as well as contribute to decisions at an appropriate time.
- Provide factual information to all affected/interested stakeholders as soon as reasonably possible, and
- Make contact with external agencies to obtain legislative or regulatory approvals, or to collect pertinent technical information.

Figure 2.1 identifies the interaction of study stakeholders.

Figure 2.1. Interactions of Study Stakeholders



2.2 Agency Consultation

2.2.1 Technical Committee

The Technical Committee (TC) consisted of representatives of key governmental agencies involved in water resource management and public policy, and senior City staff. A list of members is provided below.

Wayne Jackson	Director, Utility Services Department	City of Peterborough
Malcolm Hunt	Director of Planning and Development	City of Peterborough
Dan Ward	Flood Reduction Program Manager	City of Peterborough
Chris Lang	Water Resources Engineer	City of Peterborough
Bruno Bianco	Manager, Infrastructure Planning	City of Peterborough
Peter Southall	Manager, Public Works Division	City of Peterborough
Chris Bradley	Director of Public Works	County of Peterborough
David Burritt / Lucas Pitts	Watershed Engineer	Otonabee Conservation
Doug Ryan	Engineering Technologist	Ministry of Natural Resources
Jane Tymoshuk	Fish Habitat Biologist	Department of Fisheries and Oceans

2.2.2 Letters and Notices

The following letters and notices were sent the external agencies:

- Notice of Study Commencement – February 3rd, 2006
- Notice of Public Open House Meeting # 1 – November 9, 2007
- Notice of Public Open House Meeting # 2 – December 18, 2009
- Notice of Study Completion – April 28, 2010

2.3 Public Consultation

2.3.1 First Public Open House Meeting

A newspaper notice of the meeting was published in the Peterborough This Week on November 9, 2007 for the meeting as set out below:

Date:	November 21, 2007
Open House:	6:15 pm to 8:45 pm
AECOM Presentation:	7:15 pm
Location:	Holiday Inn Waterfront – Regency Room A 150 George Street North

The first part of the meeting was a drop-in/roundtable working session from 6:15 p.m. to 7:15 p.m. that outlined the Study process, provided key information about the urban drainage network, and offered an opportunity to complete a Flooding Survey. The formal part of each evening was from 7:15 p.m. to 8:45 p.m. including a question and answer session led by AECOM. The public commented on observed conditions, identified concerns, and asked questions. Twenty-eight people were recorded on the sign-in sheets, and 14 comment forms were received.

The meeting was facilitated by Sue Cumming of Cumming + Company, an independent consultant engaged to facilitate the question and answer part of the public meetings. Representatives from AECOM were present throughout the meeting to provide information, answer questions and receive comments from all participants. The public was encouraged to provide anecdotal evidence on what they had experienced.

The input received from the public was summarized to provide both insight into the aspects of the flooding which are of most concern to local residents, flood protection measures which the public felt to be the most appropriate, and the weightings of various evaluation factors proposed by the public.

The public input from the first Open House is summarized as follows:

- When asked which areas of stormwater management the public would like to see the City focus on it was determined that the urban storm sewer and overland flow systems as well as a combination of creek and urban improvements were the first priority, and lastly creek improvements only.
- Public perception of the top urban priority is weighted towards upsizing and replacement of storm sewers; second, third and fourth priorities were to establish and expand stormwater management ponds, create and formalize overland flow routes, and to install source controls;
- The public felt that the first priority for creek improvements is to increase the capacity of bridges and culverts. The second priority closely following the first was to establish and/or expand stormwater management ponds, closely followed by increasing the channel capacity and the installation of a trunk relief sewer. The last priorities were to construct a diversion channel, improve creek maintenance and consider flood proofing private property. No priority was given to lining downtown Jackson Creek with Armour stone.
- The top three factors for determination of remedial measures were Engineering Applicability, followed by Cost and Social disruption.

Display material was available after the public meeting through the project website. A copy of the display material and the Public Meeting Summary Report documenting the first public meeting is included in Appendix A.

2.3.2 Second Open House Meeting

The second public open house meeting was held as follows:

Date:	January 13, 2010
Open House:	6:15 pm to 8:45 pm
AECOM Presentation:	7:15 pm
Location:	Holiday Inn Waterfront – Regency Room A 150 George Street North

The format for PIC #2 was similar to PIC #1 with an open house concept to start, and a formal presentation starting at 7:15. As the public arrived they were able to look through the information boards set up to begin to understand existing problems and our proposed solutions. AECOM and City staff were also available at this time to explain boards and answer questions. The public were asked to sign in and were given a comment form to fill out. Thirty people were recorded on the sign-in sheets, and 7 comment forms were received.

The formal presentation included a summary of the extent of flooding from Jackson Creek and along the urban drainage systems and corresponding damage estimates. The different flood reduction alternatives were described, the evaluation of the various alternatives was summarized, and details of the preliminary preferred solutions were provided.

The presentation was followed by a question and answer session, facilitated by Sue Cumming. The information from the public received either at the open house or through the comment forms is summarized below:

- The public generally agreed with the preferred creek alternative to have a diversion sewer conveying excess creek flow from just upstream of the downtown corridor to the Otonabee River
- There was a request to investigate the alternative of flood storage in Jackson Park.
- The preferred solution for the urban area is selective upgrades, and while majority of the attendees agreed with this solution, there were some who preferred installation of 100 year storm sewer systems throughout the study area.
- There was some concern regarding erosion along the Jackson Creek banks.
- An increase in creek maintenance was a common complaint among the attendees of the open house
- Several attendees were concerned that recent and planned development in the watershed will worsen flooding in Jackson Creek.

After the question / answer period the public were able to once again take a closer look at the display boards and ask questions to AECOM and City staff. Display material was available after the public meeting through the project website. A copy of the display material and the Public Meeting Summary Report documenting the public meeting is included in Appendix A.

2.3.3 Notice of Study Completion

A Notice of Study Completion for the Jackson Creek Flood Reduction Master Plan was placed in the local newspapers on April 28, 2010 and on April 30, 2010. The Notice announced the completion of the Master Planning Study and provided details regarding the process to be followed and solicited input from interested and affected parties. A copy of the notice is included in Appendix A.

3. Existing Drainage Conditions

In rural headwater areas, rainfall will slowly begin to flow overland to local low points in the landscape once the moisture capacity of the soil is exceeded. Shallow valleys, or draws, lead from these depressed areas, joining together to form larger draws. As more and more draws are added, the valley becomes more defined and a stream channel is created.

During small to moderate rainfall events, the flow is typically confined to the banks of the defined channel. Every year or two on average, a large storm occurs that produces more runoff than the channel can carry, and flow spreads out of the channel and onto the floor of the valley. During very rare, severe storms, floodwater may fill the entire valley. If there is development within or adjacent the valley, it may be subject to flood damages from the rising floodwater during such severe storm events. Also, urban infrastructure within the valley systems, such as roadways and railways, may restrict the natural flow carrying capacity of the valley corridor and contribute to high water levels during severe storm events.

In an urban environment, rainfall may fall on natural ground, or may land on hard surfaces such as rooftops or pavement. Typically, this rainfall only has to travel a short distance to reach an engineered drainage system, such as a ditch or a catchbasin. These drainage systems are generally sized to carry the runoff from relatively common storms that might occur once every 2 to 5 years on average, and quickly deliver the runoff to a nearby watercourse or lake. During more severe storm events, the capacity of the ditch or storm sewer system may be exceeded. Similar to the rural environment, excess water will build up at the low points in the urban landscape. From these depressions, water will travel along the lowest paths in the landscape to the receiving watercourse or lake. These are referred to as major systems or overland flow routes.

Approximately two to three decades ago urban drainage design was expanded to encompass "dual drainage" where both minor and major drainage systems are designed. The minor system generally consists of catch basins and storms sewers intended to convey relatively common (nuisance) runoff. The major system typically consists of road networks and or dedicated flood easements/channels designed as the lowest points in the landscape, such that runoff will be contained when the capacity of the (minor) storm drainage system is exceeded during severe storm events. Unfortunately, virtually all Canadian cities & towns were built before the advent of dual drainage design, consequently, there is more potential for flooding of property and buildings along the overland flow routes during severe storm events.

3.1 Riverine Drainage System

3.1.1 Jackson Creek Study Area

The Jackson Creek watershed covers an area of approximately 11,900 ha illustrated in Figure 1.1. The study area includes the entire watershed and two areas within the City that do not drain directly to Jackson Creek, but were analysed as part of this project. The watershed and subwatershed boundaries were delineated by AECOM staff using 0.5 m contour mapping within the City of Peterborough limits and 5 m contour mapping

(Ontario Base Map) beyond the City limits. The upstream end of the Jackson Creek watershed is just east of Ski Hill Road between Sharpe Line and Hayes Line. A series of tributaries combine to form Jackson Creek. The creek generally flows in a northeast direction, passing through the Cavan Bog and feeding into Lily Lake before flowing into the City of Peterborough where it passes through the developed downtown area and outlets into the Otonabee River. Jackson Creek has been significantly altered through the urban area of Peterborough to the extent where at many locations the creek is confined on all four sides.

3.1.2 Hydrologic Analysis

In order to evaluate flooding conditions along Jackson Creek, one must be able to determine the magnitude of the flow resulting from severe storm events. Many tools are available for this purpose, ranging from desktop calculations (i.e. Rational Method) to detailed continuous simulation models. For the subject study, the SWMHYMO computer model was used to estimate peak flow rates resulting from severe storm events. SWMHYMO is a complex hydrologic model used for the simulation and management of stormwater runoff in rural and urban areas. SWMHYMO can use single rainfall events or continuous rainfall records to simulate the transformation of rainfall into surface runoff. Computed hydrographs can be routed through pipes, channels or stormwater control ponds and reservoirs. SWMHYMO was developed and widely used in the Southern Ontario area and proved to be suitable for modeling the watersheds in the area and thus was selected for the current hydrologic analysis on Jackson Creek.

To calculate peak flow rates, the SWMHYMO model requires physical characteristics of the watershed and details of the rainfall events to be simulated. Soil conditions through the watershed were obtained from agricultural soils mapping. The predominant soil through the study area is Otonabee Loam, which is classified as a Type B soil according to the USDA SCS classification system. Land use and land cover through the study area were initially obtained from the Natural Resources Canada Land Inventory Level (Source: http://geogratis.cgdi.gc.ca/CLI/frames.html). This information was adjusted based on observed conditions from field visits and air photo analyses. Upstream (west) of the Peterborough municipal boundary, land use is predominantly agricultural (pasture and crops), as well as extensive wetland areas within the headwaters. Within the City limits, urban development in the form of single detached dwellings dominate the landscape. Farther downstream Jackson Creek enters the downtown area of Peterborough before discharging to the Otonabee River. The downtown area is entirely developed with little to no pervious cover.

The SWMHYMO model was set up using the Williams Unit Hydrograph approach for the rural areas, and the STANDHYD approach for the urban areas. For both urban and rural areas, runoff from the pervious portions of the watershed was determined using SCS Curve Number hydrology. The Cavan Bog has considerable capacity to store and slowly release runoff from the rural areas upstream of Highway 7. The Cavan Bog was represented in the SWMHYMO using a ROUTE RESERVOIR command based on the storage characteristics of the bog and the hydraulics of the Highway 7 culvert. There is also a man-made flood control structure on Jackson Creek, located just downstream from Lily Lake. The structure, known as the Jackson Weir, controls flooding by restricting the flow in Jackson Creek during severe storm events and storing floodwater in Lily Lake and the considerable surrounding wetland areas. The storage and discharge characteristics of the Jackson Weir were calculated and represented in the SWMHYMO model using a ROUTE RESERVOIR command. The storage volumes were estimated from available topographic mapping in the study area, and discharge through the weir at different elevations was calculated using the HEC-RAS hydraulic model (see Section 3.1.4). Finally, there are several areas in downtown Peterborough that are serviced by storm sewers that discharge directly to the Otonabee River. During severe storm events that exceed the capacity of the storm sewer, overland flow from these areas will enter Jackson Creek. The COMPUTE DUALHYD command was used in SWMHYMO to calculate the major overland flow from these areas to Jackson Creek. Detailed information on the calculation of the parameters for the hydrology model can be found in the Jackson Creek Hydrology Study Report (AECOM, 2010), included as Appendix C.

The Jackson Creek watershed hydrology was then calibrated with recorded precipitation data from the summer of 2006 and stream flow data from the two Water Survey of Canada (WSC) gauges located at the Jackson Weir and in the downtown area. Precipitation data was available from the Trent University Climate Station, a rainfall gauge on the roof of Peterborough City Hall, and a rainfall gauge at the Waste Water Treatment Plant to the south of the study area. As the SWMHYMO model is designed and intended to be used to estimate peak flows through the Jackson Creek watershed resulting from severe storm events, the largest rainfall and flow events from the summer of 2006 were selected for the calibration exercise.

The SWMHYMO model was initially adjusted to reflect the initial soil moisture conditions at the start of the event, and then the select recorded events were simulated. The rural areas were calibrated using the stream flow data from the Jackson Weir. The shape of the hydrograph was close to observed, but the initial abstraction parameter was increased to better match observed flow rates and volumes. The urban areas were subsequently calibrated using data from the downstream gauge. The assumed directly connected and total impervious values were reduced and the initial abstraction depths were increased to obtain the best agreement with observed data over the range of calibration events.

Finally, the SWMHYMO model was used to predict the peak flows through Jackson Creek resulting from severe storm events. A number of synthetic storm distributions and durations were evaluated. Based on model output and available literature, both the 1 hour and the 24 hour AES storm distribution were selected for the analyses. The longer, 24 hour duration is appropriate for the long, rural watershed, as it takes a long time for the flow from the headwater areas to reach the urban areas at the base of the watershed. The 1 hour storm event is more appropriate for urban areas, where water reaches the receiving stream very quickly. In the case of Jackson Creek, it is possible for the 1 hour storm over the urban area to generate a higher peak flow rate that a 24 hour storm over the entire watershed area. Both the 1 hour and 24 hour storm events were used for the analysis.

The 5 year and 100 year return period storm events for both the 1 hour and 24 hour AES distributions were simulated, representing moderate and severe storm events. The 2004 July 14th Peterborough storm event was also simulated. Input precipitation data for this storm event was created from RADAR records, as discussed in Appendix B. Finally, the Regional storm event was simulated. The Regional storm event is defined in the "Technical Guide - River and Stream Systems: Flooding Hazard Limit" (MNR, 2002), and represents the worst storm on record that did or could have potentially occurred over the study area. For the Peterborough area, the MNR Technical Guidelines specify that the Timmins storm should be used as the Regional storm event.

The peak flows for the range of events at different locations through the study area are presented in Table 3.1. The hydrology model predicts that, if the July 2004 storm occurred evenly over the entire Jackson Creek watershed, the resulting peak flow rates would be of similar magnitude to the Regional storm event, and approximately 2.5 times greater than the 100 year storm event.

Table 3.1: Hydrology Model Output

Location	Storm Event					
	Timmins Storm	July 2004	100 yr 24 hour	100 yr 1 hour	5 yr 24 hour	5 yr 1 hr
Jackson Creek at the Jackson Weir (m^3/s)	83.67	76.45	29.78	8.64	10.32	2.16
Jackson Creek at Charlotte Street (m^3/s)	84.34	82.61	31.27	37.59	13.21	15.09
Jackson Creek at the Outlet to the Otonabee River (m^3/s)	84.34	83.40	33.15	45.94	14.74	18.65

3.1.3 Hydraulic Analysis

Following the hydrologic analysis to determine the peak flow rates along Jackson Creek, a hydraulic analysis was completed to determine the water levels in the creek corresponding to the different peak flow rates.

The HEC-RAS hydraulic model was selected for the analysis. HEC-RAS was developed by the US Army Corps of Engineers and has been used extensively throughout North America to estimate flood levels in valley systems. It is listed as an accepted model for flood plain mapping in Ontario (MNR, 2002). In addition to peak flow rates, the model requires topographic information to define the geometry of the stream corridor, details (dimensions) of bridge and culvert crossings over the watercourse, and hydraulic roughness values (Manning's n).

Topographic information for the stream corridor was obtained from the 0.5 m contour mapping through the study area. The HEC-GeoRAS software package was used to automatically generate cross sections for the HEC-RAS model from the topographic mapping in a GIS environment. Information on bridges and culverts was taken from a total station survey undertaken in 2006, while roughness values were based upon field visits / visual inspection.

More information on the HEC-RAS model set-up can be found in the Jackson Creek Hydraulic Study Report (AECOM, 2010), included as Appendix D.

3.1.4 Hydraulic Model Output

The extent of flooding along Jackson Creek predicted for the 5 year, 100 year and Regional (Timmins) storm event are presented in Figures 3.1, 3.2, and 3.3 respectively.

For the 5 year storm event, the HEC-RAS model predicts that flow will be confined to the Jackson Creek channel through much of the study area, and most culverts have sufficient capacity to convey the flow. The only exception is one location in downtown Peterborough, near Charlotte Street, where a small area of flooding is predicted.

When the 100-year storm event was run through the hydraulic model, the output indicated that the creek would spill beyond the creek banks at several locations impacting the adjacent properties. The model predicts that the 100 year flow would not be confined to the channel for most of the river system downstream of the intersection of Stewart Street and Murray Street. The excess floodwater is predicted to spill from the channel and flow overland along roads and through private property.

During a Regional storm event, the HEC-RAS model predicts that the channel would spill outside the channel corridor through most of the study area downstream of Parkhill Road. The width of flooding is up to 230 m through the downtown core, impacting a large number of properties near the channel.

Figure 3.1. Jackson Creek Flood Plain – 5 Year Event

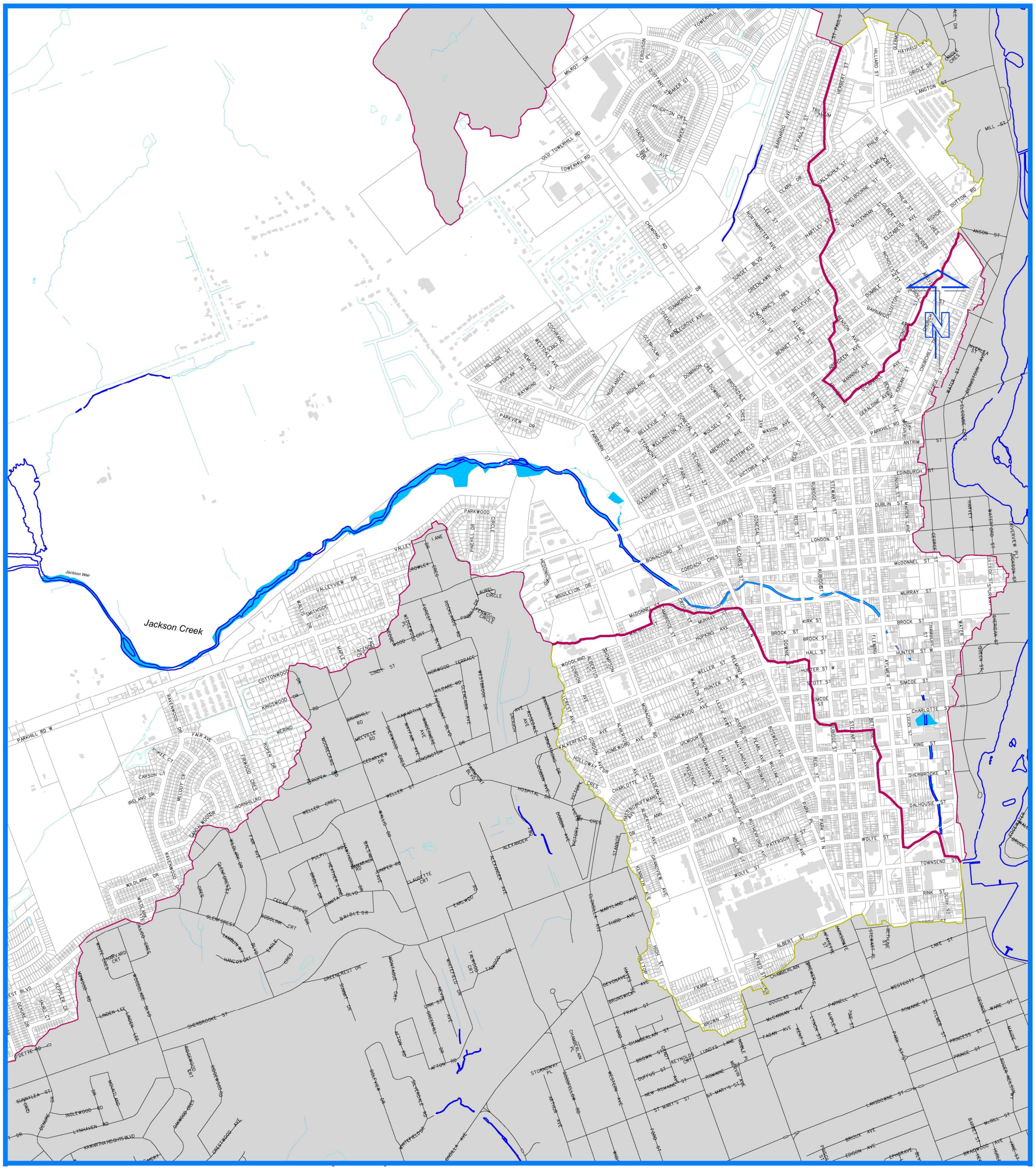


Figure 3.2. Jackson Creek Flood Plain – 100 Year Event

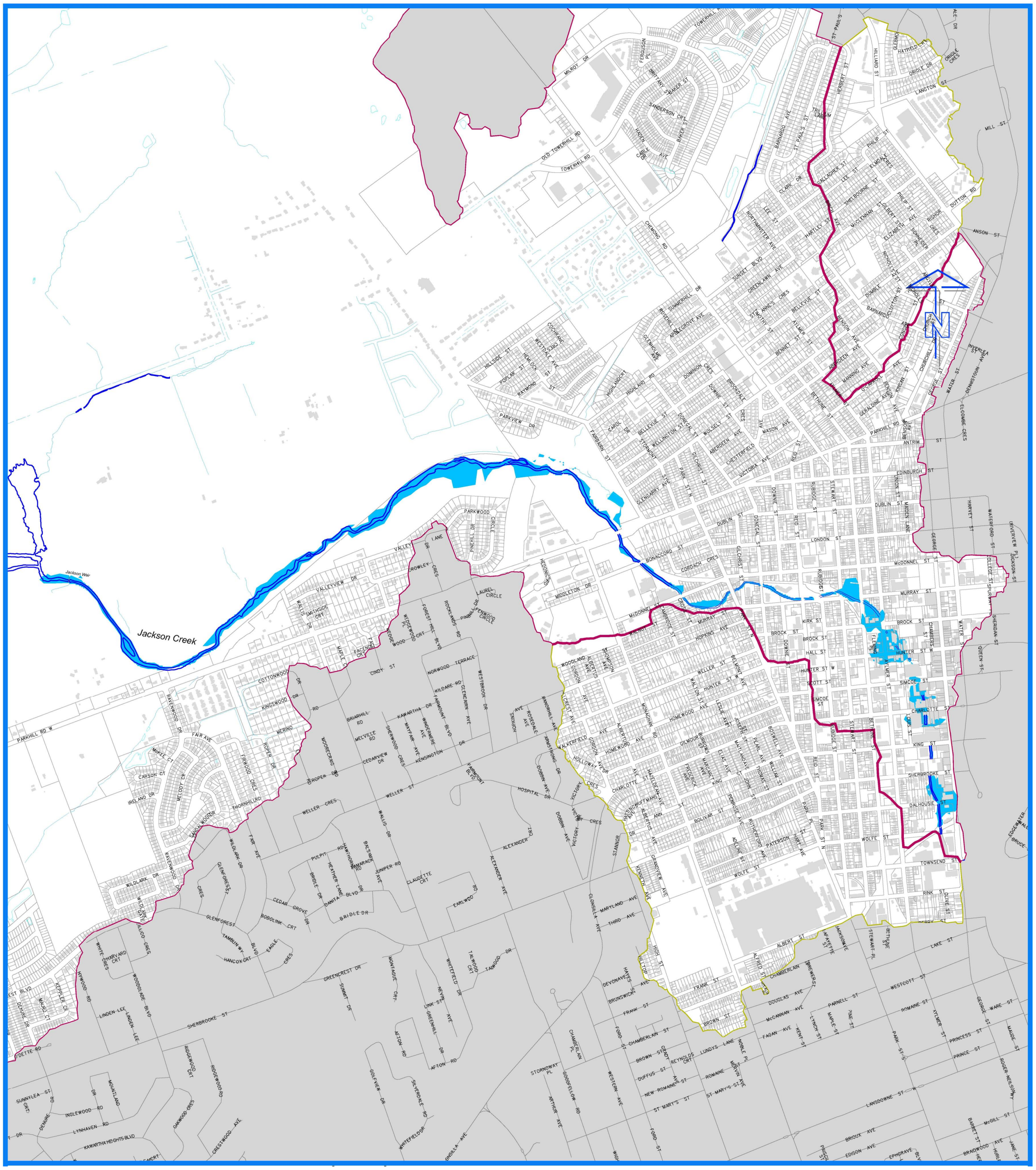
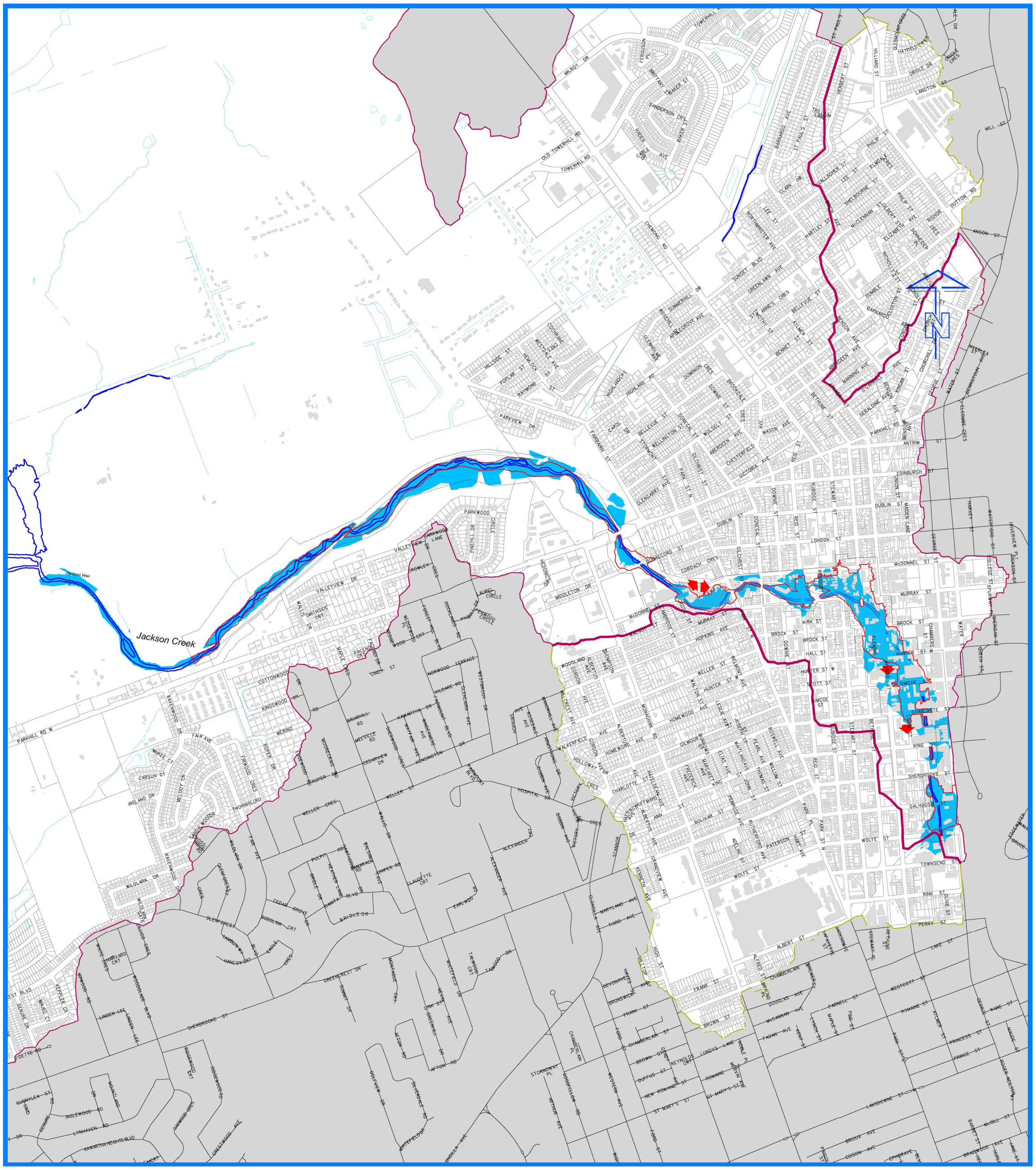


Figure 3.3. Jackson Creek Flood Plain – Regional (Timmins) Storm Event



3.1.5 Damage from Riverine Flooding

Damages to buildings impacted by riverine flooding in Jackson Creek are difficult to estimate. Depth damage tables have recently been updated by MNR, however information provided by Alan Pang from CGI Insurance Business Services indicates that the correlation between flooding depth and resultant damages is not overly valid. An empty unfinished masonry basement will suffer significantly less damage than a finished basement being used as a living space. Additionally, the mechanism by which flooding may enter buildings is relatively complex, as overland flows over sanitary manholes may overwhelm foundation drains, or flows may enter buildings through doors and windows. Moreover, if exposed to severe flood depths and velocities, buildings could collapse entirely.

It is not feasible to investigate every single building in the study area to identify the mechanisms for flood damages and estimate direct flood damages for different storm events. Instead, it was agreed that to provide consistency between the various studies being undertaken for the City, flood damages would be taken as 20% of the value of the buildings within flood lines, regardless of flood depth, velocity and duration. This approach provides consistency between the various studies the City is undertaking, (to allow setting of City wide priorities), and allows relatively simple updating of the damage figures, and avoids the house by house inspection that would be required to fully utilize a depth/damage approach.

The assessed values of the impacted properties through the Jackson Creek study area were based on the latest property assessments completed by the Municipal Property Assessment Corporation (MPAC), which were provided by the City of Peterborough.

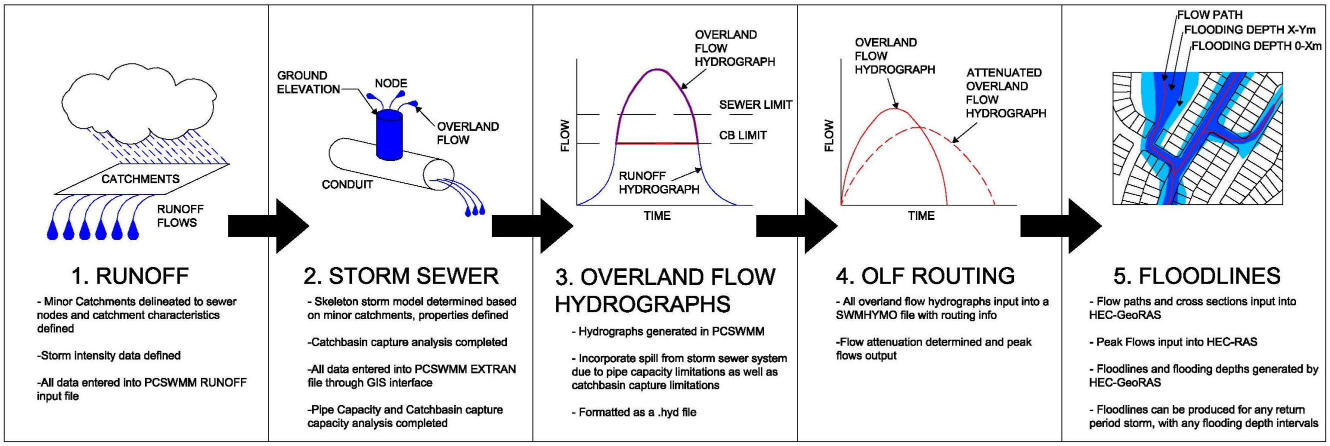
For the Regional (Timmins) storm event, a total of 250 buildings are predicted to be impacted for damages totalling $18.7 Million. Predicted flood damages for the 5 year and 100 year return period events are $4.6 Million (33 buildings) and $ 8.6 Million (118 buildings), respectively. Some of these buildings are also impacted by urban flooding and would continue to be impacted even if the flooding from Jackson Creek were remediated.

3.2 Urban Drainage Systems

3.2.1 Study Area

The analysis of the urban drainage systems through the Jackson Creek watershed included the entire storm sewer system and some of the storm sewers within the Otonabee watershed, with discrete modelling being undertaken on all storm sewers draining more than 2 - 5 ha. Under this threshold, the small drainage areas typically do not generate sufficient runoff to pose significant flooding concerns, and storm sewers are usually sized based on minimum allowable diameter, rather than capacity constraints. The analysis methodology used is illustrated schematically in Figure 3.4, below, and described in text in the following sections.

Figure 3.4. Urban Analysis Schematic



The Jackson Creek study area consists of the urban Jackson Creek watershed which is divided into seven subwatersheds, including two subwatersheds that are drained by storm sewers that discharge directly to the Otonabee River. The “Brookdale” subwatershed is the area that drains to the concrete lined channel on the north side of Jackson Creek and the connected storm sewers. The remaining Jackson subwatersheds were named Northwest Jackson, Southwest Jackson, Northeast Jackson, Southeast Jackson, and Southeast Jackson-Otonabee. One of the additional subwatersheds is considered part of Northeast Jackson subwatershed, but is actually a depressed area that does not drain overland to Jackson Creek. The storm sewers from this area lead to the Otonabee River, but runoff from the area could spill to Jackson Creek if the storm sewer capacity was exceeded and the depression filled with water to a sufficient depth. This area was considered as part of the study area since the area could potentially spill to Jackson Creek. The other area added to the Jackson study area is just south of the Southeast Jackson subwatershed. This area consists of a complex storm sewer network which outlets into the Otonabee River adjacent the Jackson Creek outlet. It is considered part of the Jackson Creek study area due to its large area and relative location to the Jackson watershed.

The storm sewer segments included in the analysis are presented in Figures 3.5 – 3.9. Storm sewer diameter, slope, depth, & connectivity data was provided by the City of Peterborough in the form of as-built drawings, and electronic databases. Any information that was missing or questionable was verified by the City of Peterborough and updated within the database.

3.2.2 Modelling Approach – Storm Sewer Systems

The urban storm sewer systems were analyzed with the aid of the PCSWMM 2006 computer model. PCSWMM is a software support package for the US EPA SWMM4 program which was developed in 1984. SWMM was first developed in 1971 and has undergone many upgrades since and is now used around the globe. PCSWMM is capable of dynamic modeling for storm and waste water flows for quality and quantity analyses. PCSWMM is a popular choice among hydraulic modellers since it supports extremely large model sizes with thousands of elements, has a graphic interface which renders the program comparatively user-friendly, is compatible with many other computer programs, and has several valuable reference tools.

The PCSWMM model was selected as it has been used extensively throughout North America for the analysis of storm sewer systems. It is much more robust than the traditional Rational Method calculations typically used to design storm sewers, as it is capable of generating a runoff hydrograph based on historic or synthetic rainfall events and routing it through a storm sewer network. The model also allows separate hydrographs to be prepared for the flow within the storm sewer system (minor system) and the flow in excess of the storm sewer capacity (major system). Finally, the PCSWMM model is based on the USEPA SWMM model, and therefore expensive proprietary software packages are not necessary for any future refinement of the models.

Initially, minor drainage catchment areas were delineated through the study area. Catchments were delineated with areas ranging from 2 ha to 5 ha, and 'lumped' model parameters were developed to represent the cumulative characteristics of each catchment. Catchments were set with the existing number of catch-basins to allow the addition of extra catch basins, or different catch basin types, without model recalibration.

Catchment model parameters required for the RUNOFF module of the PCSWMM model include percent impervious, slope, roughness, and initial and final soil permeability. Values for these parameters were determined from the GIS data provided by the City & County, and reflect standard values for Southern Ontario.

The storm sewer characteristics were entered into the EXTRAN module of PCSWMM, using the as-built storm sewer information provided by the City. As many of the sub-catchments included several lengths of potentially different diameter storm sewers, equivalent (longer) pipes were developed to represent these systems in the model. This approach both reduces model complexity, and potentially improves model accuracy, as EXTRAN model stability is typically enhanced by longer pipe lengths. Finally, rating curves were used to determine the capacity of the catchbasins within each catchment, limiting the flow entering the pipe network in the model. More information on the set-up of the PCSWMM models can be found in Appendix E.

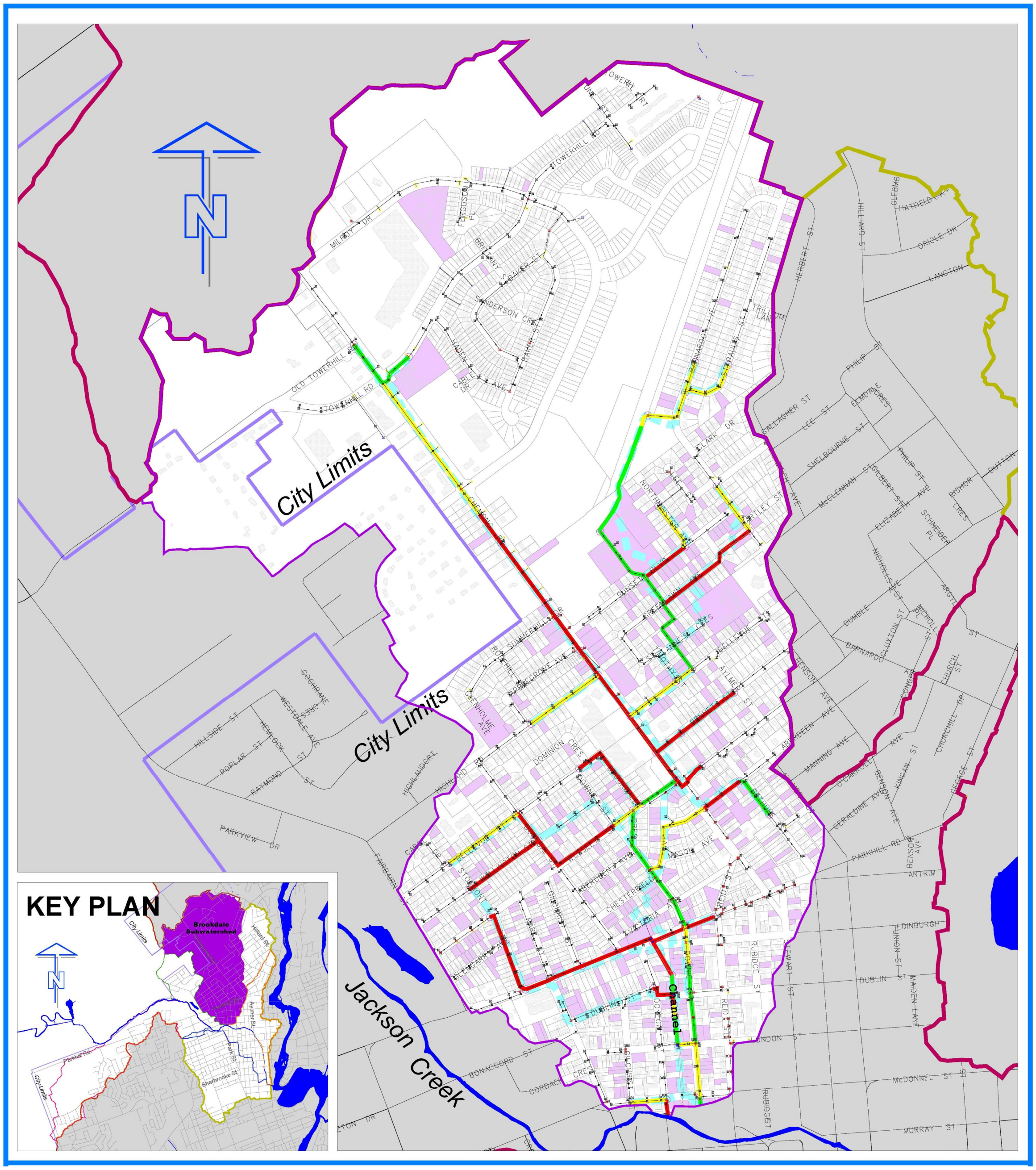
The model was then calibrated based on available rainfall and sewer flow data. A flow gauge was installed at the downstream end of the trunk storm sewer discharging to Jackson Creek near the intersection of Downie and McDonnell Streets collecting sewer flow data during the summer months of 2006. Three other flow monitors were located within the urban area, and were also used for calibration purposes. The same precipitation gauges used for the calibration of the Jackson Creek watershed hydrology model (Trent University, City Hall and Treatment Plant) were used for the calibration of the urban drainage system.

As with the riverine system calibration, considerable differences in rainfall duration and intensity were observed between the rainfall gauges for the same storm event. In general, however, the initial PCSWMM model overestimated the volume of runoff and peak flow rates relative to the gauged data, and predicted a much faster response than was observed in the gauged data. Several model parameters were adjusted to obtain better agreement between the modelled and observed flow hydrographs. The best agreement was achieved by increasing the assumed roughness of the paved surfaces in the catchments (adjusting Manning's 'n' from the default of 0.013 to 0.050) and reducing the estimated total impervious surface area in each catchment by 20%. More information on calibration of the PCSWMM model can be found in Appendix E.

Following calibration, select storm events were simulated using the PCSWMM model. A 5 year return period storm was simulated, as present day storm sewer standards for the City of Peterborough specify a 1 in 5 year storm. The 100 year return period storm event was also simulated, as modern major drainage systems in urban areas are typically designed to convey the 1 in 100 year storm. To provide consistency between the various studies being undertaken by the City, the 1 hour AES storm distribution was used for both the 5 year and 100 year events. Storm sewer systems are most likely to be overwhelmed during short duration, high intensity storms, and the AES distributions are more representative of storm patterns in southern Ontario relative to other available distributions (Chicago, SCS, etc).

The calibrated model was used to determine the existing flow rates in the storm sewers through the study area during both the 5 year and 100 year return period storm events. A second analysis was completed to determine the flow conveyed through the storm sewers if all runoff was captured. These second (modelled) sewer flow rates were compared to the existing storm sewer capacity to convey the total flow from upstream areas. Pipes were then classified as 'green', 'yellow' or 'red' depending on the percentage of total runoff the existing storm sewers are able to capture and convey. Storm sewers that had sufficient capacity to convey a 5 year rainfall runoff were coded 'green'. Where pipe capacity was 50 % to 100 % of the total upstream flow, the sewer was labelled yellow. While these sewers do not have full capacity, they are likely to operate under surcharged conditions with few flooding impacts. Finally, sewers with less than half the required capacity were labelled 'red', representing potentially significant restrictions in the storm sewer system. This analysis roughly indicates which sections of storm sewer would need to be upgraded to properly convey the 5 year flow. The classification of the storm sewers throughout the study area are presented in Figures 3.5 – 3.9 for the different subwatersheds. A catchbasin capture analysis was also completed to determine whether catchments have an adequate amount of catchbasins to capture the flow generated by a 5 year storm event. These results were calculated based on MTO rating curves for catchbasins depending on type and topographic location. The results can be found in Appendix E.

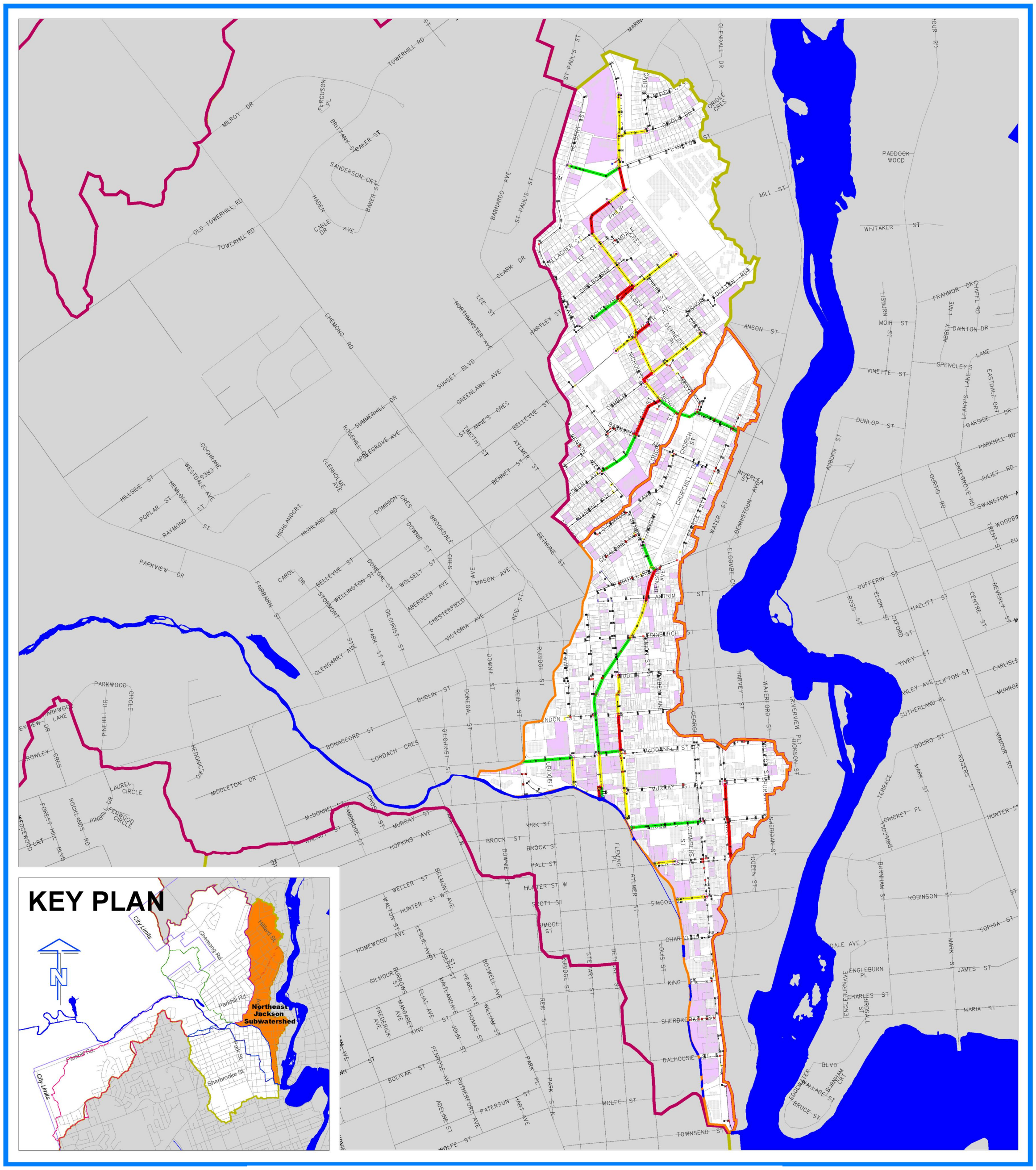
Figure 3.5. Estimated Storm Sewer Capacity – Brookdale



Legend

- 5-year flow is less than storm sewer capacity
- 5-year flow is 1-2 times storm sewer capacity
- 5-year flow is greater than 2 times storm sewer capacity
- Modeled storm sewer maintenance hole
- Modeled storm sewer outfall
- 100-year Overland Flow Centreline
- Jackson Study Area Boundary
- Jackson Watershed Boundary
- Brookdale Subwatershed Boundary
- Flood-affected Parcels from 2004 Event
- Existing Storm Sewer
- Existing Maintenance hole
- Existing Catchbasin
- Existing Outlet
- Building
- Property Line

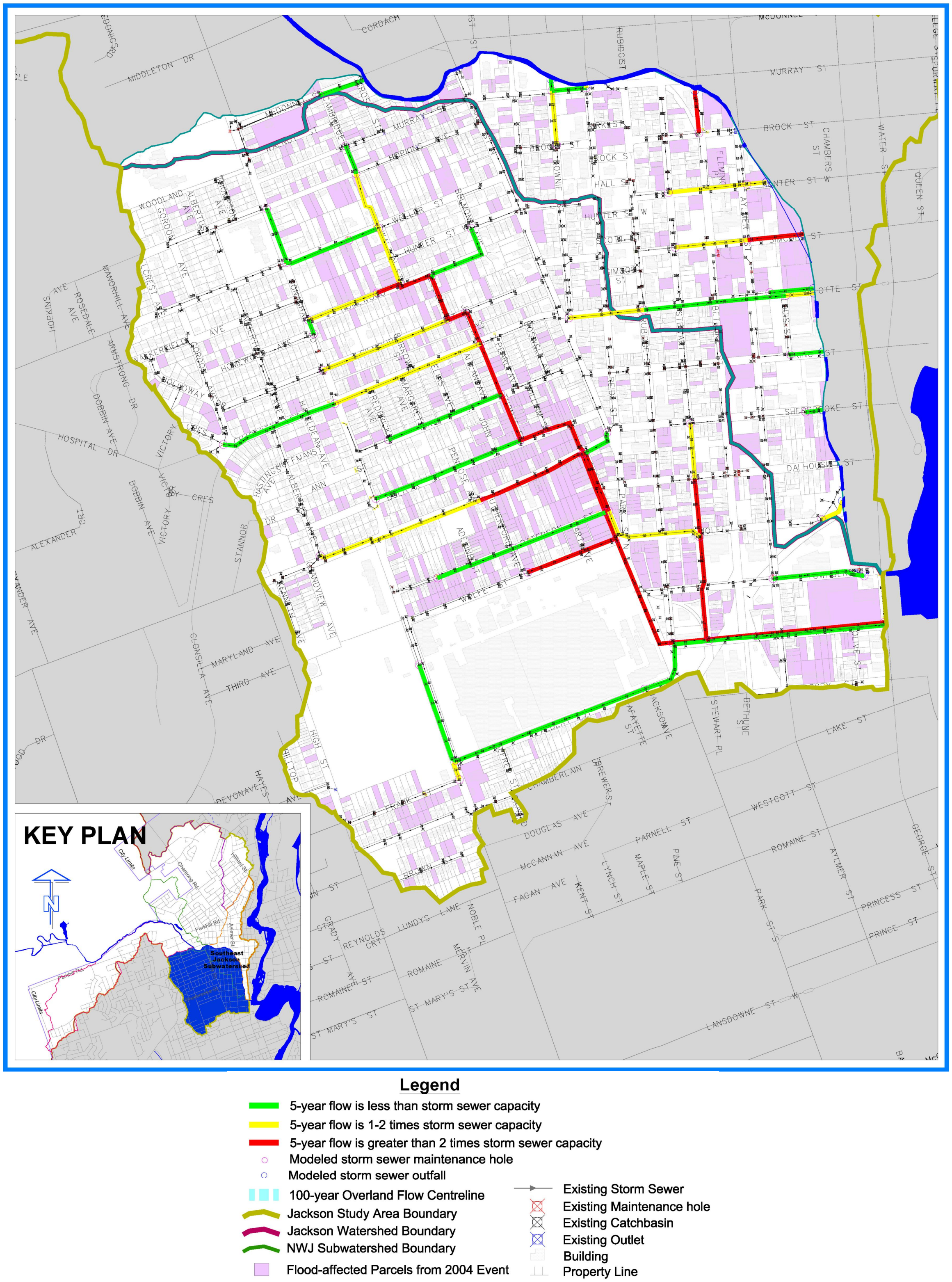
Figure 3.6. Estimated Storm Sewer Capacity – Northeast Jackson



Legend

- 5-year flow is less than storm sewer capacity
- 5-year flow is 1-2 times storm sewer capacity
- 5-year flow is greater than 2 times storm sewer capacity
- Modeled storm sewer maintenance hole
- Modeled storm sewer outfall
- 100-year Overland Flow Centreline
- Jackson Study Area Boundary
- Jackson Watershed Boundary
- NWJ Subwatershed Boundary
- Flood-affected Parcels from 2004 Event
- Existing Storm Sewer
- Existing Maintenance hole
- Existing Catchbasin
- Existing Outlet
- Building
- Property Line

Figure 3.7. Estimated Storm Sewer Capacity – Southeast Jackson (& Otonabee Area)



AECOM

Figure 3.8. Estimated Storm Sewer Capacity – Southwest Jackson

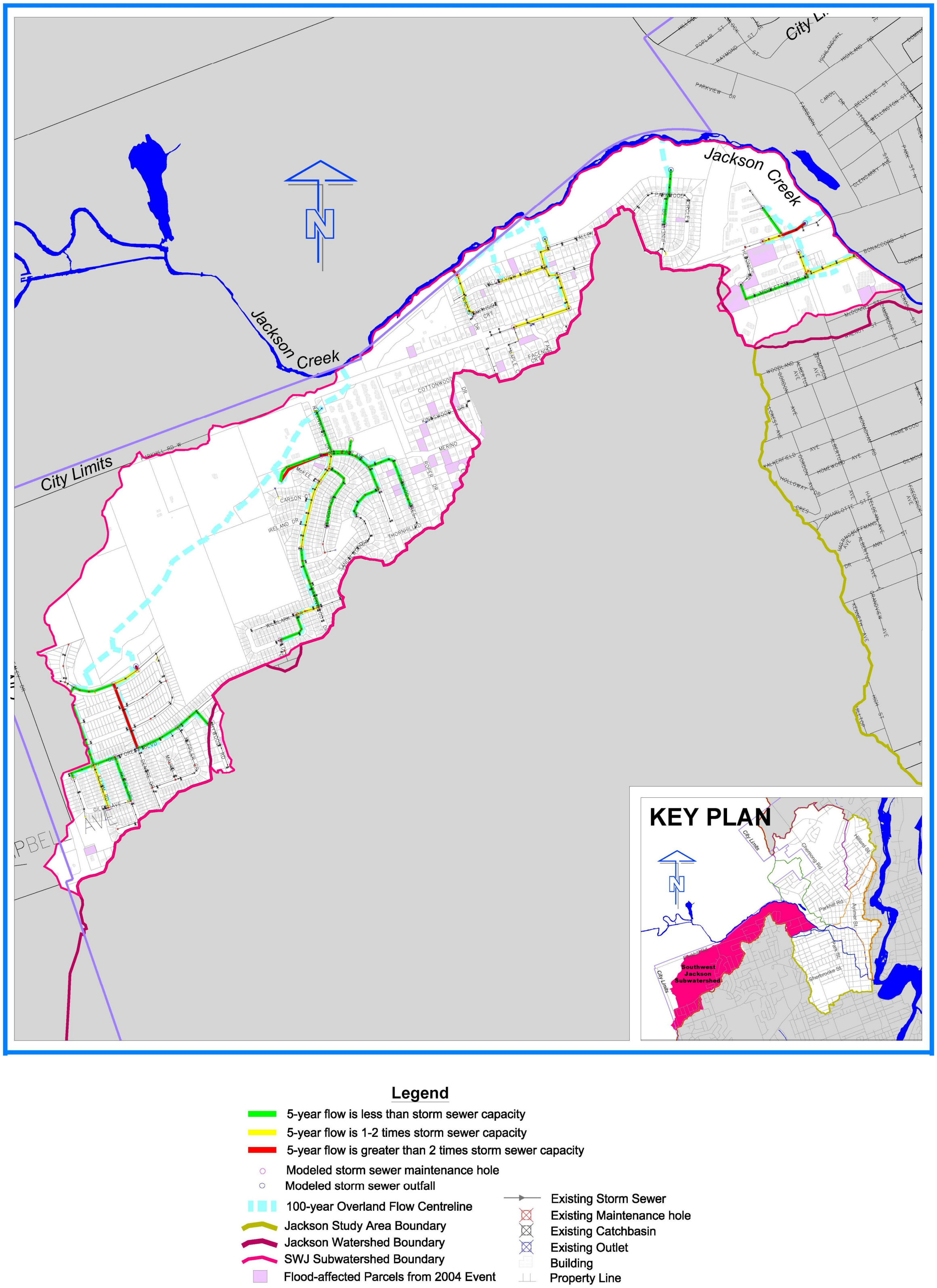
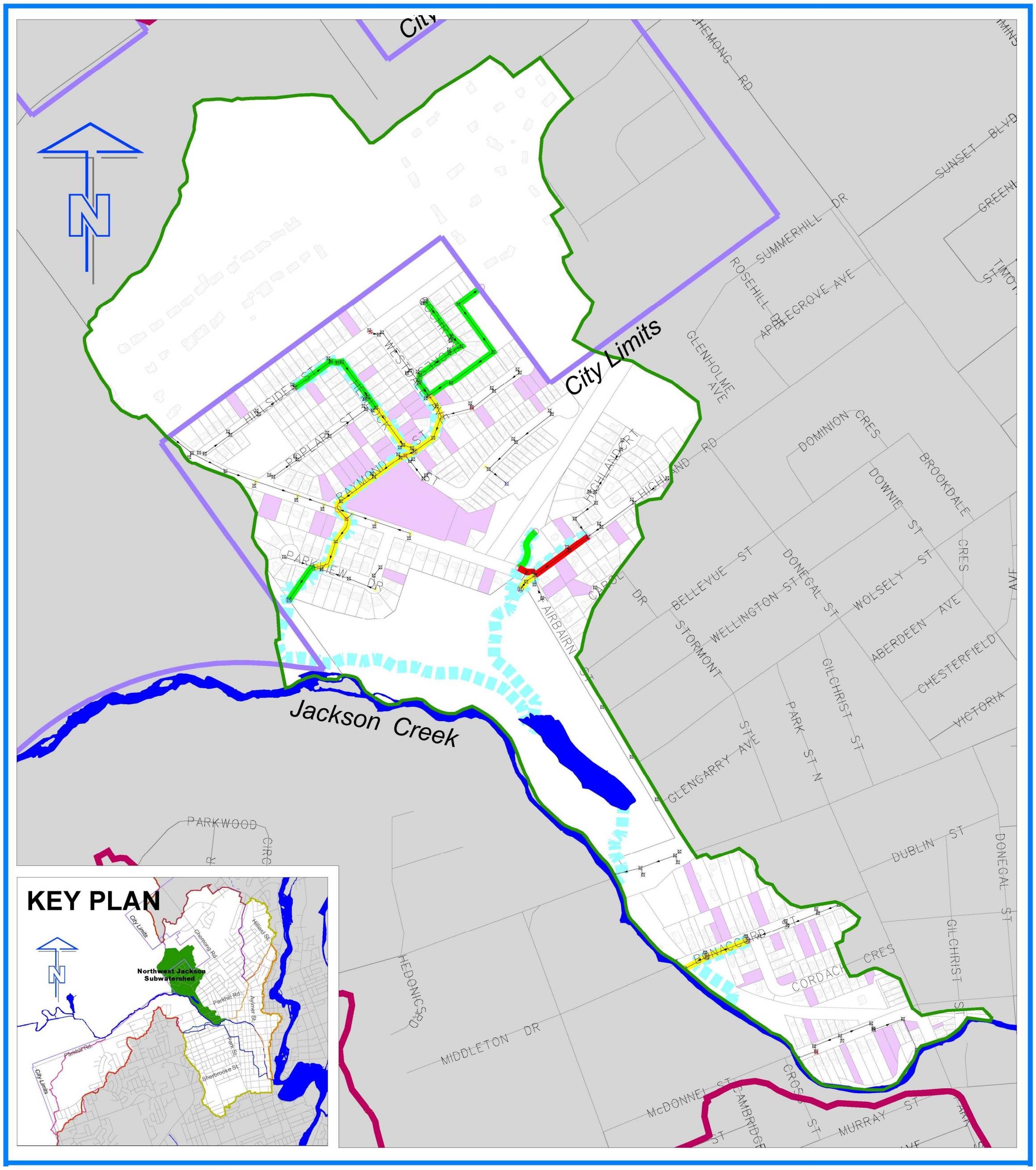


Figure 3.9. Estimated Storm Sewer Capacity – Northwest Jackson



Legend

- 5-year flow is less than storm sewer capacity
- 5-year flow is 1-2 times storm sewer capacity
- 5-year flow is greater than 2 times storm sewer capacity
- Modeled storm sewer maintenance hole
- Modeled storm sewer outfall
- 100-year Overland Flow Centreline
- Jackson Study Area Boundary
- Jackson Watershed Boundary
- NWJ Subwatershed Boundary
- Flood-affected Parcels from 2004 Event
- Existing Storm Sewer
- Existing Maintenance hole
- Existing Catchbasin
- Existing Outlet
- Building
- Property Line

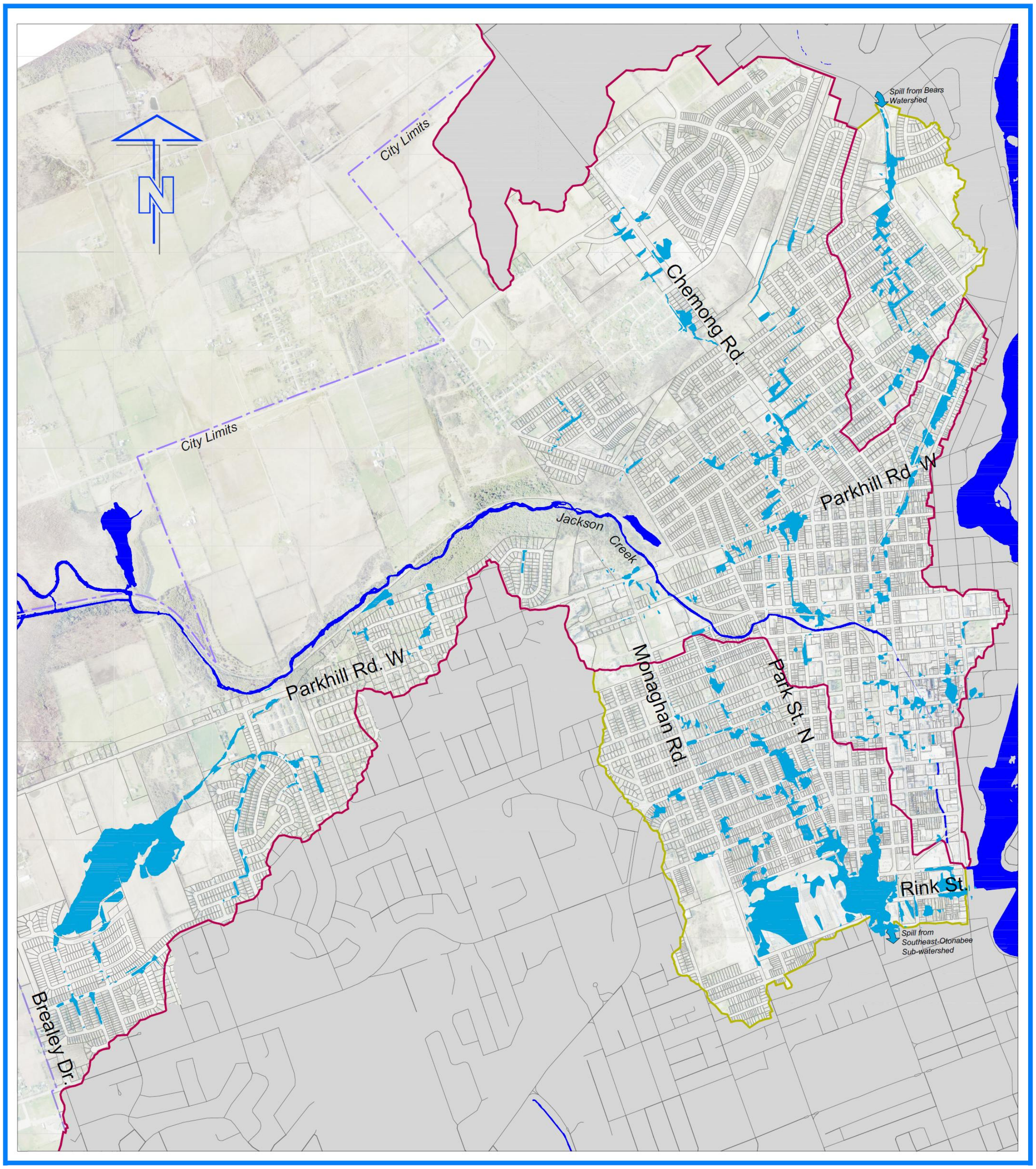
3.2.3 Modelling Approach – Overland Flow

The EXTRAN module of the PCSWMM model was also used to prepare separate hydrographs for the flows entering the storm sewer systems and the excess (major system) flows. The major system flow hydrographs for each catchment include both the flow that cannot reach the storm sewer system due to limited catchbasin capacity, as well as the 'spill' from the storm sewer when the predicted flow exceeds the capacity of the sewer.

The major system hydrographs from the PCSWMM model were imported to a SWMHYMO hydrologic model to route the flows through the overland flow paths to Jackson Creek and the Otonabee River. The overland flow in the depression area was also analysed with SWMHYMO. Overland flow routes through the study area were determined with the aid of detailed topographic mapping, and were confirmed during subsequent site visits. The SWMHYMO model was required, as PCSWMM is not able to simultaneously route flows through both the pipe systems and overland. SWMHYMO is a hydrologic model used extensively throughout Southern Ontario, and has several routines available to add hydrographs together where major drainage systems meet. The model accounts for reductions in peak flows due to ponding and attenuation along the overland flow route, and the time of concentration depending on surface roughness and slope. The SWMHYMO model produced estimates of the peak flow rates along all of the overland flow routes through the study area for both the 5 year and 100 year storm events.

Finally, a HEC-GeoRAS model was created to estimate the maximum flood depths along the overland flow routes through the study area, corresponding to the peak flow rates determined from the SWMHYMO model. The HEC-GeoRAS model was described earlier in Section 3.1.3. The flood elevations determined by the HEC-RAS model were exported to a GIS environment, and the depths and limits of flooding along the overland flow paths were determined. The predicted extent of flooding for the 5 year and 100 year storm events are presented in Figures 3.10, and 3.11, respectively.

Figure 3.10. Jackson Urban Overland Flow – 5-year storm



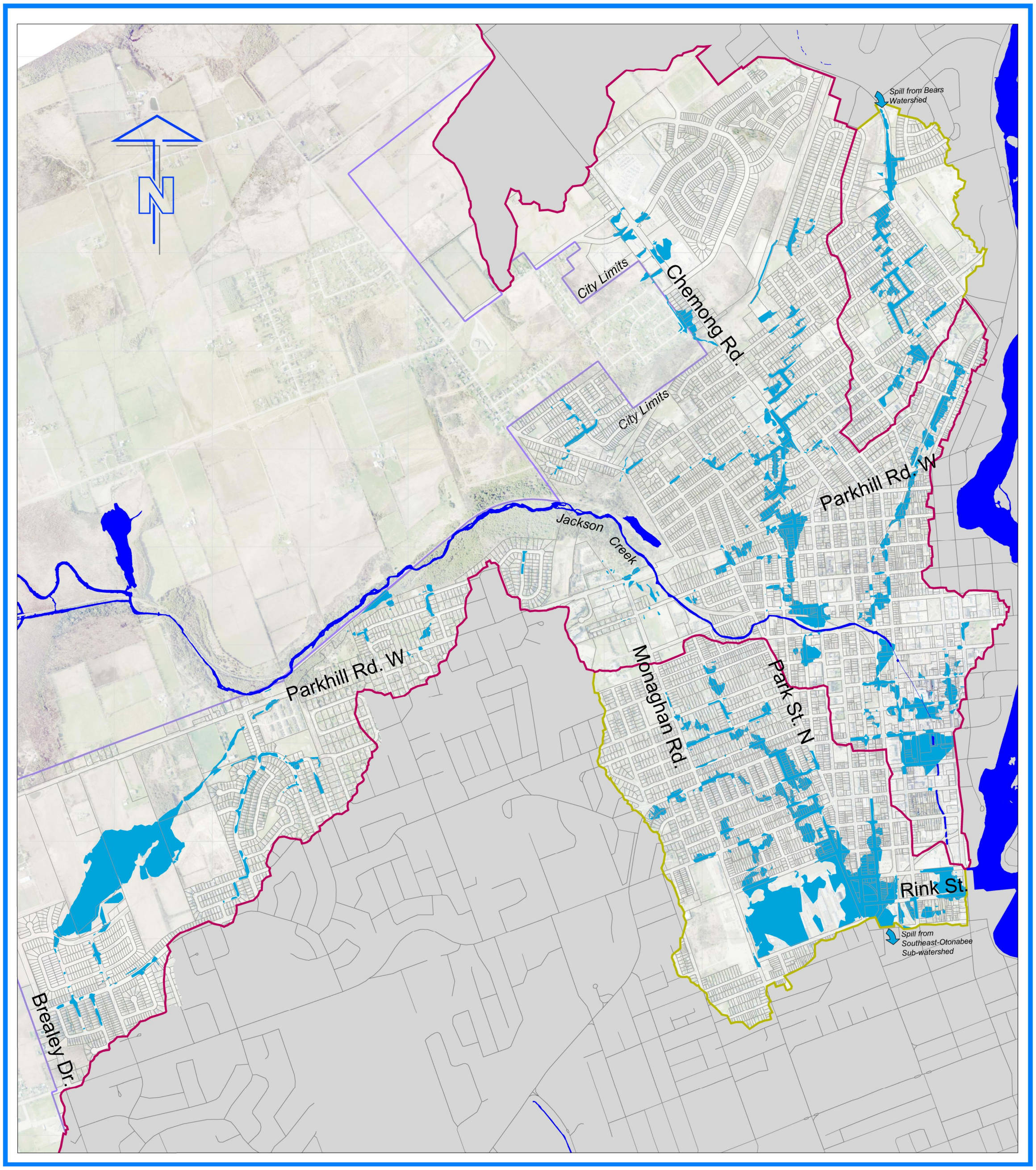
Legend

- 5-year urban overland flow
- Jackson Study Area Boundary
- Jackson Watershed Boundary
- Peterborough City Limits

5-year Damages

$26.5 Million
483 building impacted

Figure 3.11. Jackson Urban Overland Flow – 100-year storm



Legend

- 100-year urban floodlines
- Jackson Study Area Boundary
- Jackson Watershed Boundary
- Peterborough City Limits

100-year Damages

$35.8 Million

663 building impacted

3.2.4 Urban Flood Damages

The City of Peterborough provided AECOM with GIS information representing the lot and building fabric through the study area, as well as the latest property assessments as determined by the Municipal Property Assessment Corporation (MPAC). GIS tools were used to overlay the flood plain mapping along the overland flow routes on the lot and building fabric, and a database of flood impacted buildings and properties was created.

Consistent with the riverine analysis, flood damages from the urban drainage systems were calculated as 20% of the assessed (MPAC) value of the impacted properties, regardless of flood depth or building classification (residential, industrial etc.).

The extent of flooding along the overland flow routes in the Jackson Creek Study area for the 5 year storm event is presented in Figure 3.10. A total of 483 buildings are predicted to be impacted by urban flooding, not including the buildings impacted by the creek flooding. Using 20% of the assessed value of these buildings, damages from the 5 year flood event are estimated to be approximately $26.5 Million.

The 100 year flood plain along the overland flow routes through the study area is illustrated in Figure 3.11. A total of 663 buildings are predicted to experience flooding, resulting in estimated damages of $35.8 Million.

Where there are multiple owners per property and only one building it was assumed that different floors were owned by different people, and so the damage values were based on the largest value (to be conservative). If there was more than one impacted building on a property, they were each counted as part of the damages building count, and damage costs were based on 20% of the property value.

4. Existing Environment

The following sections describe the existing natural, social, economic, and cultural environments within the Jackson Creek Study Area. The characterization of the Study Area identifies the constraints and opportunities that form the basis for selecting the Recommended Solution(s) for flood control. Furthermore, it serves as the baseline for identifying and assessing potential impacts associated with the proposed undertaking(s). Specific information on existing drainage conditions and flood damages through the study area are presented in the next section.

4.1 Natural Environment

Although some lands within the Jackson Creek Study Area are designated for urban residential, rural residential, open space and light industrial uses, the Jackson Creek Study Area includes a number of natural environmental features. Details regarding the Study Area's natural environmental features are provided below.

4.1.1 Physiography and Topography

The Study Area is situated within the Physiographic Region called the Peterborough Drumlin Field. This Region is characterized by elongated oval hills known as drumlins (Chupman and Putnam, 1984). During the late Wisconsinan age, the Study Area was covered by an ice mass advancing southwest to Lake Ontario, which deposited significant amounts of till at its base. As the ice sheet advanced, it shaped the till deposits into drumlins (OMNR 1980a; ORCA, 1983). The bedrock geology of the Study Area is characterized by the Trenton limestone formation of the Ordovician age (Gillespie and Acton, 1981). The Trenton limestone is thinly bedded, with deep glacial till deposits overlying the bedrock. The surficial deposits overlying the bedrock are characterized as thick, moderately stony, calcitic limestone till.

4.1.2 Soils and Agricultural Capability

Soil conditions through the study area were determined from the *Soils of Peterborough County Report, No. 45* (1981). The most prevalent soil type within the Study Area is the Otonabee loam, which develops on rolling moraine of moderately stony, calcareous, loam till (Gillespie and Acton, 1981). The Otonabee loam soils are typically not suitable for cropping, and are generally used for pasture.

Review of the Canada Land Inventory (CLI) Soil Capability for Agriculture mapping indicates that the majority of the soils within the Study Area are mapped as Class 1 soils, and are suitable for agriculture. The exception is an area within the City of Peterborough in the most southerly portion of the Study Area, where the land use is predominantly urban and data is currently not available to classify soil capability.

4.1.3 Fisheries and Aquatic Ecosystems

Jackson Creek is classified as providing warm water fish habitat, and is suspected to provide some cool water fish habitat as well. Fish species have been observed at six watercourse crossings along the creek, according to the June 2006 *Jackson Creek Fisheries Report* prepared by EcoTec.

The investigation completed by EcoTec determined that there are two distinct different fish environments along Jackson Creek. The first being the undisturbed, undeveloped natural upstream section, and the second being the developed residential and downtown section where the creek bed and banks have been altered drastically. The upstream section of the creek is considered to have fair to good habitat for warm and cool water fish, a good capacity for flow attenuation, and a good woody riparian zone. Fish species detected in this reach included blacknose dace, longnose dace, white sucker, creek chub, mottled sculpin, common shiner and pumpkinseed. In the second section of the creek the aquatic habitat is considered to be poor due to channel realignment, bank stabilization, backyard waste dumping, storm sewer pollution, and high peak flow volumes and velocity during storm events. Despite the poor habitat conditions, the reach contained many of the species that were detected in the upstream habitat. The downstream reach also contained young smallmouth bass.

4.1.4 Wildlife Species Composition

The 2006 *Jackson Creek Terrestrial Report* completed by EcoTec recorded a list of potential bird, mammal and plant species within its study area (i.e. from the City of Peterborough's municipal boundary to the Otonabee River/Little Lake).

The 2001 *Loggerhead Marsh Management Plan* reported approximately 19 breeding bird species and 130 migratory bird species within the vicinity of Loggerhead marsh in the in the southwest portion of the study area. In the 2006 *Jackson Creek Terrestrial Report s*everal other birds and mammals were also listed as habitants of the Jackson Creek study area. The following were spotted during the field investigation.

Canada goose (*Branta Canadensis*)
Mallard duck (*Anas platyrhynchos*)
American crow (*Corvus brachyrhynchos*)
Rock dove (*Columba livia*)
Chipping sparrow (*Spizella passerine*)
Great blue heron (*Ardea Herodias*)
Swallow (*Hirundo sp*.)
Raccoon (*Procycon lotor*)
Muskrat (*Ondatra zibethicus*)

There are some other mammals that are assumed to live within the study area, such as beaver (*Castor Canadensis*), while tailed deer (*Odocoileus virginianus*), skunk, and grey squirrel among others.

Some of the animals determined to inhabit the study area have been defined by the Ministry of Natural Resources as rare within the local area as well as the province. Some of these animals include the Red-shouldered Hawk (*Buteo lineatus*), the Loggerhead Shrike (*Lanius ludovicianus*), the Least Bittern (*Ixobrychus exilis*), the five-lined skink (*Eumeces saucium*), the Blanding's turtle (*Emydoidea blandingi*), and the eastern red damsel (*Amphiagrian saucium*).

The only plant species in the within the study area that was determined to be vulnerable was the ram's head lady's slipper (*Cypripedium arietinum)*. More information on species at risk can be found in the next section.

4.1.5 Species at Risk

A review of the Ministry of Natural Resources (MNR) Natural Heritage Information Centre (NHIC) database[1] for rare, threatened and endangered species was conducted. There are 24 species at risk listed for NTS Map Sheet 31 D08. As noted below, three species are considered as "threatened", four are considered as "special concern", while three are considered to be "endangered". When referenced to the corresponding NTS map sheet, the NHIC indicates the following species.

Least Bittern (*Ixobrychus exilis*)	Threatened
Red-shouldered Hawk (*Buteo lineatus*)	Special Concern
Black Tern (*Chlidonias niger*)	Special Concern
Loggerhead Shrike (*Lanius ludovicianus*)	Endangered
Yellow-breasted Chat (*Icteria virens*)	Special Concern
Henlow's Sparrow (*Ammodramus henslowii*)	Endangered
Blanding's Turtle (*Emydoidea blandingii*)	Threatened
Five-lined Skink (*Eumeces fasciatus*)	Special Concern
Eastern Hog-nosed Snake (*Heterodon platirhinos*)	Threatened
Butternut (*Juglans cinerea*)	Endangered

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is mandated to assess and designate wildlife species that are considered to be in danger of becoming extinct in Canada. A search of the COSEWIC database revealed the same status for the above species. The noted exceptions being the Blanding's Turtle which COSEWIC lists as "endangered" (2005) and the Black Tern which COSEWIC lists as "Not at Risk" (1996).

A search of Environment Canada's Species at Risk website database was also carried out. Based on this search, the following significant species were identified under the federal *Species at Risk Act* (SARA).

Least Bittern (*Ixobrychus exilis*)	Threatened
Henlow's Sparrow (*Ammodramus henslowii*)	Endangered
Butternut (*Juglans cinerea*)	Endangered

4.1.6 Significant Natural and Environmentally Sensitive Areas

The Jackson Creek study area is comprised of low lying mixed forest, edge habitat, upland mixed forest and urban riparian areas according to the June 2006 *Jackson Creek Terrestrial Report*. The naturally forested area along Jackson Creek should be considered sensitive since it provides a significant natural buffer for the creek; it is habitat for local wildlife and is used for nature-based recreation and ecological studies. The creek flows through many natural areas upstream of the City Limits, some of which are Bests Pond, Cavan Bog, Jackson Creek wetland, Lily Lake and other small wetlands. Cavan Bog and Jackson Creek wetland are considered Provincially Significant Wetlands. Other natural feature within the study area are Jackson Creek Kiwanis Trail, Loggerhead Marsh, Jackson Creek Drumlins and Cavan Swamp (EcoTec, 2006).

4.2 Socio-Economic Environment

4.2.1 Land Use

The Study Area overlaps the City of Peterborough, the County of Peterborough and the City of Kawartha Lakes. Within the County of Peterborough, the study area includes the Townships of Smith-Ennismore-Lakefield and Cavan-Monaghan.

Peterborough County has a 2-tier planning system whereby planning responsibilities are divided between the County and its area municipalities. From a planning perspective, the proposed undertaking, that is, implementation of flood control measures, may impact the Counties (upper-tier municipality), the Townships within the counties, and the City of Peterborough (lower-tier municipalities). Given that they are each responsible for regulating land use and establishing policies for physical, economic and social development within their respective jurisdiction, details regarding the applicable planning policies for each are provided below.

County of Peterborough

The County of Peterborough Official Plan was amended and consolidated in 2006. This Plan sets out the general direction for planning and development in the County, and implements a strategic approach to land use planning based on a watershed planning process.

The intent of the Official Plan is to direct and guide the actions of local municipalities and the County in policy planning and physical planning on a very broad basis. Local municipal official plans complement the Peterborough County Official Plan by providing detailed strategies, policies and land use designations for the planning and development at a local municipal level.

The City of Peterborough

Policies contained within the City of Peterborough's Official Plan regulate the use for much of the lands within the southern portion of the Study Area (i.e. lands under the jurisdiction of the City of Peterborough).

The majority of the lands in the Study Area within the City of Peterborough are designated for Residential-type land uses. Residential land uses permit low, medium and high density housing and other uses that are considered to be supportive of a residential environment, such as local commercial, home occupation, public and institutional uses, as well as parks, recreation areas, churches and special care facilities. The east end of the study area consists of the City's downtown core and permits a range of commercial activities, such as retail, business, hotels and restaurants.

In addition, the City's Official Plan designates some lands adjacent Jackson Creek as Major Open Space and Protected Natural Areas. These designations refer to areas of habitat of endangered or threatened species, significant wetlands and local environmental significant areas. They may also apply to fish habitat, woodlands, valley lands, wildlife habitat and are for natural and scientific interest. Uses are limited to nature based recreation, outdoor education and non-destructive research, horticulture, conservation, forestry, wildlife management, natural storm water management and trails for non-motorized transportation.

Schedule C of the Official Plan also designates lands within 30 meters of Jackson Creek as "Lands Adjacent to Fish Habitat". The only exception to this designation is where the creek is piped underground in the downtown portion of the study area.

4.2.2 Cultural Environment

Approximately 114 sites within the County of Peterborough are registered with the Ministry of Culture. These registered sites suggest that humans have occupied the area since the early Archaic and late Paleo-Indian period dating back 10,000 years (Horne, pers. Comm., 1998). Soldiers who accompanied the French explorer, Samuel de Champlain, were believed to be the first Europeans to enter the Peterborough region in 1615. They traveled with a tribe of the Lake Ontario Iroquois peoples known as the war party of Huron, to reach the Onondaga of the Five Nations Iroquois to the south of Lake Ontario. Their route followed a chain of lakes and rivers linking Georgian Bay and the Bay of Quinte.

During the eighteenth century, Europeans infrequently traveled on routes along the Kawartha Lakes and Trent River. This area was mainly occupied by Aboriginal peoples and their travels. By 1798, the province of Upper Canada introduced the Newcastle District which encompassed the entire Peterborough region. The pressure of further immigration introduced new settlers into this region from Lake Ontario's north shore. Settlers traveled northerly from Lake Ontario following major water routes, such as the Trent and Otonabee Rivers.

The Peterborough area experienced a period of agricultural settlement between 1818 and 1850. During this time, immigrants from Ireland (circa 1825) and Britain (circa 1831) came to settle in the Peterborough area.

Rivers and lakes in the Peterborough area changed substantially with the introduction of canal locks and dams as a result of economic development during the mid and late 19th Century. Towns and villages throughout the Peterborough area were influenced by lumbering activity, such as that produced from processing mills and transportation facilities. Lumbering activity in the Peterborough area thrived from the 1850's until the introduction of stream-driven mills and the Lindsay-Toronto railway line in the mid-1960's.

5. Alternative Solutions

As described in the previous sections, flooding through the Jackson Creek study area is due to both deficiencies in the urban drainage systems and capacity restrictions/high water levels in Jackson Creek. The mechanisms for flooding are different for urban versus creek drainage systems; consequently potential measures to remediate urban and creek flooding have been developed and evaluated separately.

5.1 Riverine Drainage Systems

Simply put, flooding along Jackson Creek is due to the system receiving more water than can be contained within the channel corridor / conveyed through bridges, culverts and constrained areas. Flood damages can therefore be reduced by decreasing the peak flow to the capacity of the system, increasing the capacity of the system to carry the peak flow, or a combination of the two. Future flood damages can also be reduced by removing flood prone structures or renovating structures to prevent water from entering.

5.1.1 Peak Flow Reduction Solutions

As discussed in Section 3.1.2, the Jackson Weir is an existing structure located immediately downstream from Lily Lake. The weir was designed to restrict the flow in Jackson Creek and store floodwater in Lily Lake and the surrounding wetlands. The existing weir consists of a 4.6 m wide opening extending from the stream bed to an elevation of 236.8, above which a 16 m wide opening extends to the top of the weir at 238.0 m. The total width of the weir is approximately 39 m. During the planning for the weir, easements were secured over the lands that were potentially subject to flooding due to the weir.

To reduce flooding through Jackson Creek, alternative retrofits of the existing Jackson Creek weir were investigated. The initial alternatives involved maintaining the existing notch widths at the weir, but raising the weir crest by 0.3 m and then by 0.5 m. The revised weir discharges at different elevations were re-calculated using the HEC-RAS model, and the resulting stage-storage-discharge table was input to the SWMHYMO hydrology model. It was determined that by raising the weir crest by 0.5 m, the Regional storm peak flow rate at the Jackson Weir (and downstream) would be reduced by approximately 10 %, and would result in a 10 cm increase in water levels at Lily Lake during the Regional storm. The 10 % reduction in peak flow rates at the Jackson Weir during a Regional storm event would not result in any reduction in flood damages.

An additional scenario was evaluated, in which it was assumed that the existing weir would be narrowed, such that the 4.6 m wide notch would extend up to an increased weir crest elevation of 239.0 m. The analysis determined that the weir could reduce the Regional storm peak flow rate by 40%, and would result in a 70 cm increase in flood levels at Lily Lake. The increased Regional flood plain upstream of the weir would extend beyond the existing easements, and therefore additional easements would need to be secured over the expanded flood plain. As well, the high (3 m) and narrow weir opening required for this alternative would pose significant structural challenges. It would likely necessitate the construction of a formal flood control dam at this location to safely regulate the flow in Jackson Creek.

Even with the 40% reduction in peak flow rates, the Regional storm flow downstream through Jackson Creek would remain well in excess of the current 100 year peak flow rate, and would still result in significant flood damages. It was further determined that, even if the flow from the rural areas of the watershed were eliminated, the peak flows from the urban areas of Jackson Creek would be sufficient to cause significant flood damages. It was therefore concluded that it is not feasible to reduce peak flow rates in Jackson Creek through modifications to the existing Jackson Weir.

At the second public open house, it was suggested that a control structure could be constructed on Jackson Creek upstream of Parkhill Road to store flood water in the former quarry in Jackson Park. Following the open house, AECOM staff explored this alternative. It was determined that the former quarry could store approximately 1.5 ha*m of floodwater. This is insignificant relative to the storage volume of more than 200 ha*m above the Jackson Weir. The investigations into the retrofit of the Jackson Weir determined that an additional storage volume of approximately 11.5 ha*m would reduce the Regional storm peak flow rate by only 10%. It was concluded that a second flood control reservoir in Jackson Park would not result in any meaningful reduction in peak flow rates in Jackson Creek.

5.2 Riverine System Capacity Solutions

Several potential options are available to increase the flow carrying capacity of Jackson Creek. The alternatives considered include: constructing a new diversion channel to convey high flows in Jackson Creek around the City to the Otonabee River; constructing a new diversion sewer within the City to convey excess flows in Jackson Creek to the Otonabee River, and re-constructing Jackson Creek to a new, natural valley corridor through the City of Peterborough. Each of these alternatives are described below:

5.2.1.1 Division Channel Downstream of Jackson Weir

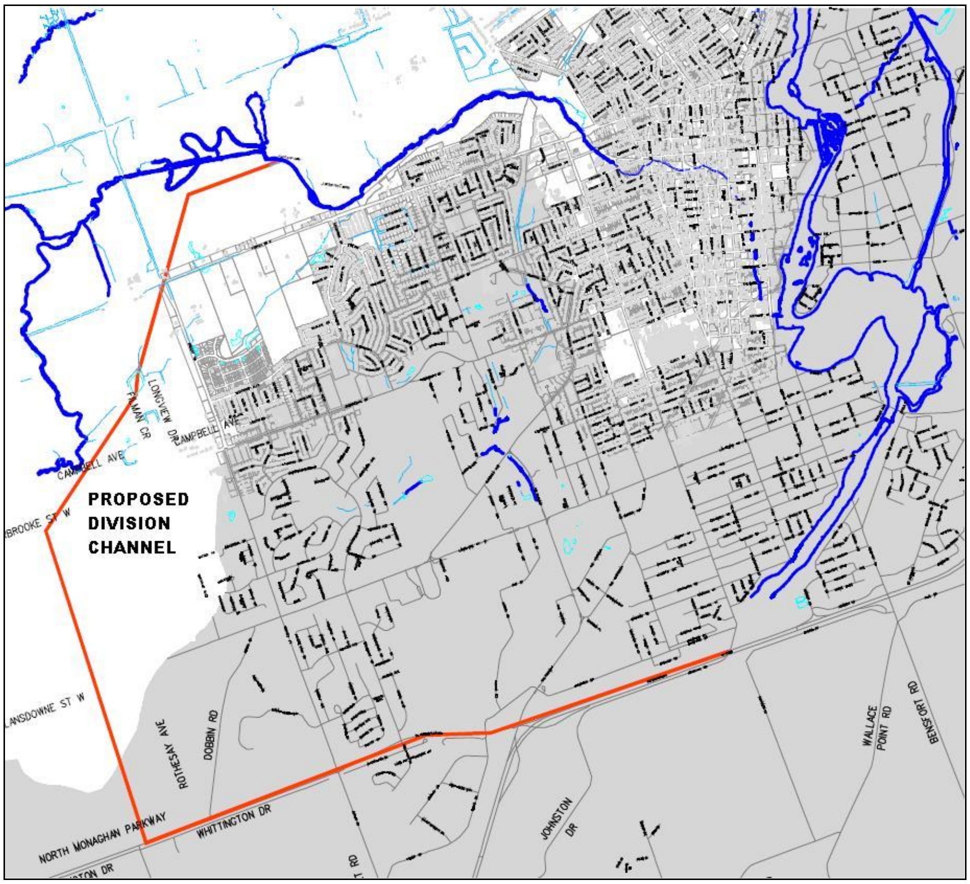
A diversion channel could be constructed to convey excess flows in Jackson Creek around the City to the Otonabee River. The flow delivered downstream to Jackson Creek would be limited to or below the capacity of the existing system, and the excess would be diverted around the City in the new channel.

A potential diversion channel alignment is illustrated in Figure 5.1. The channel starts immediately downstream of Jackson Weir, then extends south-west at the un-developed area west of Brealey Rd., and extends east along Highway 7 towards the Otonabee River ending at Lock 19. The diversion channel would be approximately 11 km long and would have an average slope of approximately 0.7 %. Construction of the channel would require a significant amount of earthworks, with an estimated cost of approximately $ 43 Million.

The diversion channel would also require property purchases or easements, and would require routine inspection and maintenance. There would be significant impacts to the natural environment, both due to short term construction impacts, and longer term impacts due to the diversion of flows from smaller tributaries intersecting the channel alignment.

Even with the Diversion Channel, there would continue to be flood damages through the urban portions of the watershed. Jackson Creek does not have adequate capacity to safely convey the peak flow rates from the urban portions of the watershed (downstream of the Jackson Weir) during the 100 year storm event. While flood damages would be reduced during the Timmins storm event, there would continue to be damages of approximately $8.6 Million resulting from the 100 year storm.

Figure 5.1. Potential Diversion Channel Alignment



5.2.1.2 Division Sewers to the Otonabee River

The existing extent of flooding for the 100 year and Regional storm events are illustrated in Figures 3.2 and 3.3, respectively. They show that the majority of the properties and structures impacted by flooding are located south of McDonnel Street, where the Jackson Creek channel has been highly impacted.

A relief storm sewer could be constructed to divert excess flows from this section of Jackson Creek eastward to the Otonabee River during large storm events that would otherwise cause flooding in the urban areas of Jackson Creek.

The HEC-RAS model was used to determine the capacity of the Jackson Creek channel downstream of Bethune Street. It was determined that the existing system can convey a peak flow of up to approximately 15 m^3/s without flooding adjacent properties and structures. The Regional storm peak flow is more than 80 m^3/s. It is not feasible to construct a diversion sewer to convey the excess Regional storm flow underground to the Otonabee River.

The reduced standard of protection to the 100 year storm event was examined. Through the critical areas in the downtown area, the 100 year peak flow in Jackson Creek is predicted to be 46 m^3/s. To prevent flooding during the 100 year storm event, the relief sewer would need to convey a peak flow of 46 – 15 = 31 m^3/s.

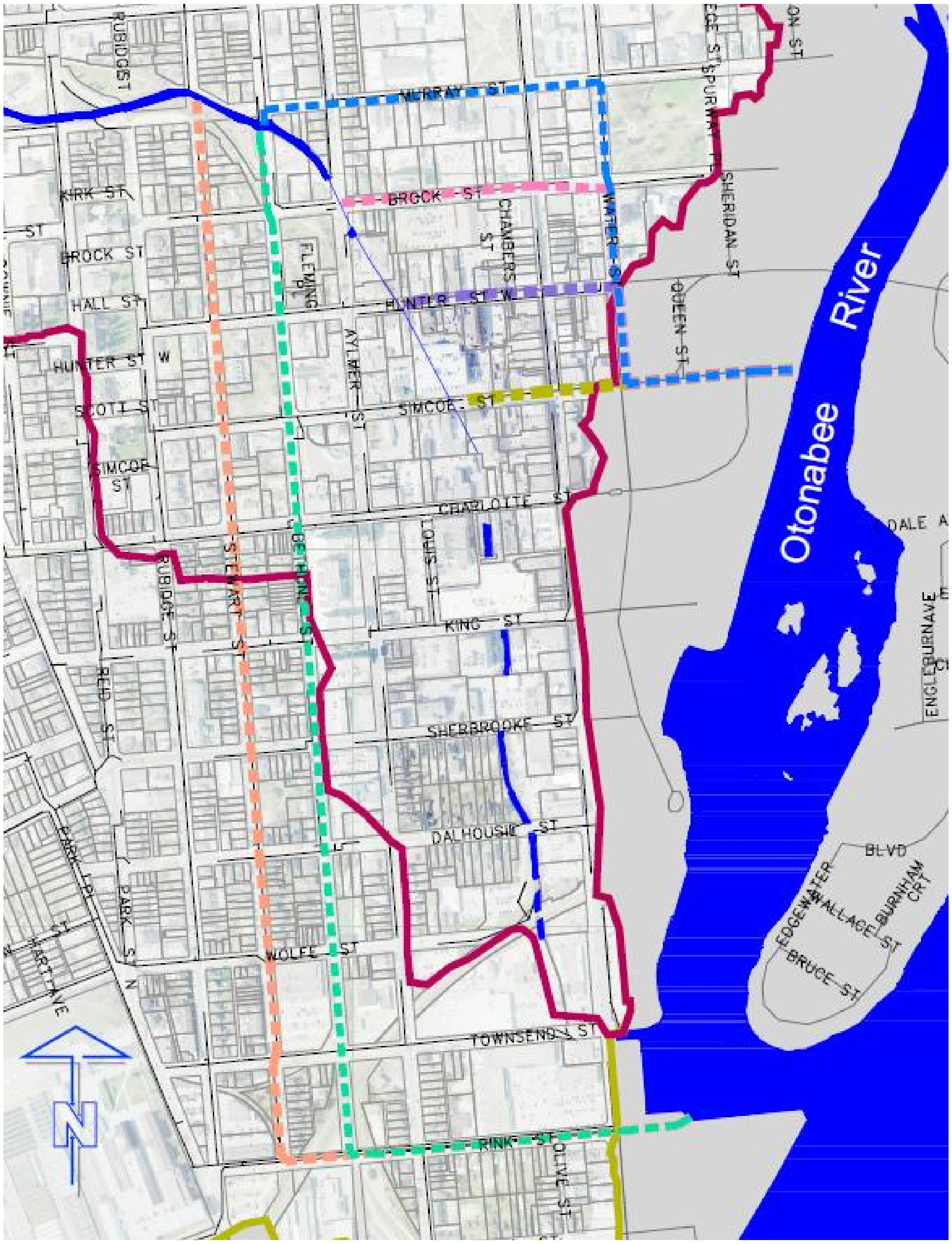
There are a number of potential alternative alignments for a diversion sewer to the Otonabee River. One of the better sewer alignments would extend from Jackson Creek along Murray Street, then southward on Water Street, and finally eastward on Simcoe Street to the Otonabee River. This alignment intercepts the flows at the upstream end of the critical flooding area, and could also be serve as an upgraded storm sewer to alleviate urban flooding in this area (the existing storm sewers on Water Street and Simcoe Street currently do not have adequate capacity). However, there are many other suitable alignments, as shown in Figure 5.2. Further study is required to determine the best alignment for the diversion sewer, considering planned road upgrades, conflicts with existing utilities, and co-ordination with recommended upgrades to the urban drainage systems (Section 5.2).

The Murray Street – Water Street – Simcoe Street alignment was used to develop a preliminary cost estimate for this alternative. It was determined that a 3.0 m circular pipe or a 3.0 m wide x 2.1 m high concrete pipe box section would be required to convey the relief flow of 31 m^3/s. The cost to install this 1100 m long diversion sewer is estimated to be approximately $6.5 Million.

The HEC-RAS model for existing conditions was updated to reflect the revised flows in Jackson Creek downstream of the diversion storm sewer. It confirmed that flows would be contained within the existing channel through the urban area during the 100 year storm event, with no buildings impacted by flooding.

The HEC-RAS model was also used to estimate the extent of flooding along Jackson Creek during the Regional storm event with the diversion sewer in place. The model predicted that approximately 30 buildings would be removed from the flood plain relative to current conditions, reducing flood damages by approximately $3 Million for the Regional storm event. Increasing the size of the diversion storm sewer could further reduce flows and flood damages, but is not capable of eliminating flood damages during a Regional storm event.

Figure 5.2. Potential Diversion Sewer Alignments



5.2.1.3 Culvert Upgrades

The capacity of Jackson Creek could be improved by replacing any culverts that act as bottlenecks in the system through the urban areas. In this alternative, the potential to alleviate flooding through culvert replacements was examined.

Through much of the urban area, the capacities of the culverts are comparable to the capacity of the small open channels connecting them. Therefore, improved capacity cannot be achieved through culvert replacements alone. Furthermore, many of these culverts extend beyond the road right-of-way and are located under buildings and other structures. These culverts could not be significantly upgraded without first removing the buildings over them. It was concluded that it is not feasible to improve flow capacity through culvert upgrades.

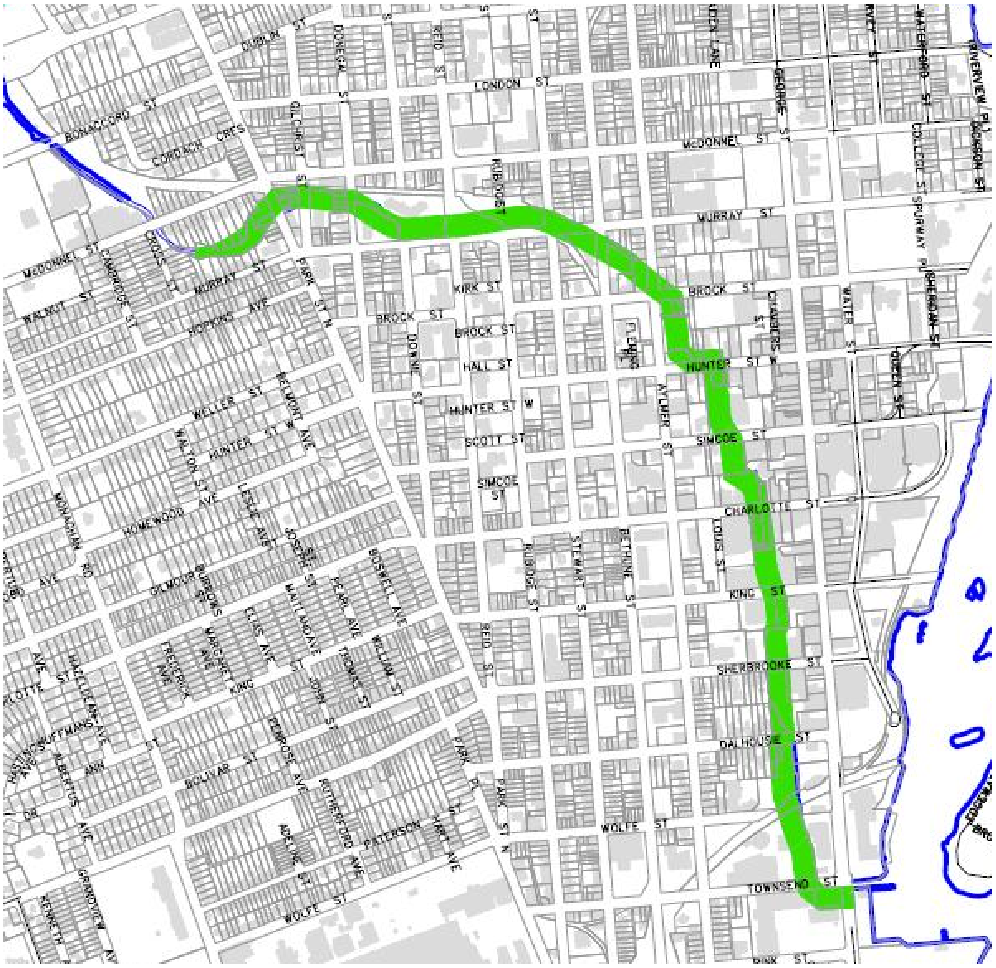
5.2.1.4 Reconstructed Jackson Creek Valley Corridor

In the previous section, it was noted that the existing Jackson Creek channel through the urban area does not have capacity for the Regional storm event. To safely convey the Regional flood through Jackson Creek to the Otonabee River, the channel itself must be reconstructed to a more natural form.

A conceptual configuration was prepared for a naturalized Jackson Creek corridor through the urban area. It would consist of a 5 m wide x 0.75 m deep low flow channel, and 5 m wide overbank areas on each side of the channel to convey larger storm events. The reconstructed channel would need to be approximately 2.75 m deep to safely convey the Regional storm peak flow rate. With the reconstructed valley walls at a safe side slope of 5H:1V, the channel corridor would be approximately 40 m wide.

The costs associated with this alternative include approximately $3 Million for channel reconstruction, $4 Million for culvert replacements across the reconstructed channel corridor, and approximately $18 Million to obtain property for construction of the corridor. A potential corridor alignment is illustrated in Figure 5.3.

Figure 5.3. Potential Naturalized Jackson Creek Valley Corridor



5.2.2 Flood-Proofing Solutions

Public purchase and removal of flood prone structures was also considered as a flood reduction alternative. While this may be a cost-effective solution over a very long term planning horizon, it represents a very significant initial cost, with considerable social disruption. In addition, as roadways through the study area would remain overtopped and impassable during severe storm events, there may continue to be issues accessing the remaining homes in the study area during such events. Purchasing all flood prone properties was therefore not carried forward for further evaluation.

The final solution examined to reduce flood damages was flood proofing structures that could be impacted by flooding during the Regional storm event. Due to the alignment of the creek and road crossings through the urban portion of the watershed, regional-scale flood proofing alternatives such as dykes or floodwalls are not feasible. Individual residences could be re-constructed/flood-proofed to eliminate basement openings and to include watertight ('submarine') doors, windows, and cladding. However, these measures, while frequently quoted as an alternative solution, and potentially quite cost effective, are not widely applied in practice, may reduce the aesthetic appearance and value of the house, would require restrictions on ownership, (to avoid the flood proofing measures being removed and replaced with conventional doors and windows and new openings during future renovations), and would be subject to human error, (an open door or window won't be water tight). Flood proofing measures were therefore not carried forward for further evaluation.

5.2.3 Evaluation of Alternative Solutions

5.2.3.1 Evaluation Criteria

The above solutions to reduce flooding from Jackson Creek were evaluated against a number of criteria, which are described in the table below. They reflect mandatory criteria to satisfy the Environmental Assessment process, and concerns and priorities raised at the public open houses. The feedback from the first Public Open House ranked engineering applicability as the most important criterion, followed by social factors and cost, and lastly the natural environment.

Table 5.1: Evaluation Criteria

Category	Considerations
Natural Environment	Impacts on terrestrial habitat and wildlife Impacts on aquatic habitat Impacts on ground and surface water quality and quantity
Social Environment	Need for property acquisition Long-term community impacts (i.e. recreation opportunities) Short-term construction impacts (noise, dust, etc)
Economic Environment	Land acquisition cost Construction cost Operation and maintenance costs
Technical Environment	Reduction in anticipated flood damages Technical feasibility / complexity Time required for implementation

5.2.3.2 Evaluation Summary

The following table summarizes the evaluation of the alternative solutions to reduce flood damages associated with the flow in Jackson Creek.

Table 5.2: Evaluation of Alternatives – Riverine Drainage System

Criteria	Alternative			
	Do Nothing	Diversion Channel	Diversion Sewer to the Otonabee River	Naturalized Jackson Creek Valley Corridor
Natural Environment				
Terrestrial Habitat and Wildlife	No impacts anticipated	There will be considerable impacts to habitat along the diversion channel alignment	Few impacts are anticipated, as works are located within the road ROW	Additional habitat would be created within the naturalized corridor
Aquatic Habitat	High flow velocities at restricted locations may result in scour and erosion, damaging fish habitat	Aquatic habitat may be impacted due to the diversion of flows	No impacts are anticipated, as the works are located outside the channel	Aquatic habitat would be improved through the urban area
Surface and Ground Water Quality and Quantity	No impacts anticipated	No impacts anticipated	No impacts anticipated	Water quality could be improved by the naturalized corridor
Social Environment				
Property Acquisition / Displacement	No property required	Property must be obtained for the diversion channel	No property is required, as the works are confined to the road ROW	A large number of properties must be acquired and many structures must be removed for the channel corridor
Long Term Community Impacts	Continued exposure to flooding from Jackson Creek during severe storm events	Few impacts are anticipated	Few impacts are anticipated	The naturalized corridor could include trails, and would benefit the community
Short Term Construction Impacts	No impacts anticipated	Moderate, as a significant length of channel construction is required	Minor, as the works could be co-ordinated with scheduled road reconstruction	Major, as extensive works are required to create the corridor

Criteria	Alternative			
	Do Nothing	**Diversion Channel**	**Diversion Sewer to the Otonabee River**	**Naturalized Jackson Creek Valley Corridor**
Economic Environment				
Property Acquisition and Construction Costs	No property required	Property and construction costs: $43 Million	Construction costs: $6.5 Million	Property and construction costs: $25 Million
Operation and Maintenance	Regular removal of debris along creek corridor is required to prevent blockage of the restricted culverts	Regular removal of debris along creek corridor will remain required to prevent blockage of the restricted culverts, and the diversion channel will require regular inspection and maintenance	Regular removal of debris along creek corridor will remain required to prevent blockage of the restricted culverts,	Limited maintenance will be required within the naturalized corridor
Technical Environment				
Anticipated Flood Damage Reduction	No reduction in flood damages ($8.6 Million for the 100 year event)	Jackson Creek will continue to be subject to flooding from the urban areas downstream of the diversion channel ($8.6 Million in flood damages for the 100 year event)	There will be no flood damages during the 100 year event. Flood damages will be reduced by approximately $3 Million for the Regional Storm	The Regional flood would be confined to the corridor, with no flooding or damages to private property
Technical Feasibility / Implementation	N/A	Many potential difficulties due to the significant length of channel and road crossings	Moderate, but the works can be implemented relatively quickly	It will take a long time to acquire properties and implement the new channel corridor.
Overall Evaluation	Flooding and flood damages are not reduced – the problem is not addressed	Flood damages through the urban area will not be eliminated, and there are considerable impacts to the natural and social environment	**Preferred Alternative** Flood damages will be significantly reduced for the 100 year storm event, and the works can be implemented relatively easily	This alternative is extremely expensive, and would take a very long time to implement

The diversion sewer to the Otonabee River has been selected as the preferred alternative to mitigate damages from flooding in Jackson Creek. The diversion channel is the most expensive and most technically difficult alternative, produces the greatest environmental impact, and does not completely eliminate flood damages along Jackson Creek. It is clearly the least preferred alternative. A reconstructed, naturalized stream corridor through the urban area could eliminate flood damages and provide many social and environmental benefits. However, it would require acquisition of more than 50 separate properties, 17 culvert replacements and would be technically challenging to construct. The diversion sewer alternative has been selected as it results in few environmental impacts, can be implemented relatively quickly and is a cost-effective means of reducing flood damages for the 100 year storm event. The design and construction of the sewer may be difficult, but not nearly as difficult as the other alternatives.

The diversion sewer was presented as the preferred solution at Public Open House # 2. Based on feedback received at the meeting and on comment forms (See Appendix A), the majority of the attendees agreed that the diversion sewer was the preferred solution.

5.3 Urban Drainage Systems

Flood levels in Jackson Creek have some influence on the extent of flooding along the urban drainage systems through the study area. As the storm sewers through the Jackson Creek watershed outlet to the creek, high water levels in the creek during flood events can diminish the capacity of the sewer systems and even contribute to flooding through storm sewer back-ups.

Therefore, before developing flood reduction solutions, the urban drainage systems were re-analyzed to assess potential flood damages if flooding in Jackson Creek were remediated through construction of the diversion sewer under Murray Street. Eliminating storm sewer restrictions caused by high water levels in Jackson Creek can reduce some flooding mostly in the Northeast Jackson and Southeast Jackson sub-watersheds, but flood damages from the urban drainage system would still be in excess of $35.4 Million for the 100 year storm event.

5.3.1 Flow Reduction Solutions

Flow attenuation (storm water management ponds or tanks) can be a very effective method of reducing peak flows, and allowing existing or less expensive smaller diameter pipes to be utilised downstream of the tank or pond. In order to be effective, flow attenuation typically requires a minimum of approximately 1 metre elevation drop in the collection system at the tank or pond, location in the approximate middle of the drainage system, an upstream area typically in excess of 5 ha and ongoing maintenance to remove accumulated sediments from a tank.

As the majority of the storm sewers within the study area do not provide 5 year conveyance, their utilization as part of a 100 year flow reduction system was not found to be viable. Similarly, in the instances examined, the savings in downstream pipe costs were not sufficient to offset the cost of a tank.

Utilization of surface storage in lieu of a tank was briefly examined, however the associated property (6:1 side slopes down 3+ metres) removed this option from further consideration.

5.3.2 Urban System Capacity Solutions

The targeted solution is to bring the study area up to current storm drainage standards, such that there are no flood damages for storm events up to and including the 100 year return period storm event.
The first alternative developed proposes to achieve this goal by upgrading all of the storm sewer systems through the study area to convey the 100 year storm flow. If sufficient catch basins were provided and cleared of debris through regular maintenance programs, there would be no overland flow from the urban areas, and therefore no flood damages. Implementation of this solution would require almost all of the roads through the study area to be reconstructed for replacement of the existing sewers.

Recognizing the significant expense and disruption to replace all storm sewers through the study area, a second alternative was developed consisting of several localized upgrades in combination. Overland flow during severe storm events is not a significant concern, provided it is confined to municipal right of ways and easements. The storm sewer systems through the study area were examined to identify key capacity restrictions, or 'bottlenecks' where localized sewer upgrades would be appropriate. These storm sewers are proposed to be replaced in this alternative. The storm sewers were also analysed for longer sections of storm sewer that are under capacity that would warrant a parallel storm sewer to capture and convey the excess runoff. These two solutions were considered in combination with additional catch basins where warranted and localized re-grading to prevent or contain overland flow.

5.3.3 Flood-Proofing Solutions

For the same reasons presented above, flood proofing solutions such as the purchase of all flood prone properties or reinforcing structures to be water-tight were not carried forward for further evaluation.

5.3.4 Evaluation of Alternatives

The alternative solutions to reduce flooding from the urban drainage systems through the study area were evaluated against the same criteria presented in Table 5.3. Note that almost all of the work associated with the improvements will occur within the developed road right-of-ways or in manicured rear yard areas. Therefore, the impacts of the solutions on the natural environment are minimal, provided that appropriate sediment and erosion control practices are employed during implementation of the solutions.

The evaluation of the alternative urban drainage solutions are presented in the table below.

Table 5.3: Evaluation of Alternatives – Urban Drainage System

Criteria	Alternative		
	Do Nothing	**Upgrade Storm Sewers to 100 Year Capacity**	**Selective local upgrades**
Natural Environment	No impacts	No impacts are anticipated, as the works are limited to the road right of way	Few impacts are anticipated, as the works are limited to the road right of way and manicured residential lots
Social Environment			
Property Acquisition / Displacement	No property required	No property required	Easements may be required for regarding in private property
Long Term Community Impacts	No impacts anticipated	No impacts anticipated	No impacts anticipated
Short Term Construction Impacts	No impacts anticipated	Significant impacts anticipated, as all roads require reconstruction	Moderate impacts anticipated, as some roads require reconstruction
Economic Environment			
Property Acquisition	None required	None required	Negligible required
Construction Costs		Upgrades to all storm sewers: $28.4 Million	Selective construction upgrades: $20.4 Million
Operation and Maintenance	Regular catchbasin cleaning and debris removal is required	Regular catchbasin cleaning and debris removal remains required	Regular catchbasin cleaning and debris removal remains required
Technical Environment			
Anticipated Flood Damage Reduction	No reduction in flood damages ($35.9 Million for the 100 year event, with creek improvements)	Almost all flow would be piped to Jackson Creek for the 100 year event, with no flood damages anticipated	Overland flow would be confined to the road right of ways and dedicated easements, with little to no flood damage anticipated
Technical Feasibility / Implementation	N/A	Upgrading all storm sewers in the study area is a significant undertaking and will take a long time for implementation	The key bottlenecks in the storm sewer system can be remediated relatively easily in a short period of time.
Overall Evaluation	Flooding and flood damages are not reduced – the problem is not addressed	Flooding will be eliminated, but it will take a long time and considerable expense for implementation	**PREFERRED ALTERNATIVE** Flood damages are effectively eliminated in a relatively short period of time at a moderate expense

The combination of upgrading selected storm sewers, adding catchbasins and relief sewers, and re-grading areas to contain the major system flows was selected as the preferred alternative. It provides flood reduction benefits comparable to the replacement of all storm sewers in the study area at a significantly reduced cost and with less disruption to the community.

The preferred solution of selective local upgrades was presented at the Public Open House # 2 (See Appendix A). While some attendees expressed a preference for 100 year storm sewers throughout the study area, most were in agreement with the preferred solution. There is a significant increase in cost associated with 100 year storm sewers, and increased social disruption due to the removal and replacement of all storm sewers and associated road reconstruction. Selective Local Upgrades remains the preferred solution to mitigate urban flood damages.

6. Recommended Action Plan

6.1 Recommended Projects

The preferred flood reduction alternative involves construction of a diversion sewer under Murray Street, upgrades to selected storm sewers and re-grading in areas to contain overland flows in road right-of-ways and municipal easements.

Implementation of the preferred alternative requires a large number of individual construction projects. Funding limitations, the availability of contractors, and the economies achievable by undertaking flood reduction projects in concert with other municipal initiatives, such as road reconstruction, are unlikely to allow all of these projects to be implemented simultaneously. Therefore, further analyses were undertaken to prioritize the individual construction projects. Projects were ranked based on the degree of flood damage reduction that can be achieved relative to the construction cost. See Figures 6.1 and 6.2 for a summary of proposed improvements and estimated costs.

6.1.1 Brookdale

The main stormwater constraint within the Brookdale watershed is the concrete open channel followed by a 1200 mm diameter storm sewer. The reduction in cross-sectional area as well as the several 90-degree turns along the storm sewer reduce capacity and cause stormwater to back up the channel and impact adjacent properties. It is proposed that the concrete channel be expanded slightly so that it can contain runoff from all storm events, and extended all the way to Jackson Creek. The expanded and extended section could be in the form of an open channel or a pipe, or a combination. This will reduce flooding upstream and provide some relief for the storm sewer system on Downie Street where the channel is currently draining. This proposed upgrade has a very high benefit-cost ratio and is first on the priority list for upgrades.

The remainder of the Brookdale upgrades include upgrading select storm sewers, re-grading private and public property, adding catchbasins to low points, adding relief storm sewers, and upgrading some storm sewer systems to 100-year capacity. If road works are planned for any part of the subwatershed where storm sewer replacements are proposed, it might be logical to wait until road reconstruction is underway to replace storm sewers. These upgrades have a relatively low benefit-cost ratio and are therefore 5th on the priority list for upgrades.

6.1.1 Northeast Jackson and Depression Area

The Northeast Jackson subwatershed upgrades should be considered after the Brookdale channel, making it 2nd on the priority list for upgrades. The first section of upgrades is for the short storm sewers that outlet to Jackson Creek. Many of the properties along the Creek in this section of downtown are also affected by the Creek flooding as well as urban flooding. While the creek solution will improve flooding conditions, it will take some time to implement. There are no select upgrades to relieve urban flooding for this section, simply the installation of 100-year storm sewers to replace the existing storm sewers. This is the only feasible solution due to the complete development of the area. These upgrades could possibly be coordinated with proposed road improvements in the area and scheduled accordingly. The next upgrade for Northeast Jackson is the storm sewer that conveys flow from north of Parkhill Road to Jackson Creek. It should be upgraded to 100-year storm capacity and installation should be coordinated with future road improvements. The final upgrade for Northeast Jackson is in the "depression" area outside of the watershed. It is recommended that some storm sewer sections be upgraded and relief sewers be provided for other sections, so that the main trunk storm sewer has capacity for the 100-year event and will therefore not flood the low point even during large storm events. All upgrades should start at the downstream ends of storm sewer systems if possible.

6.1.2 Jackson Creek

The next highest priority project is the construction of a large sewer to divert some of the flows from Jackson Creek to the Otonabee River. While a number of different alignments are possible, the intake for the diversion sewer should be located as far upstream on Jackson Creek as possible, and should be co-ordinated with road reconstruction projects and the recommended storm sewer system upgrades. The sewer should be sized to reduce downstream flows such that there are no flood damages through the urban area for up to the 100 year flood. Several potential storm sewer alignments are shown on Figure 6.2.

6.1.3 Southeast Jackson and Southeast-Otonabee

Once the Northeast upgrades have been considered, the southeast Jackson subwatershed should be analysed, making it 4^{th} on the priority list for upgrades. This completely developed area has only one possible solution, which is to replace the trunk storm sewers with 100-year capacity storm sewers. It is suggested that the improvements start at the downstream end and continue upstream if possible. The upgrades suggested for this section are widespread and expensive, causing it to have a fairly low benefit-cost ratio. These upgrades should be scheduled to coincide with road improvements.

6.1.4 Northwest and Southwest Jackson

The last two areas to be considered are Northwest Jackson and Southwest Jackson. These areas were developed more recently than the other areas and have been designed and graded considering stormwater management practices. Only minimal grading is recommended in a few locations to relieve the small amount of flooding in these two areas. Most of the improvements involve regrading on private property and so these upgrades should occur when owners are making other improvements on property. These areas are last on the priority list for upgrades since most of the proposed works are on private property and scheduling of these improvements will be up to home owners rather than the City of Peterborough.

Figure 6.1. Preferred Urban Alternative – Selective Upgrades

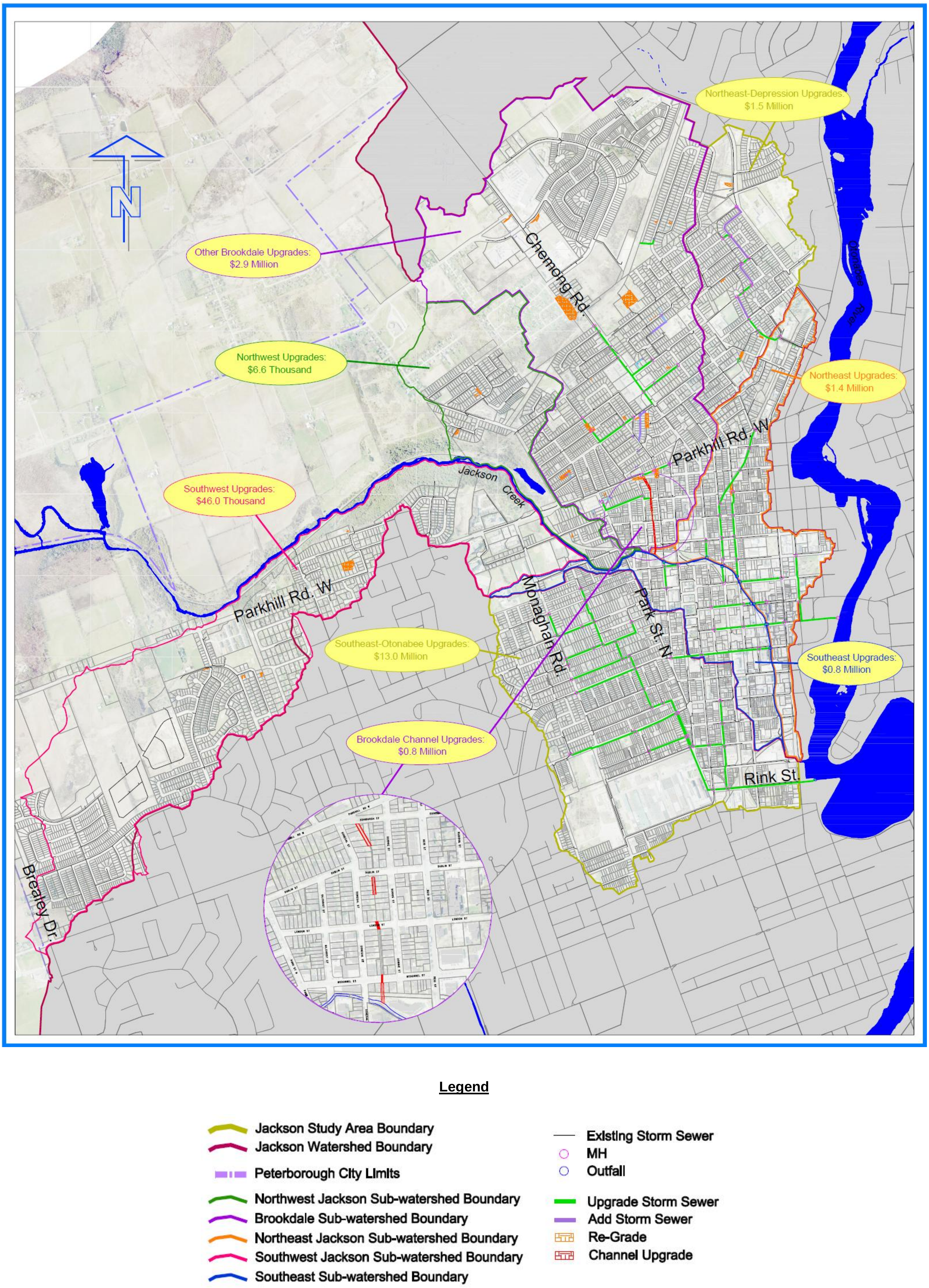


Figure 6.2. Preferred Creek Alternative – Diversion Sewer

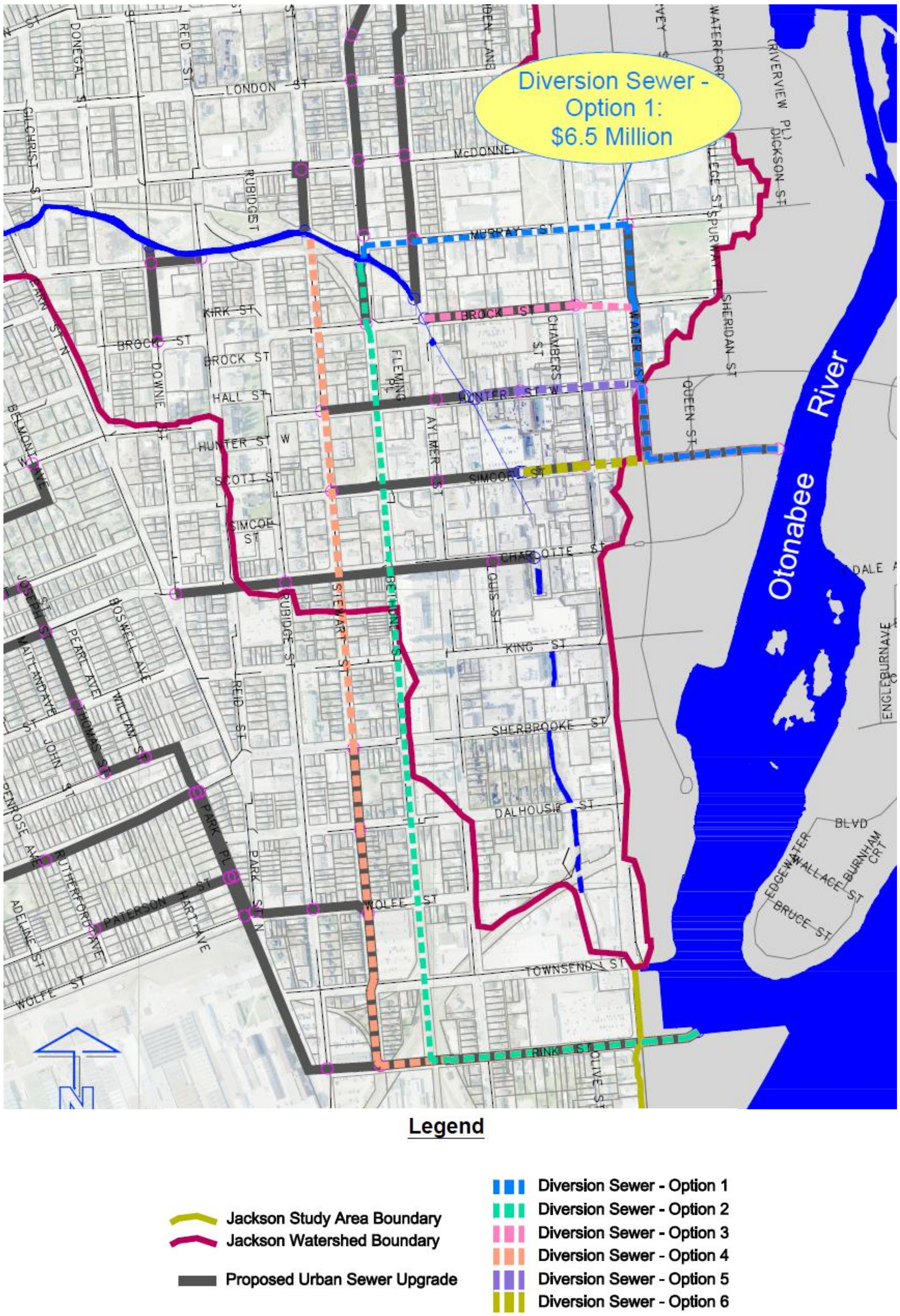


Table 6.1: Prioritization of Recommended Works

Priority	Project Name	Project Details	Estimated Cost	Flood Damage Reduction (100 Year Storm)	Benefit-Cost Ratio
1	Brookdale Channel Upgrade	Expand and Extend the existing concrete channel through the south end of the subwatershed	$0.8 Million	$3.0 Million	3.8
2	Northeast Jackson Select Upgrades	Upgrade several storm sewers to 100-year capacity, and construct a relief storm sewer at the north end of the subwatershed	$2.8 Million	$10.4 Million	3.7
3	Jackson Creek Diversion Sewer	Construct a diversion sewer under Murray Street to prevent flood damages for up to the 100 year storm event	$6.5 Million	$8.6 Million	1.3*
4	Southeast Jackson Select Upgrades	Install 100-year storm sewers through the trunk storm sewers in the area	$13.9 Million	$20.3 Million	1.5
5	Remaining Brookdale Select Upgrades	Regrade specified areas, upgrade select storm sewers and add storm sewers	$2.9 Million	$4.2 Million	1.4
6	Northwest Jackson Select Upgrades	Re-grade sections of private property as residential developments occur	$7 Thousand	$135 Thousand	20.5
7	Southwest Jackson Select Upgrades	Re-grade sections of private property as residential developments occur	$46 Thousand	$316 Thousand	6.9

***** *The Jackson Creek Diversion Sewer could replace several of the recommended storm sewer upgrades in NE Jackson*

Additional Recommendations

In addition to the Recommended Projects set out above, we also recommend the City consider the following items which will enhance the success of Flood Damage reduction within the Jackson Creek Study area:

Maintenance: Throughout the study the public consistently expressed a desire/need for increased Jackson Creek and Urban Catchbasin/storm sewer maintenance. Enhanced maintenance of the storm sewer system (catchbasin cleanouts, CCTV inspections, sewer flushing) is recommended to ensure that the capacity of the storm sewer system is fully available.

There were also concerns from the public regarding debris in the watercourse (fallen trees, etc) and deteriorating storm sewer outlets and other structures that could potentially reduce the capacity of the Jackson Creek channel. An inspection and maintenance program is recommended to routinely inspect the channel, remove debris and identify structures (culverts, outlet headwalls, etc) that require rehabilitation.

Streambank Erosion Protection: Through much of the downtown Peterborough area, Jackson Creek flows through culverts and channels with near vertical concrete or armourstone walls. However, upstream of Aylmer Street, there are sections of Jackson Creek where one or both banks are not adequately protected and are actively eroding toward adjacent property and structures. It is recommended that that the City and/or the Otonabee Region Conservation Authority undertake a study to identify erosion prone reaches of Jackson Creek and develop a plan to mitigate further erosion impacts.

Stormwater Management for New Development: At both of the Public Open Houses, attendees were concerned that recent and planned development in the Jackson Creek watershed could worsen flooding along Jackson Creek. Stormwater management controls are recommended for new development to prevent any increases in peak flow rates in Jackson Creek for up to the 100 year storm event. Pre and post development peak flow rates in Jackson Creek should be evaluated both at and downstream of the outlet from the development.

Sanitary Backup: Sanitary sewer back-up risk within the City of Peterborough remains a subject of interest to both the insurance industry and residents. Implementation of the recommendations of this, and the other storm system studies the City has commissioned, will reduce surface water flood damages. However, there will still be some potential for flood damages due to sanitary sewer back-up. The City has initiated a Detailed Sanitary Sewer Environmental Assessment to determine the key causes of sanitary sewer back-up, and to develop a plan to mitigate potential damages from sanitary sewer back-up. This study should be completed and recommendations implemented as soon as possible.

7. References

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