Town of Oakville

Flood Mitigation Opportunities Study

Fourteen Mile Creek and McCraney Creek Systems

March 28, 2025 Final

Flood Mitigation Opportunities Study

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Town of Oakville

Final

Project No.: CA-EI-TP111031
Date: March 28, 2025

WSP E&I Canada Limited
3450 Harvester Road
Burlington, ON
Canada L7N 3W5

wsp.com

March 28, 2025

Final

Town of Oakville
1225 Trafalgar Road
Oakville, ON
L6H 0H3

Attention: **Diana Michalakos, Project Leader - Capital Projects, Transportation and Engineering**

Dear Ms. Michalakos:

Subject: **Technical Report - Flood Mitigation Opportunities Study Fourteen Mile Creek and McCraney Creek Systems**

The WSP Team is pleased to submit the Final Report for the Flood Mitigation Opportunities Study of Fourteen Mile Creek and McCraney Creek. This report has been compiled based upon the consultation and numerous previous technical analyses completed over the course of this study, the comments provided by Conservation Halton and the Town during the various working meetings, and the input provided by the public and agency stakeholders during the Public Information Centres.

On behalf of the WSP Team, we thank the Town for the opportunity to work on this study and are pleased to bring the project to a successful conclusion.

Yours sincerely,

Per: Matt Senior, M.A.Sc., P.Eng.
Manager, Water Resources
WSP Canada Inc.

Per: Abhijeet Patel, M.Eng., P.Eng.
Water Resources Engineer
WSP Canada Inc.

WSP ref.: CA-EI-TP111031

Revision History

TECHNICAL MEMORANDA (1)

July 2011	"Phase 1 Problem Identification Report Flood Mitigation Opportunities Study for Fourteen Mile Creek/McCraney Creek Systems Class Environmental Assessment" (AMEC Earth & Environmental)	
September 6, 2012	Memo: "Fourteen Mile Creek/McCraney Creek Hydrologic Modelling Update" (AMEC Earth & Environmental)	
January 18, 2013 (Updated January 23, 2013)	Memo: "Fourteen Mile Creek/McCraney Creek Hydrologic Modelling Update" (AMEC Environment & Infrastructure)	
May 17, 2013	Memo: "Fourteen Mile Creek / McCraney Creek Hydrologic Modelling Update" (AMEC Environment & Infrastructure)	
July 17, 2013 (Updated September 26, 2013)	Memo: "Fourteen Mile Creek / McCraney Creek Flood Management Alternative Assessment" (AMEC Environment & Infrastructure)	
December 7, 2016	Memo: "Fourteen Mile Creek / McCraney Creek Supplemental Alternative Assessment" (Amec Foster Wheeler Environment & Infrastructure)	
December 7, 2018	Memo: "Fourteen Mile Creek and Taplow Creek Flow Diversion Summary Results, Fourteen Mile Creek Flood Mitigation Study, Class Environmental Assessment (EA)" (Wood Environment & Infrastructure Solutions)	
Prepared by	Reviewed by	Approved by
Steve Chipps, Senior Water Resources Engineer	Ron Scheckenberger, Manager, Water Resources	Ron Scheckenberger, Manager, Water Resources

TECHNICAL MEMORANDA (2)

June 15, 2017 (Revised July 24, 2017)	Memo: "Hydrologic Assessment and Model Re-Validation for Fourteen Mile Creek / McCraney Creek On-Line Control Structures" (Amec Foster Wheeler Environment & Infrastructure)	
December 7, 2016 (Revised June 28, 2018)	Memo: "Fourteen Mile Creek / McCraney Creek, Supplemental Alternative Assessment" (Wood Environment & Infrastructure Solutions)	
February 22, 2019	Memo: "Comparison of Regional Storm Hydrographs for Proposed Fourteen Mile Creek Diversion to the Receiving System Bronte Creek" (Wood Environment & Infrastructure Solutions)	
March 4, 2019	Memo: "DRAFT – Fourteen Mile Creek and McCraney Creek Flood Mitigation Alternative Costing Estimate" (Wood Environment & Infrastructure Solutions)	
Prepared by	Reviewed by	Approved by
Steve Chipps, Senior Water Resources Engineer Matt Britton, Water Resources Engineer	Ron Scheckenberger, Manager, Water Resources	Ron Scheckenberger, Manager, Water Resources

TECHNICAL MEMORANDA (3)

July 11, 2019 (Revised October 25, 2019)	Memo: "DRAFT – Fourteen Mile Creek and McCraney Creek Flood Mitigation Scenario Cost Benefit Assessment" (Wood Environment & Infrastructure Solutions)	
Prepared by	Reviewed by	Approved by
Steve Chipps, Senior Water Resources Engineer Ali Aamir, Water Resources EIT	Ron Scheckenberger, Manager, Water Resources	Ron Scheckenberger, Manager, Water Resources

(DRAFT DELIVERABLE NOT STAMPED)

TECHNICAL MEMORANDA (4)

November 10, 2023	Memo: "DRAFT – Fourteen Mile Creek and McCraney Creek Flood Mitigation Scenario Cost-Benefit Assessment, Flood Management Class EA" (WSP E&I Canada Limited)	
Prepared by	Reviewed by	Approved by
Steve Chipps, Senior Water Resources Engineer Abhijeet Patel, Water Resources EIT	Steve Chipps, Senior Water Resources Engineer	Steve Chipps, Senior Water Resources Engineer

(DRAFT DELIVERABLE NOT STAMPED)

DRAFT REPORT

29 Jan 2025	Compilation of Technical Memoranda into initial Draft Report for Town Review	
Prepared by	Reviewed by	Approved by
Steve Chipps, Senior Water Resources Engineer (First Draft – Jan 3, 2025) Abhijeet Patel, Water Resources Engineer (Issued Draft - Jan 29, 2025)	Matt Senior, Manager, Water Resources	Matt Senior, Manager, Water Resources

(DRAFT DELIVERABLE NOT STAMPED)

FINAL		
28 Mar 2025	Updated based on Town Review comments	
Prepared by	Reviewed by	Approved by
Abhijeet Patel, Water Resources Engineer	Matt Senior, Manager, Water Resources	Matt Senior, Manager, Water Resources

NOTE: The Revisions made to this report are to address comments from the Town of Oakville and to resolve any minor issues related to consistency and clarity. The information presented in the previous versions of the report (i.e. the Technical Memoranda) have been used as the fundamental basis for the compiled reporting.

The seal of the original engineer has been retained as a record of the engineer responsible for the original analyses and work. The seal and signatures of those responsible for the modifications in this revision testify that that such modifications do not alter the original analyses and design in the previous technical memoranda, and they are therefore not responsible for the original analyses and work completed by others.

Signatures

Prepared by

March 28, 2025

Per: Abhijeet Patel, M.Eng., P.Eng.
Water Resources Engineer
WSP Canada Inc.

Date

Approved[1] by

March 28, 2025

Per: Matt Senior, M.A.Sc., P.Eng.
Manager, Water Resources
WSP Canada Inc.

Date

WSP E&I Canada Limited (WSP) prepared this report solely for the use of the intended recipient, Town of Oakville, in accordance with the professional services agreement. The intended recipient is solely responsible for the disclosure of any information contained in this report. The content and opinions contained in the present report are based on the observations and/or information available to WSP at the time of preparation. If a third party makes use of, relies on, or makes decisions in accordance with this report, said third party is solely responsible for such use, reliance or decisions. WSP does not accept responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken by said third party based on this report. This limitations statement is considered an integral part of this report.

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Contributors

Town of Oakville

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WSP

Project Manager, Water Resources Engineer	Steve Chipps (to January 3, 2025)
Project Reviewer\Manager	Matt Senior (after January 3, 2025)
Water Resources Engineer	Abhijeet Patel (after January 3, 2025)
Format (non-technical) / Proof	Melinda Nowak

Subconsultants

Fluvial Geomorphology	Montrose Environmental (formerly Parish Geomorphic, formerly Matrix Solutions)
Terrestrial Ecology	Dougan Ecology (formerly Dougan & Associates)
Aquatics and Fisheries	C. Portt and Associates

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EXECUTIVE SUMMARY

Introduction

The Town of Oakville initiated an assessment of the existing flooding conditions, through the Town-wide Flood Study, April 2008. The Town-wide Flood Study determined flood prone sites and a priority-based work program, including conducting Flood Mitigation Opportunities Studies to further assess flooding conditions and develop flood mitigation actions to be implemented to reduce flood risk.

In response, the Town of Oakville has initiated the Flood Mitigation Opportunities Study to formalize the understanding of flood risks within the Fourteen Mile and McCraney Creeks systems. This initiative aims to reduce flood risks to the public, property, buildings and infrastructure.

The Town of Oakville has engaged WSP E&I Canada Limited (WSP), previously known as Wood Environment & Infrastructure Solutions Canada Limited (Wood), Amec Foster Wheeler, and Amec; to evaluate the current flood risk levels of Fourteen Mile Creek and McCraney Creek. The goal of this study is to create alternative flood mitigation recommendations and develop a comprehensive flood risk reduction plan for both creek systems.

The project limits, herein referred to as the Study Area, include 3183.6 ha +/- draining to Fourteen Mile Creek and 970.50 ha +/- draining to McCraney Creek (ref. **Exhibit ES-1**). The watersheds consist of a mixture of industrial, commercial, and residential land uses. The lower reaches of the Fourteen Mile Creek, as well as the lower reach of McCraney Creek, are conveyed through the Town of Oakville to the outlets at Lake Ontario.

Class Environmental Assessment Process

This study has been completed as a Master Plan Approach # 2 Detailed Master Planning of the Municipal Engineers Association (MEA) Class Environmental Assessment (Class EA) Process (ref. Municipal Engineers Association's Municipal Class Environmental Assessment October 2000, as amended in 2007, 2011, 2015 & 2023), completing the first two phases of MEA Class process and satisfying recommended Schedule B projects. The approved MEA Class EA document describes the process that a proponent must follow for a class or group of undertakings in order to satisfy the requirements of the Environmental Assessment Act. Additionally, it represents a method of obtaining an approval under the provincial Environmental

Assessment Act and provides alternatives to carrying out individual environmental assessments for each separate undertaking or project within the class. This study has been developed, based upon the following Phased approach:

Phase 1: Problem Definition

Phase 2: Develop and Review Alternatives

Phase 3: Preferred Alternatives Selection and Preliminary Design

Phase 4: Preparation of Environmental Study Report

Consultation

Public Information Centres (PIC) have been held at planned intervals during the Flood Mitigation Opportunities Study process to inform the public of the study progress and seek input. The first PIC for the Flood Mitigation Opportunity Study was held on November 14, 2013, at the Town of Oakville Town Hall, while a second PIC was held on December 2, 2014, and a third PIC was held on November 6, 2024. Notifications of the three PICs were sent to stakeholders, local residents, agencies and municipal staff by mail and email.

Consultation has also been conducted with indigenous groups, namely the Six Nations of Grand River Territory, Mississaugas of the New Credit First Nation, Haudenosaunee Confederacy Council, Alderville First Nation and Metis Nations of Ontario.

The Class EA has been completed under the oversight of a Technical Steering Committee which included representatives from the Town of Oakville and Conservation Halton. Meetings have been held at key milestones throughout the study to review data needs and findings while providing input and guidance to achieve the study objectives.

Baseline Assessment

A PCSWMM hydrologic/ hydraulic model has been used as the base model to determine peak flows for the 2-year to 100-year and Regional Storm (Hurricane Hazel) events for both creek systems. The PCSWMM model has been refined and calibrated based on observed flows and rainfall.

Hydraulic (HEC-RAS) modelling for both the Fourteen Mile Creek and McCraney Creek has been prepared for this study. The detailed hydraulic models for Fourteen Mile Creek and McCraney Creek, have been prepared, based on topographic mapping and field reconnaissance by WSP (to confirm details of the road crossings and the associated immediate upstream and downstream creek reaches). The updated existing HEC-RAS hydraulic modelling has been used to determine flood elevations for the 2- to 100-year and Regional Storm (Hurricane Hazel) events. Floodplain maps have been prepared for both creeks based on the foregoing modelling.

For Fourteen Mile Creek approximately 132 properties and 140 buildings (buildings located on the flood risk properties) have been determined to be at flood risk, while for McCraney Creek, 131 properties and 149 buildings (buildings located on the flood risk properties) are at flood risk during the Regional Storm event. The identified flood risk primarily stems from inadequate flow conveyance capacity at crossings and/or historical land use encroachment into natural hazard lands.

Alternative Assessment

Detailed analyses have been completed to evaluate various alternatives to mitigate the flood risk within both Fourteen Mile Creek and McCraney Creek.

A long-list of flood mitigation alternatives has been assessed through the use of evaluation criteria and scoring of the results, with the resulting short-list of alternatives undergoing a detailed assessment using the hydrologic and hydraulic modelling, and a cost / benefit assessment. Conservation Halton and the Ministry of Natural Resources and Forestry (MNRF) reviewed the initial preferred alternatives and rejected the proposed online flood storage located upstream of the QEW Highway, as a result, supplemental alternatives were established and assessed to determine additional ways to mitigate flood risk.

To determine the preferred alternatives, a cost benefit assessment was conducted, comparing smaller scale local improvements which offer the possibility of reducing flood risk in a targeted area (e.g., culvert / bridge upgrades), versus, system wide improvements, which offer the potential of reducing system wide peak flows and lowering flood risk over a broader area. In comparison, the system-wide improvements offer limited additional flood risk reduction but come with a significant increase in cost compared to the local improvements. As a result, the local improvement approach to flood mitigation was selected as the preferred approach.

The preferred alternatives consist of Low Impact Development (LIDs), crossing upgrade (McCraney Creek at Lakeshore Road) and berming to be located where feasible on town owned lands and private lands where no alternative is available.

Non-structural alternatives were also evaluated, including creek maintenance, emergency preparedness, flood forecasting / warning, and regulation. These programs are currently in effect and help to reduce the threat to life and property, but do not reduce existing flood conditions. Land acquisition of flood-risk properties and buildings could take place if it is determined that the benefits of purchasing the property outweigh the mitigation costs; however, there are significant social and economic considerations that reduce its viability.

The potential flood risk reduction benefits for the 10-year, 100-year storm and Regional Storm events for both Fourteen Mile Creek and McCraney Creek for the preferred alternatives have been provided in **Tables ES-1, ES-2** and **ES-3**. The tables summarize the benefits from the combined alternative (culvert upgrades and localized berming) for the 10-year, 100-year and Regional Storm events, respectively. Where a building floods under the existing conditions but the risk of flooding is lowered to the property parcel and the building is removed from flooding under a specific flood mitigation alternative scenario, those cases are denoted in parentheses.

Table ES.1: Summary of Flood Risk Reduction Benefits Resulting from Alternatives (10-year)

Alternative	Existing Number of at Risk Properties	Existing Number of at Risk Buildings	Properties with Reduced Flood Risk	Buildings with Reduced Flood Risk	Properties Removed from Floodplain	Buildings Removed from Floodplain
Fourteen Mile Creek						
Combined	92	12	23	0	4	0
McCraney Creek						
Combined	97	48	5	0	7	0

Table ES.2: Summary of Flood Risk Reduction Benefits Resulting from Alternatives (100-year)

Alternative	Existing Number of at Risk Properties	Existing Number of at Risk Buildings	Properties with Reduced Flood Risk	Buildings with Reduced Flood Risk	Properties Removed from Floodplain	Buildings Removed from Floodplain
Fourteen Mile Creek						
Combined	130	46	30	1(1)	15	1
McCraney Creek						
Combined	96	88	2	14	12	3

Table ES.3: Summary of Flood Risk Reduction Benefits Resulting from Alternatives (Regional Storm)

Alternative	Existing Number of at Risk Properties	Existing Number of at Risk Buildings	Properties with Reduced Flood Risk	Buildings with Reduced Flood Risk	Properties Removed from Floodplain	Buildings Removed from Floodplain
Fourteen Mile Creek						
Combined	132	140	27	0	21	13(15)
McCraney Creek						
Combined	131	149	5	9	14	3(3)

The results in **Tables ES-1, ES-2** and **ES-3**, indicate the largest benefit is provided for the Regional Storm event, which has a total benefit of 110 properties and buildings with either reduced flood risk, or are removed from flood risk for both Fourteen Mile and McCraney Creeks combined.

Costing has been prepared for the preferred alternatives as indicated in **Table ES-4** for both creek systems.

Table ES.4: Summary of Preliminary Costs Associated with Proposed System Upgrades

System	Total Cost ($M)	Total Cost with 15% Contingency ($M), 25% Contingency for Berming
Culvert Upgrade (McCraney Creek at Lakeshore Road)	$ 5.34 M	$ 6.15 M
Berming	$ 1.48 M	$ 1.85 M
Total	**$ 6.95 M**	**$ 8.0 M**

The total number of properties and buildings which benefit from the alternatives by being removed from the Regional Storm floodplain is provided in **Table ES-5**. **Exhibits ES-2** and **ES-3** indicate the existing and proposed Regional Storm floodlines with the preferred alternatives implemented.

Table ES.5: Summary of Flood Risk Reduction Benefits Resulting from Alternatives (Regional Storm)

Alternatives	Total Cost ($M)	Reduced Flood Risk (Reduced or Removed)
Culvert Upgrade (McCraney Creek at Lakeshore Road) and Berming	$ 8M	110

Implementation

The preferred alternatives for mitigating the flood risk at various identified sites on Fourteen Mile and McCraney Creeks, as presented herein, can be advanced to the next stages of planning and design. Prioritization of the alternatives would be established by the Town as part of overall flood risk mitigation works and stormwater network works being considered through the lens of the Rainwater Management Financial Plan (RMFP). The Rainwater Management Financial Plan (RMFP) takes a comprehensive approach to integrate the state of good repair and increase resiliency of the town's stormwater network based on various studies and assessments completed to date. The multi-phase RMFP will deliver a financing plan that provides an all-inclusive approach to planning and implementing stormwater-related infrastructure renewal and improvement projects into the future.

Implementation of each of the alternatives has been considered based on the Municipal Class EA process and associated project schedules (ref. **Table ES-6**) and whether each alternative will or will not require a more detailed Class Environmental Assessment. For the recommended culvert upgrade and the proposed flood protection berming, this Class EA has fulfilled the Municipal Class EA process and associated assessment requirements.

The Town will implement LIDs within the Fourteen Mile Creek and McCraney Creek Subwatershed areas, as town projects occur with the appropriate conditions (e.g. groundwater depths, soil conditions, availability of space, etc.) and in accordance with the Town of Oakville's Stormwater Management Master Plan and Town of Oakville Climate Action Plan.

Table ES.6: Summary of Preferred Alternatives and Implementation Considerations

Location	Municipal Class EA Schedule	EA Status	Other Considerations
Crossing Upgrade at Lakeshore Road, McCraney Creek	– McCraney Creek Bridge Replacement Class EA (Schedule B Completed in 2022)	– Culvert Crossings upgrades are exempt under the 2023 Municipal Class EA Guidelines, based on Table C – Municipal Transit Projects: o Project Classification 8b: *Culvert repair or replacement where the capacity of the culvert or drainage area is changed.* – Should culverts be replaced solely for the purpose of flood control, then under Table B Municipal Water and Wastewater Projects (Shoreline / In Water Works): o Project Classification 50: *Modify existing water crossings for the purposes of flood control a Schedule B is required.*	– Conservation Halton to be consulted. May require Department of Fisheries and Oceans (DFO) consultation. – Cultural heritage and archaeology – subsequent EA carried out determined that no further cultural heritage evaluation nor additional archaeological evaluation would be required. – Design to consider: o property o construction access o road design o structural design o utilities o geotechnical conditions, o excess soils o hydraulics o erosion conditions o stream morphology o fisheries passage and habitat o terrestrial vegetation assessment o wildlife and species at risk o construction timing restrictions

Flood Protection Berms	– Schedule B (fulfilled by this Class EA)	– *As per Table B Municipal Water and Wastewater Projects (Shoreline / In Water Works) flood protection berms are a Schedule B activity based on:*
		o *Project Classification 49 : Construct berms along a watercourse for the purposes of flood control in areas subject to damage by flooding*
		o *Project Classification 50: Modify existing watercourses for the purpose of flood control*
		o *Project Classification 51: Works undertaken in a watercourse for the purposes of flood control or erosion control, which may include:*
		  o Bank or slope regrading
		  o Deepening the watercourse
		  o Relocation, realignment or channelization of watercourse
		  o Revetment including soil bio-engineering techniques
		  o Reconstruction of a weir or dam
		– Based on this Flood Mitigation Opportunities Study fulfilling Schedule B requirements, a subsequent Schedule B Class EA for the proposed berm works would not be required.
			– Conservation Halton, DFO and Ministry of Environment Conservation and Parks (MECP) to be consulted (for species at risk).
			– To be located on town-owned lands to the full extent possible.
			– For berms entirely on private property and berms adjacent to private property as grading may extend into private property, property owners to meet with Town to understand what is entailed in constructing a localized flood protection berm and provide permission for works to proceed. Depending on location, multiple property owners will need to agree to a flood protection berm to allow berm design and construction.
			– Town to coordinate design and construction of berms with other creek improvements (erosion mitigation) whenever possible.
			– Cultural heritage and archaeology – The proposed berming sites do not correspond to areas of cultural heritage, and significant ground disturbances post 1960 negates the need for further archaeological evaluation
			– Design to consider:
			o construction access for berm and creek works
			o creek overbank grading to offset flood storage lost by berm works
			o utilities
			o existing land use and amenities (i.e. decks, pools, sheds, etc.)
			o geotechnical and hydrogeological conditions,
			o excess soils
			o hydraulics
			o erosion conditions
			o stream morphology
			o fisheries habitat protection
			o terrestrial vegetation assessment
			o wildlife and species at risk
			o construction timing restrictions
			o post construction monitoring and adaptive measures
			o maintenance of creek works – town and private landowner agreement

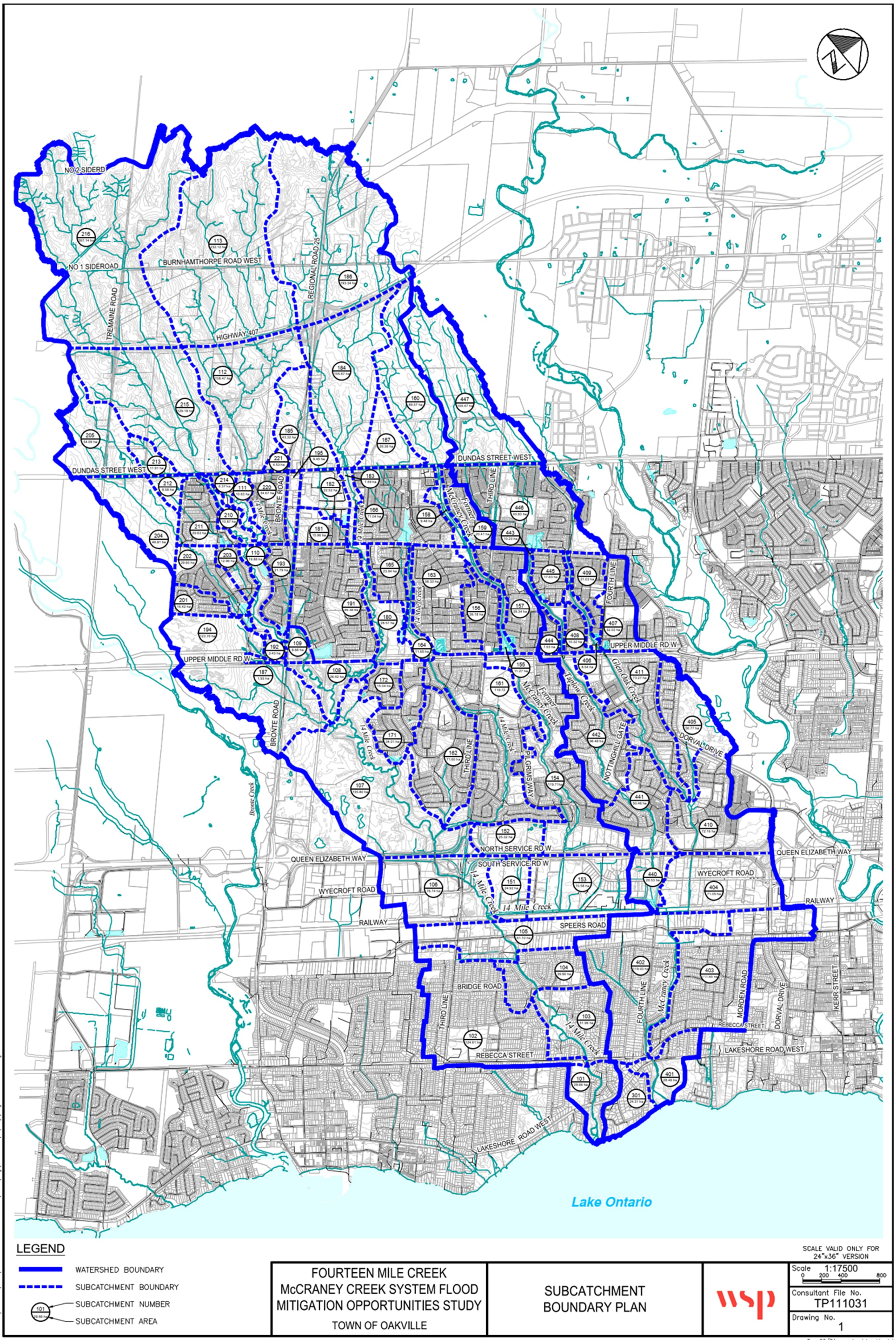


Exhibit ES-1: Fourteen Mile Creek and McCraney Creek Drainage Area Plan

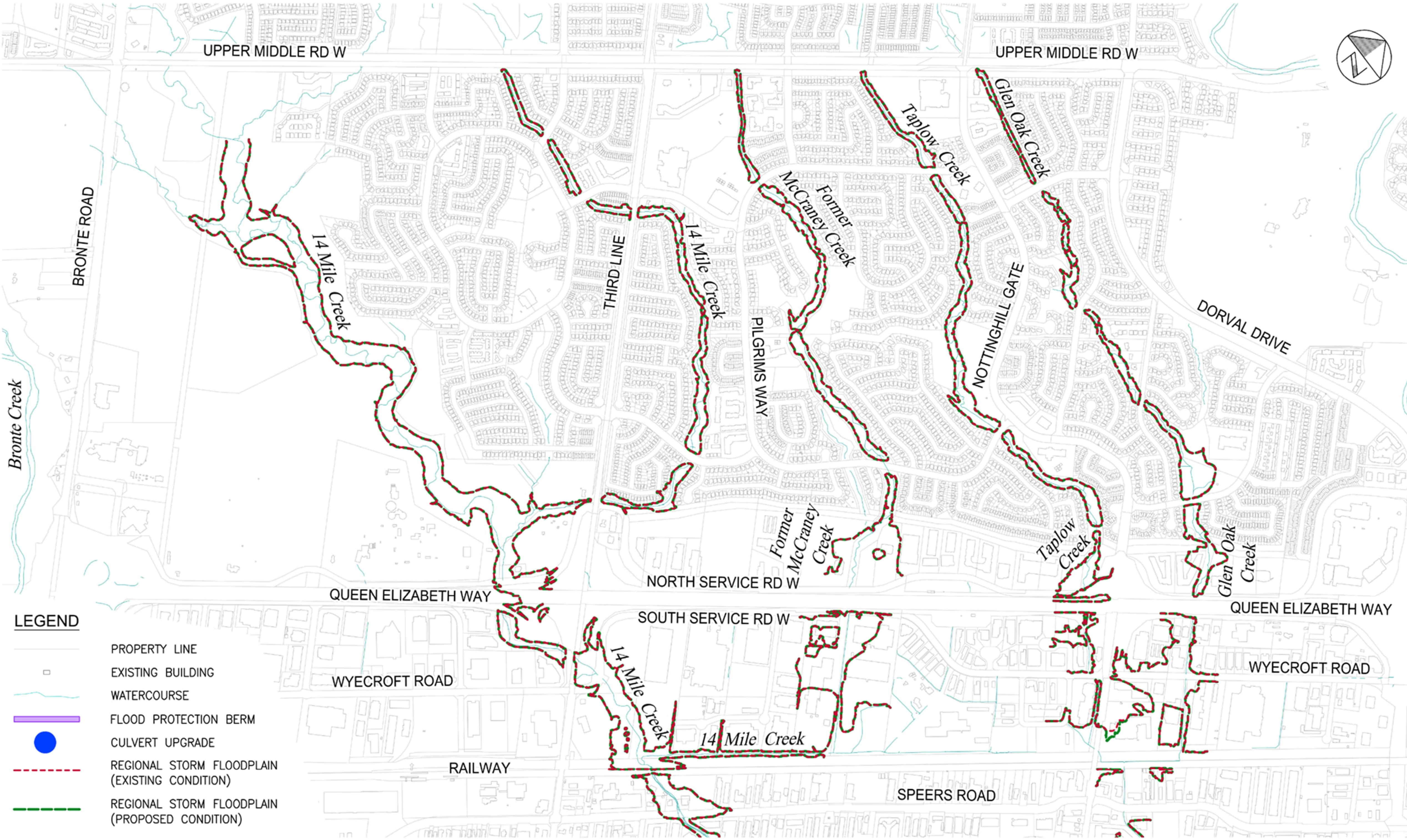


Exhibit ES-2: Fourteen Mile Creek and McCraney Creek Regional Storm Floodlines North of the QEW Highway

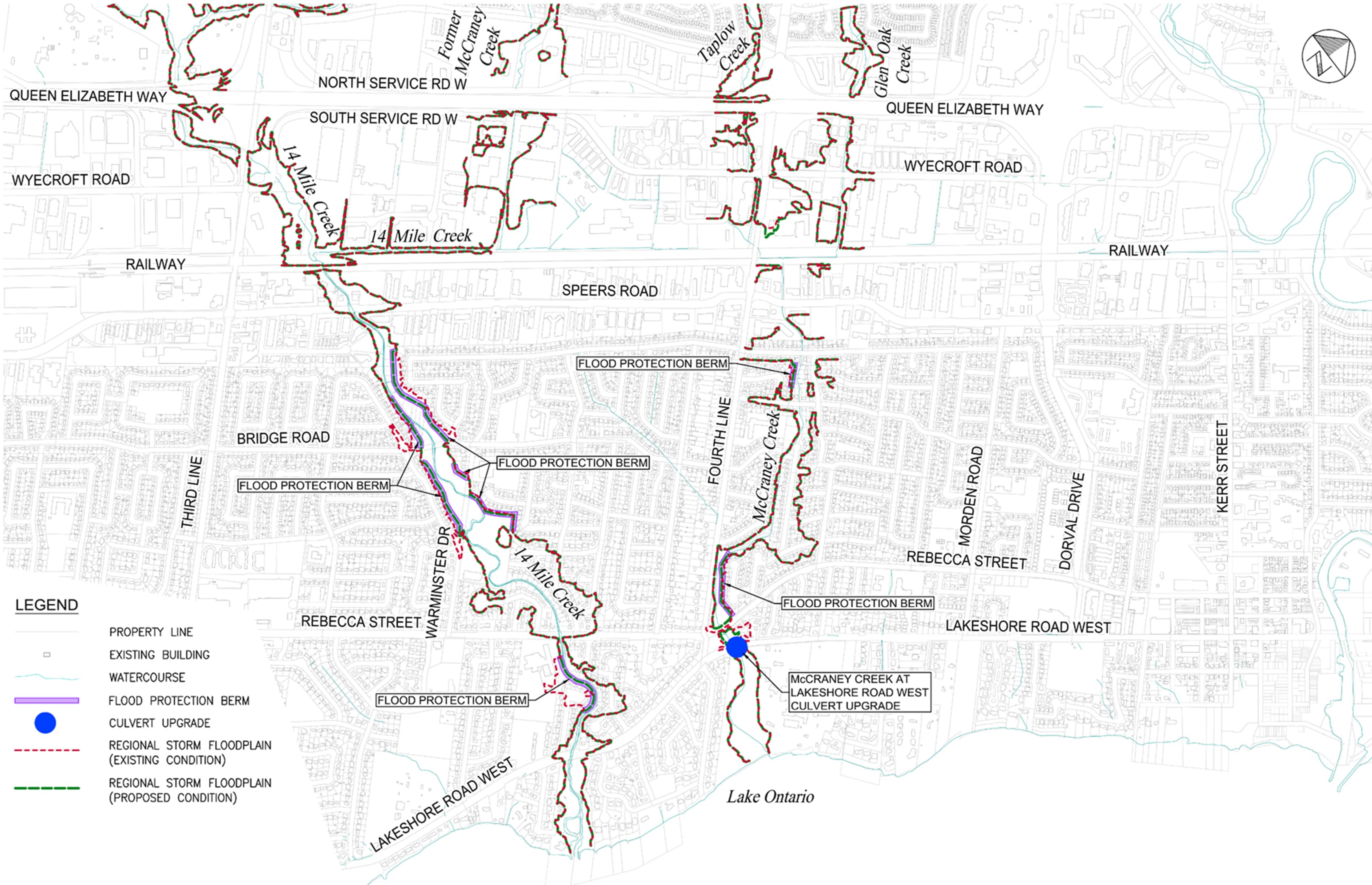


Exhibit ES-3: Fourteen Mile Creek and McCraney Creek Regional Storm Floodlines South of the QEW Highway

1 INTRODUCTION

1.1 Purpose / Overview

In recent years, the intensity and frequency of rainfall-induced flooding have become increasingly prevalent and significant. Given limited provincial and federal initiatives and funding to address riverine-based flooding, there is growing emphasis on municipalities to address this situation directly. As such, the Town of Oakville has initiated an assessment of the existing flooding conditions on Fourteen Mile and McCraney Creeks, to develop an implementation plan for the management of flooding and the associated risks to property and life.

The study has required extensive review of existing conditions in order to establish representative numerical modelling tools for assessment of flooding including hydrologic and hydraulic modelling.

The intent of this study is to develop a comprehensive plan of flood mitigation measures through municipality-led capital works to reduce the risk of flooding on . The Town of Oakville has worked with Conservation Halton to provide direction and input to the study process and findings, leading ultimately to the preferred solutions that will be implemented on a priority basis.

1.2 Description of Study Area

The Fourteen Mile Creek and McCraney Creek Watersheds (ref. Drawing 1, attached) are approximately 3,017 hectares and 993 hectares at the outlet to Lake Ontario. Fourteen Mile Creek commences north of Highway 407 and is currently agricultural land uses north of Highway 5 and a mixture of urban land uses south of Highway 5 (Dundas Street). McCraney Creek consists of the tributaries Taplow Creek and Glen Oak Creek north of the CNR tracks south of the QEW. Land use is predominantly commercial south of the QEW and residential south of Speers Road down to Lake Ontario.

Both watercourses, particularly south of the QEW have been have been straightened or modified over time. There has also been historical encroachment by development south of the QEW, where the creek blocks have been narrowed and lined with gabion baskets, armour stone or other retaining wall systems. The creek is typically privately owned with rear yards backing immediately onto the creek with no setbacks or buffers.

1.3 Background

The Fourteen Mile Creek and McCraney Creek hydrology was initially developed as part of the Fourteen Mile Creek - McCraney Creek Watershed Planning Study in 1992 by Triton Engineering. The hydrology has not been updated since the Triton study. The hydraulics was originally developed as part of the 1985 Halton Conservation Authority's Fourteen Mile Creek and McCraney Creek Flood Damage Reduction Program conducted by Philips Engineering Ltd. and is considered to be dated due to the HEC-2 modelling platform used. In recent years Conservation Halton updated the hydraulic modelling using the current HEC-RAS hydraulic modelling platform.

Due to climate change, flooding has become a greater concern as a result of more severe storm events which have increased risk of flood susceptibility. The Town of Oakville Town-wide Flood Study, 2008, established on a priority basis, creek reaches that should be further investigated for flooding mitigation. The intent of this study is to investigate the extent of the flooding risk along the Fourteen Mile and McCraney Creeks and to develop various alternative solutions to protect public safety, municipal infrastructure, and private property.

1.4 Class Environmental Assessment

The Class Environmental Assessment process is a mechanism by which the provision of municipal servicing is provided in an efficient, timely, economical and environmentally responsible manner. It represents a consistent, streamlined and easily understood process for planning and implementing municipal infrastructure projects. Under the Provincial Environmental Assessment Act, projects are classified as approved, subject to screening, subject to a Class Environmental Assessment (Class EA), or subject to a full Environmental Assessment. This project is classified as being subject to the Class EA process. It is being conducted according to the requirements outlined in the Municipal Engineers Association document titled *Municipal Class Environmental Assessment* (October 2000, as amended 2007, 2011, 2015 & 2023)).

Consistent with the Municipal Class EA, the study approach has been designed to meet the following objectives:

1. Protection of the environment, including natural, social and economic components of the environment.
2. Participation of a broad range of stakeholders in the study process to allow for sharing of ideas, education, testing of creative solutions and developing alternatives.

3 Documentation of the study process in compliance with all phases of the Municipal Class EA process.

The Class EA process classifies projects according to their level of complexity and potential environmental impacts. These are termed “Schedules” and are summarized below:

— **Schedule ‘A’ and ‘A+’** projects involve minor modifications to existing facilities. Environmental effects of these projects are generally small; therefore, the projects are considered pre-approved.

— **Schedule ‘B’** includes improvements and minor expansion to existing facilities. There is a potential for some adverse environmental impacts and, therefore, the proponent is required to proceed through a screening process, including consultation with those affected. Schedule ‘B’ projects are required to proceed through Phases 1, 2 and 5 of the Municipal Class EA process.

— **Schedule ‘C’** includes the construction of new facilities and major expansion of existing facilities. These projects proceed through the environmental assessment planning process outlined in the Municipal Class EA document. These projects are required to fulfill the requirements of all five phases of the Municipal Class EA process.

This study has been completed as a Master Plan Approach #2 Detailed Master Planning of the Municipal Engineers Association (MEA) Class Environmental Assessment (Class EA) Process (ref. Municipal Engineers Association’s Municipal Class Environmental Assessment October 2000, as amended in 2007, 2011, 2015 & 2023), completing the first two phases of MEA Class process and satisfying recommended Schedule B projects.

The Class EA process includes public and agency consultation, an evaluation of flood reduction alternatives, an assessment of the potential environmental effects of the proposed improvements and identification of reasonable measures to mitigate any adverse impacts.

The Municipal Class EA requires notification of, and consultation with, relevant stakeholders. The Project Team has ensured that stakeholders were notified early in the planning process, and throughout the study.

Exhibit 1-1 illustrates the Municipal Class EA process for this project.

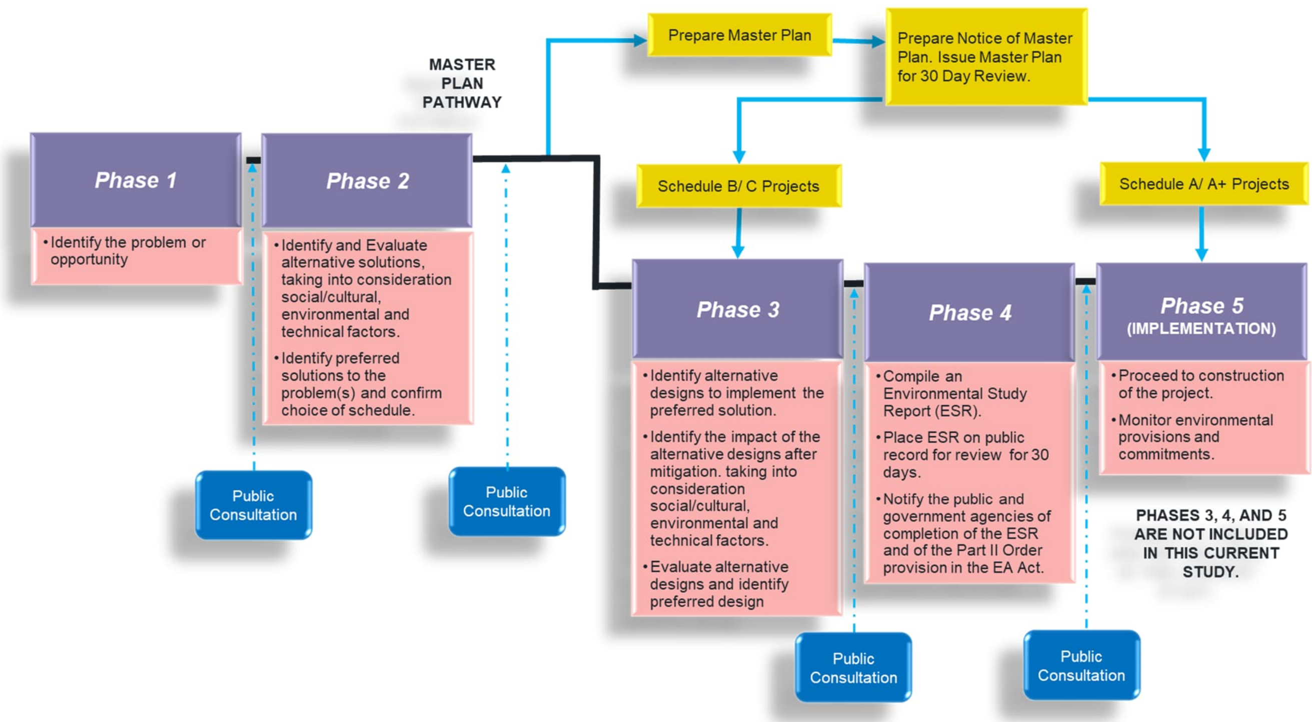


Exhibit 1-1: Class Environmental Assessment Process for this Study

1.5 Consultation

Public, Agency, and Indigenous Consultation materials have been included in **Appendix A**.

1.5.1 Notice of Commencement

A Notice of Study of Commencement detailing the study area, summarizing the objectives of the study and requesting comments, was sent to stakeholders, property owners and agencies by email and mail. The Notice was also published in the Oakville Beaver and the Halton News on July 15, and July 22, 2011, and was placed on the Town of Oakville website. A copy of the notice of commencement is included in Appendix A.

1.5.2 Public Information Centres

Public Information Centres (PIC) have been held at planned intervals during the Flood Mitigation Opportunities Study process to inform the public of the study progress and seek input. A total of three (3) separate Public Information Centres (PICs) were held over the duration of this study. This includes:

- PIC #1 – November 14, 2013
- PIC #2 – December 2, 2014
- PIC #3 – November 6, 2024

Notifications of the three PICs were sent to stakeholders, local residents within close proximity of the main branches of Fourteen Mile Creek and McCraney Creek Systems, agencies and regional municipal staff by mail and email.

Copies of the presentation(s) and PIC boards have been included in Appendix A. Copies of sign in sheets, and feedback received (both from the public and agencies) has also been included in **Appendix A**.

1.5.3 Agency Consultation

The Class EA has been completed under the oversight of a Technical Steering Committee which included representatives from the Town of Oakville and Conservation Halton. Meetings have been held at key milestones throughout the study to review data needs and findings while providing input and guidance to achieve the study objectives. Correspondence from agencies is provided in **Appendix A**

An agency review meeting was held on December 4, 2015, with staff from both Conservation Halton (CH), the Ministry of Natural Resources and Forestry (MNRF), and the Region of Halton, as well as staff from the Town and WSP (then Amec Foster Wheeler). A copy of the presentation and meeting minutes are included in **Appendix A**.

1.5.4 Indigenous Engagement

Consultation has been conducted with indigenous groups, namely the Six Nations of Grand River Territory, Mississaugas of the New Credit First Nation, Haudenosaunee Confederacy Council, Alderville First Nation and Metis Nations of Ontario.

Communication was received from the Alderville First Nation on November 14, 2013, and December 2, 2014; copies are included in Appendix A. The November 14, 2013, communication indicates the project is deemed a level 3, having minimal potential to impact First Nations' rights. The Nation did request to be informed of findings as the study progressed.

No other communications from indigenous groups were received over the course of the study.

2 BACKGROUND INVENTORY

2.1 Reports, Studies and Mapping

This section provides a summary of the background information, which has been collected and reviewed for this study to date. Numerous documents have been made available for the current study; this section, however, focuses attention to that information, which specifically pertains to the hydrologic and hydraulic aspects of the study area.

Reports & Studies

This section offers a concise overview of the reports and studies deemed relevant to the current undertaking.

Jan-11	Fourteen Mile Creek Reach 2 Stabilization and Rehabilitation, Draft Environmental Assessment Report, Aquafor Beech Limited
Apr-08	Town-wide Flood Study, Philips Engineering Ltd.
May-07	Town of Oakville Erosion Assessment Study, TSH
Jan-02	Town of Oakville, Fourteen Mile Creek, Main and West Branches Subwatershed Plan, Philips Engineering Ltd.
Sep-00	Fourteen Mile Creek Assessment Study, Final Report, Totten Sims Hubicki Associates / Parish Geomorphic / Schroeter & Associates
Jun-00	May 12 / 13, 2000, Storm Events – General Flooding and Damage, Town of Oakville Staff Report
May-95	Town of Oakville, West Oak Trails, Subwatershed Impact Study for Taplow Creek, McCraney Creek and the East Branch of Fourteen Mile Creek, Final Report, Cosburn Patterson Wardman Limited / Ecoplans Ltd. / Golder Associates
Dec-93	Glen Oak Creek Subwatershed Impact Study, Final Report, UMA Engineering Ltd.
Feb-92	Town of Oakville, Fourteen Mile Creek-McCraney Creek, Watershed Planning Study, Final Report, Triton Engineering Services Ltd., J.L. Cox Planning Consultants / Ecological Services for Planning / D.W. Draper / Terraqua Investigations Ltd.

Apr-86 Fourteen Mile Creek - McCraney Creek System, Flood Damage Reduction Preliminary Engineering Study, Philips Planning & Engineering Ltd.

Dec-85 Halton Region Conservation Authority, McCraney Creek, Town of Oakville, Technical Report on Erosion Control, Philips Planning & Engineering Ltd.

Jul-85 Halton Region Conservation Authority, 14 Mile Creek - McCraney Creek System Flood Damage Reduction Preliminary Engineering Study, Interim Report, Philips Planning & Engineering Ltd.

Jun-85 Halton Region Conservation Authority, 14 Mile Creek - McCraney Creek System Flood Control Study, Technical Report Summary of Hydrology, Hydraulics and Flood Damages, Philips Engineering Ltd.

Feb-84 Halton Region Conservation Authority, 14 Mile Creek Flood Damage Reduction Study, Notes on Review of Draft Report, Philips Planning & Engineering Ltd.

Relevant Report Summaries

Town of Oakville Town-wide Flood Study, Philips Engineering Ltd., April 2008. Flood susceptible creek reaches were identified and ranked, and preliminary flood mitigation opportunity alternatives were provided. Seven creek reaches were identified for further investigation on Fourteen Mile Creek and McCraney Creek below the QEW.

Town of Oakville, Fourteen Mile Creek-McCraney Creek, Watershed Planning Study, Final Report, Triton Engineering Services Ltd., J.L. Cox Planning Consultants / Ecological Services for Planning / D.W. Draper / Terraqua Investigations Ltd., February 1992. As part of this study, the hydrology for both Fourteen Mile Creek and McCraney Creek was developed using the GAWSER hydrologic modelling platform. Peak flows were determined at key locations for the 2- to 100-year storms and for the Regional Storm Hurricane Hazel.

Fourteen Mile Creek-McCraney Creek System, Flood Damage Reduction Preliminary Engineering Study, Philips Planning and Engineering Ltd., April 1986: Flood damages for both Fourteen Mile Creek and McCraney Creek are documented. The report provides preliminary recommendations and considerations for reducing flooding conditions and flood damages.

Technical Drawings and Maps

The following maps and drawings have been provided for the current study:

- 2002 Digital contour mapping within the Town of Oakville (1 m contour intervals)
- 2009 Digital Elevation Model (DEM)
- 2009 Digital contour mapping
- 2009 mapping of roads, buildings, creek locations within the Town of Oakville
- 2009 Aerial photograph of the study area
- 2002 Conservation Halton regulated area

Models

The Triton Engineering GAWSER hydrologic model developed for the Town of Oakville as part of the 1992 Fourteen Mile Creek and McCraney Creek Watershed Planning Study and the 2002 HEC-RAS hydraulic model developed by Conservation Halton have been obtained. Based on consultation with Conservation Halton and Town of Oakville staff, these are the most current approved models for the Fourteen Mile Creek and McCraney Creek. Updates to the hydraulic modelling have included the WSP (then Amec) modelling for the Wildwood Drive culvert which is being replaced as of July 2011.

2.2 Field Reconnaissance

Field reconnaissance has been conducted in July 2011 of the most susceptible flood risk creek reaches identified with the Town-wide Flood Study and of the McCraney Creek to Fourteen Mile Creek diversion area recommended within the 1985 Fourteen Mile Creek - McCraney Creek Flood Damage Reduction Program (FDRP) Study. The Field reconnaissance has been documented within **Appendix B**.

3 BASELINE INVENTORY

The Municipal Class EA process requires that a baseline inventory of the study area be completed. For this study the baseline inventory has been completed to document the background information and assess the existing conditions of Fourteen Mile and McCraney Creeks in various disciplines relevant to the identified flooding problem, including hydrology, hydraulics and natural inventory.

3.1 Hydrology

Hydrology is the science of determining the amount of water moving through various processes within a watershed, based on various meteorologic conditions. Hydrologic modelling allows for the determination of a runoff rate from a particular landform in response to a rainfall or snowmelt event.

3.1.1 Initial GAWSER Modelling

As part of Phase 1 of this study (July 2011 reporting), the existing GAWSER hydrologic modelling conducted by Triton Engineering Services Ltd. was reviewed as a refinement of the existing modelling, as the development of new modelling was not initially required by the Town of Oakville. Verification of the existing modelling was conducted to determine its level of reasonableness.

To determine the reasonableness of the current GAWSER hydrologic modelling, unitary flows for each storm frequency at the outlets of Fourteen Mile Creek and McCraney Creek were compared to approved calibrated hydrologic models for various watersheds in southern Ontario. The unitary flows are determined based on the peak flow rates from the modelling for the contributing drainage area.

Table 3-1 provides a summary of the existing land use (2- to 100-year) and future land use Regional Storm peak flows from the Fourteen Mile Creek / McCraney Creek Watershed Planning Study conducted in 1992 (ref. **Appendix C**). The 1992 study used the GAWSER hydrologic modelling platform to determine flows and runoff volumes. The rainfall distribution used for the design storms was the 6-hour Chicago distribution as it produced higher peak flows in comparison to other distributions such as the 24-hour SCS-Type II distribution. The rainfall used in the Chicago distribution was developed using the intensity duration frequency (IDF) curves for the Oakville Ontario Water Resources Commission (OWRC) and Burlington Transmission Station (TS) weather stations. The Hurricane Hazel (Regional Storm) was applied using the shortened 12-hour event and saturated soil conditions. Hydrologic modelling calibration was not conducted due to a lack of flow records. A sensitivity analysis was conducted and determined that the most sensitive parameter adjusted by 50% would result in only a 20% change in peak flows and a 10% change in runoff volumes, therefore peak flows and runoff volumes were determined to not be that sensitive.

Table 3.1: Simulated Design Event Flows for Future Land Use Conditions (m^3/s) using GAWSER Modelling

Location / Model	Drainage Area	Return Period (Years)						
		2	5	10	25	50	100	Regional
Fourteen Mile Creek								
302 Dundas Street	3.380	2.88	3.89	4.80	6.61	7.15	8.80	24.00
223 Upper Middle	4.296	10.80	14.40	16.60	19.90	21.90	25.60	31.10
304 Upper Middle	1.570	16.60	22.50	26.10	31.60	34.80	40.70	22.90
508 QEW	22.791	50.70	66.10	77.50	98.60	104.00	122.00	178.00
113 Speers Road	27.462	53.20	68.90	81.50	104.00	110.00	130.00	212.00
114 Rebecca Street	29.782	47.10	60.80	77.00	99.40	106.00	128.00	234.00
216 Lakeshore	30.172	47.10	60.70	76.60	99.50	106.00	127.00	238.00
West McCraney Creek								
306 Upper Middle	1.631	11.10	15.60	18.60	23.50	25.80	30.90	23.10
110 QEW	2.791	7.50	10.20	11.70	17.80	21.40	27.00	34.30
Taplow Creek								
307 Upper Middle	1.540	14.90	20.80	24.50	30.20	33.30	39.40	22.40
552 QEW	3.000	9.41	11.20	14.20	19.20	21.00	26.20	33.70
Glen Oaks Creek								
308 Upper Middle	1.710	11.60	15.60	18.50	23.20	25.60	30.50	24.10
53 QEW	3.210	10.50	15.40	20.70	31.10	34.20	39.80	42.10
McCraney Creek								
233 Speers Road	7.760	21.30	27.40	32.50	41.50	45.10	56.30	89.70
157 Lakeshore	9.930	27.30	28.70	30.10	35.50	37.20	41.00	71.80

The GAWSER design event peak flow rates have been compared to other southern Ontario watersheds on a unitary basis in **Table 3-2**. The design event (2- to 100-year) unitary flow rates are considered to be high in comparison to other studies. The Regional Storm unitary flow rates are considered reasonable and within the expected range when compared to local watersheds. The Regional peak flow rates have also been compared graphically to other watersheds such as the Credit River in **Chart 3-1**. Based on this comparison the Regional unitary flow rates are within the expected range but are on the high end of the range.

Verification of the design event versus continuous frequency flows has been conducted by comparing unitary flow rates in **Table 3-3** from various studies and watercourse systems within the Golden Horseshoe area. The results indicate that the 1992 GAWSER design event peak flows are higher than the range of unitary frequency flows (2- to 100-year) for most watercourse systems.

Table 3.2: Watercourse Unitary Peak Flow Comparison (/ha) based on GAWSER

Land Use	Location	Area (ha)	Unitary Flow Rates (m^3/s/ha) for Design Storm						
			2	5	10	20	50	100	Reg
Urban + Rural	Fourteen Mile Creek at LakeShore	30.2	0.016	0.020	0.025	0.033	0.035	0.042	0.079
Urban + Rural	McCraney Creek at Lakeshore	9.9	0.027	0.029	0.030	0.036	0.037	0.041	0.072
Rural	North Waterdown	466.9	0.006	0.011	0.014	0.018	0.021	0.023	0.090
Rural	Sixteen Mile Creek	444.4	0.003	0.006	0.009	0.012	0.016	0.019	0.075
Rural + Urban	Red Hill Creek	6,800	0.007	0.011	0.014	0.017	0.022	0.026	0.069
2009 Rural Urban	Stoney (Escarp.)	1,873.3	0.004	0.007	0.011	0.015	0.018	0.022	0.073
	Battlefield (Escarp.)	487.1	0.004	0.008	0.011	0.015	0.019	0.022	0.073
	Stoney (Outlet)	3,089.7	0.004	0.007	0.010	0.014	0.017	0.020	0.063

Table 3.3: Watercourse Unitary Peak Flow Comparison (/km^2) based on GAWSER

Situation	Location	Unitary Response Comparison ($m^3/s/km^2$) for Freq. Storm						
		2	5	10	20	50	100	Reg[1]
Rural / Urban	Fourteen Mile Creek[1]	1.56	2.01	2.54	3.30	3.51	4.21	7.89
Rural / Urban	McCraney Creek[1]	2.75	2.89	3.03	3.58	3.75	4.13	7.23
Rural / Urban	Sheldon Creek	0.79	1.64	2.37	3.14	4.2	5.06	8.57
Urban	Indian Creek (before confluence)	1.54	2.74	3.12	4.14	5.24	7.31	13.22
Urban	Indian Creek @ Outlet	1.16	1.79	2.19	2.87	3.37	4.61	9.41
Rural	North Waterdown	0.59	1.10	1.44	1.75	2.11	2.33	9.01
Rural	Sixteen Mile Creek Milton	0.31	0.63	0.89	1.17	1.56	1.87	7.49
Urban	Red Hill Parkway	0.67	1.07	1.38	1.72	2.22	2.63	6.91
Rural / Urban	Stoney (Outlet)	0.39	0.72	1.03	1.39	1.70	2.01	6.30

[1] Design Event Unitary Flows

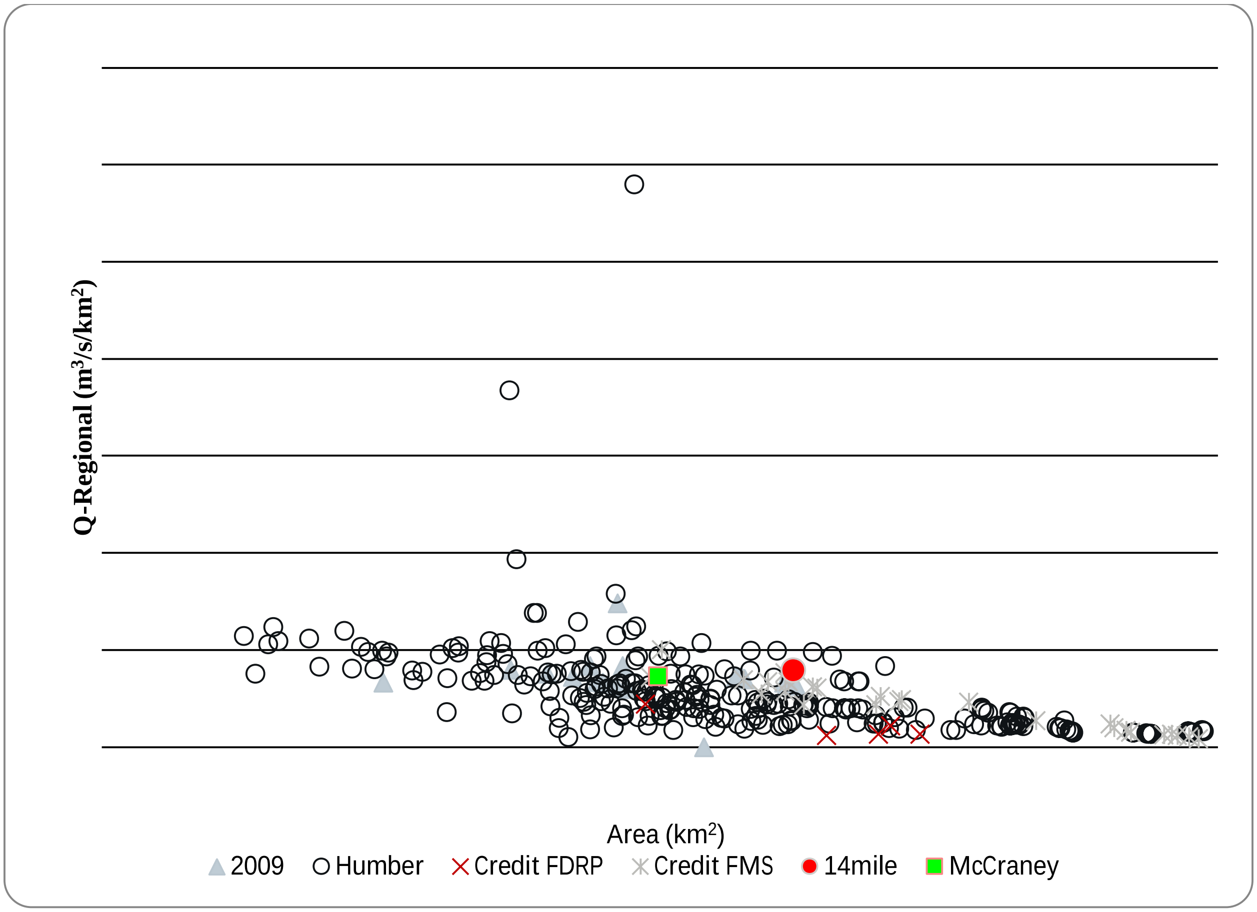


Chart 3-1: Comparison of Normalized Regional Storm Flows (GAWSER)

3.1.2 Subsequent PCSWMM Modelling

Based on discussions with Town staff, including a meeting on May 9, 2012, it was noted by Conservation Halton and Town staff that the hydrologic modelling was a problematic data gap and as such, an update (to the previous GAWSER modelling) was advanced. An updated hydrologic model was developed in PCSWMM accordingly. PCSWMM is a graphical user interface that applies the EPA-SWMM modelling code and can support both hydrologic and hydraulic modelling as required.

As documented in a technical memorandum of January 18, 2013, the PCSWMM hydrologic model was setup based on information provided by the Town of Oakville and Conservation Halton. Conservation Halton provided current hydraulic modelling of Fourteen Mile Creek (for channel routing elements) and the Town of Oakville provided land use data from the Official Plan, aerial photography, topographic mapping and stormwater management facility data to support the hydrologic modelling.

Based on the information provided to WSP (then AMEC), a drainage area (subcatchment boundary) plan was developed and circulated to both Conservation Halton and the Town of Oakville for review. Based on comments from the Town and Conservation Halton, the drainage area plan was updated accordingly.

Potential calibration data was evaluated, including available Water Survey of Canada flow gauge information and potential calibration events from 2011.

Based on an initial comparison of results, it was determined that unitary flow rates were high, and such the hydrologic modelling parameterization with respect to imperviousness values for different land uses were adjusted accordingly. A summary of adjusted hydrologic\hydraulic parameters is provided in Table 3.4; a summary of adjusted imperviousness coverages is also presented in Table 3.5.

Table 3.4: Initial PCSWMM Calibration Parameter Adjustment

Parameter	Initial Value	Adjusted Value
Hydraulic Conductivity (mm/hr)	1.2	3.0
Suction Head (mm)	50.0	210.0
Pervious Depression Storage (mm)	5.0	2.5
Impervious Depression Storage (mm)	2.5	1.0
Main Channel Roughness	0.03	0.06
Overbank Roughness	0.06	0.16

Table 3.5: PCSWMM Existing Land Use Impervious Coverages

Land Use	Initial Value		Adjusted Value	
	Total Imp (%)	Directly Connected Imp (%)	Total Imp (%)	Directly Connected Imp (%)
North of QEW				
Low Residential	30	20	40	24
Medium Residential	40	30	52	32
High Residential	60	40	60	40
Institutional	50	30	56	36
Commercial	95	80	76	68
Park	5	0	2	0
South of QEW				
Low Residential	20	40	32	20
Medium Residential	30	17	44	28
High Residential	50	26	52	36
Institutional	50	35	56	36
Commercial	95	30	76	68
Park	5	80	2	0

3.1.3 PCSWMM Model Validation

Subsequent to a meeting with the Town of Oakville on March 7, 2013, and Conservation Halton providing comments on March 23, 2013, supplementary PCSWMM model validation was requested. Conservation Halton noted that the Warminster Drive flow gauge has been operational since 2002, and that the gauge was originally set-up by Conservation Halton. It was also noted that a rainfall gauge had been operational at the same location, although it was not known as to the duration of the gauge's operation. WSP contacted Conservation Halton, Water Survey of Canada and the Town of Oakville to obtain additional flow and rainfall data. The following data has been provided:

- Conservation Halton: 15 minute rainfall data for 2002 to 2008 inclusive
- Water Survey of Canada: 15 minute observed flow data (period)
- Town of Oakville: 15 minute rainfall data for the Glen Abbey and Hopedale Mall rainfall gauges for 2008 to 2010 (2011 to 2012 had been previously provided)

In addition, Conservation Halton requested that the May 12 / 13, 2000, storm event, 14.2 mm and 63.7 mm respectively, be assessed with the PCSWMM hydrologic model, using observed high-water marks for Fourteen Mile Creek after the storm event. WSP subsequently requested this information on the storm event from both Conservation Halton and the Town of Oakville. In response, the Town of Oakville provided the June 20, 2000, Conservation Halton report. The report provides details of the storm event including the storm hyetograph (1 hour time step), observed high water marks and other incidental information.

WSP also had access to rainfall data derived using radar data for the May 2000 storm event. WSP has been working with Toronto and Region Conservation Authority (TRCA) on the Humber River Watershed Hydrology Update. As part of that study, TRCA requested WSP to establish rainfall for extreme events using radar data, including the May 2000 Oakville storm event. With permission from the TRCA the May 2000 rainfall data has been used for the Oakville study.

WSP has used the calibrated model, developed in January 2013, to evaluate this storm performance with the following modifications:

— The watershed drainage boundary within the Merton Lands, located north of the QEW, south of Upper Middle Road and west of Third Line have also been revised based on input from the Town of Oakville and Conservation Halton and Drainage Catchment 405 (196.19 ha) has been divided into three subcatchments to improve model discretization.

No other changes have been made to the January 2013 model. Based on the foregoing, WSP has executed the PCSWMM hydrologic model for 2002 to 2010 (2011 to 2012 had been previously assessed). As part of the PCSWMM model validation WSP has used Environment Canada’s Southeast Oakville IDF 11 years of data to estimate the return frequency of storm events (ref. **Appendix C**). Based on the estimated storm frequency, unitary peak flows for the observed and simulated hydrographs can be assessed for reasonableness. **Table 3.6** provides unitary flows for the PCSWMM model and other calibrated watersheds, for comparison to the 2002 - 2010 unitary flows. Unitary flows from other watersheds are shown in black; those from Fourteen Mile Creek are shown in red. In addition to assessing peak flows, runoff coefficients have been determined for the observed and simulated response hydrographs and subsequently evaluated for reasonableness.

Following execution of the PCSWMM model, the 2002 - 2010 results have been reviewed and evaluated. Based on data issues (i.e. observed flow increases during lengthy dry periods during 2003, resulting from probable operation issues with the flow gauge) it has been decided to initiate the assessment from 2004 onwards. Hydrographs for storm events during the 2004 to 2010 period selected for model validation have been included in **Appendix C** in addition to the hydrographs for each year. **Table 3.7** provides a summary of the 40 storms that have been assessed for peak flow and runoff volume. Based on the results in **Table 3.6** the following has been concluded:

— Storm events range in frequency from less than a 2-year storm up to a 100-year storm based on the Southeast Oakville IDF relationship (ref. 4th column, **Table 3.7**).

— Simulated unitary peak flows have a close correlation with the storm frequency, apart from situations when minor storm events occur prior to the storm event being assessed (i.e. high antecedent moisture).

— Observed unitary peak flows are typically significantly below the expected range of values for each storm event.

— Simulated runoff coefficients are considered reasonable, although the observed runoff coefficients are considered low with coefficients of 0.02 to 0.36 with an average of 0.11. In contrast to the simulated runoff coefficients which range in value from 0.06 to 0.65 with an average of 0.35, for storm events averaging 10 hours in duration and 34 mm in magnitude.

The calibrated PCSWMM hydrologic model has also been executed for the May 2000 storm event as requested by Conservation Halton. The rainfall data had been determined using Environment Canada's radar data. The June 2000 report to the Town of Oakville had determined that the storm event was approximately a 25-year storm event. **Table 3.8** provides the results of the May 2000 storm event for specific locations within Fourteen Mile Creek. Average deviation from observed high water elevations by the simulated water surface elevation is 0.29 m. The peak flow determined at Warminster Drive is 90.44 m^3/s, which is between 50- and 100-year storm events, based on design storm peak flows.

Based on the validation using an additional 40 storms and the May 2000 storm event the PCSWMM hydrologic / hydraulic model had been considered suitable for use for assessing alternatives.

Table 3.6: Watercourse Unitary Peak Flow Comparison ($m^3/s/ha$)

Land Use	Road	Location	Area	Unitary Flow Rates ($m^3/s/ha$) for Design Storm						
			(ha)	2 Yr	5 Yr	10 Yr	20 Yr	50 Yr	100 Yr	Reg
Rural / Urban		Unnamed Grand River Trib.(City of Kitchener)	57.77	0.025	0.04	0.052	0.067	0.089	0.109	0.108
Rural / Urban	Upper Middle	Glen Oaks Creek	101.91	0.013	0.049	0.077	0.105	0.123	0.141	0.123
Rural / Urban	Upper Middle	McCraney Creek	178.25	0.004	0.015	0.022	0.040	0.048	0.057	0.107
Rural / Urban	Upper Middle	14 Mile Creek, Trib-2	191.22	0.003	0.007	0.014	0.036	0.053	0.068	0.130
Rural / Urban	Upper Middle	Taplow Creek	204.69	0.007	0.014	0.018	0.030	0.040	0.047	0.108
Rural / Urban	QEW	McCraney Creek	297.96	0.039	0.068	0.088	0.116	0.136	0.157	0.100
Rural / Urban	QEW	Glen Oaks Creek	298.10	0.036	0.063	0.082	0.103	0.124	0.143	0.114
Rural	Dundas	14 Mile Creek, East Branch	299.01	0.004	0.013	0.021	0.032	0.041	0.047	0.107
Rural / Urban	QEW	Taplow Creek	321.63	0.016	0.030	0.041	0.054	0.062	0.068	0.097
Rural / Urban	Upper Middle	14 Mile Creek, East Trib.	401.01	0.002	0.009	0.016	0.025	0.032	0.038	0.100
Rural		Sixteen Mile Creek, Milton	444.4	0.003	0.006	0.009	0.012	0.016	0.019	0.075
Rural		North Waterdown	466.9	0.006	0.011	0.014	0.018	0.021	0.023	0.09
Rural / Urban		Battlefield Creek Hamilton (Escarp.)	487.1	0.004	0.008	0.011	0.015	0.019	0.022	0.073
Rural / Urban	Speers	East McCraney Creek	711.31	0.023	0.032	0.036	0.040	0.052	0.057	0.100
Rural / Urban	Lakeshore	East McCraney Creek	970.47	0.020	0.028	0.037	0.049	0.058	0.066	0.099
Rural / Urban		Stoney Creek Hamilton (Escarp.)	1873.3	0.004	0.007	0.011	0.015	0.018	0.022	0.073
Rural / Urban	QEW	14 Mile Creek	2380.93	0.007	0.013	0.016	0.021	0.024	0.027	0.073
Rural / Urban	Speers	14 Mile Creek	2876.45	0.011	0.017	0.021	0.026	0.029	0.031	0.069
2009 Rural / Urban		Stoney Creek Hamilton (Outlet)	3089.72	0.004	0.007	0.01	0.014	0.017	0.02	0.063
Rural / Urban	Rebecca	14 Mile Creek	3153.92	0.009	0.017	0.020	0.026	0.027	0.032	0.065
Rural / Urban	Lakeshore	14 Mile Creek	3183.58	0.010	0.016	0.020	0.025	0.027	0.030	0.064
Rural + Urban		Red Hill Creek, Hamilton	6800	0.007	0.011	0.014	0.017	0.022	0.026	0.069

Table 3.7: Summary of Storm Event Modelling Results

Date	Duration	Depth	Storm	Peak Flows (m^3/s)	Peak Flows (m^3/s)	Unitary Flows ($m^3/s/ha$)	Unitary Flows ($m^3/s/ha$)	Unitary Flows Ratios	Runoff Coefficient	Runoff Coefficient	Runoff Coefficient Ratios	Comments
	(Hrs)	(mm)	Frequency	Simulated	Observed	Simulated	Observed	Sim / Obs	Simulated	Observed	Sim / Obs	
09/28/2010	4.41	38.8	2 - 5	28.07	9.66	0.0094	0.0032	2.90	0.387	0.140	2.76	Simulated Unitary Q 2-5 year, Observed Unitary Q <2 year. Simulated RC reasonable, Observed RC low
07/24/2010	16.8	29	<2	26.09	10.48	0.0088	0.0035	2.49	0.443	0.364	1.22	Simulated Unitary Q = 2 year due to 07/23 event, Observed Unitary Q - 60% of 2 year. Simulated RC reasonable, Observed RC low
07/23/2010	1.16	33.2	10 - 25	41.76	11.38	0.0140	0.0038	3.67	0.614	0.109	5.62	Simulated Unitary Q 10-25 year, Observed Unitary Q= 2 year. Simulated RC reasonable, Observed RC low
06/27/2010	5.92	19.8	<2	16.14	4.09	0.0054	0.0014	3.95	0.300	0.111	2.70	Storm 60% of 2 year. Simulated Unitary Q almost 2 year, Observed Unitary Q - 25% of 2 year. Simulated RC reasonable, Observed RC low
08/29/2009	8.16	38	2	26.51	8.62	0.0089	0.0029	3.08	0.459	0.199	2.30	Simulated Unitary Q just over 2 year, Observed Unitary Q - 50% of 2 year. Simulated RC reasonable, Observed RC low
08/20/2009	0.58	36	>100	50.37	10.08	0.0169	0.0034	5.00	0.550	0.114	4.85	Simulated Unitary Q over 100 year, Observed Unitary Q - 60% of 2 year. Simulated RC reasonable, Observed RC low
07/25/2009	2.42	32.4	2 - 5	30.84	9.91	0.0104	0.0033	3.11	0.525	0.206	2.55	Simulated Unitary Q - 5 year, Observed Unitary Q - 60% of 2 year. Simulated RC reasonable, Observed RC low
07/23/2009	5.83	20.2	<2	10.40	4.32	0.0035	0.0015	2.41	0.208	0.069	3.00	Storm 55% of 2 year. Simulated Unitary Q - 60% of 2 year, Observed Unitary Q - 25% of 2 year. Simulated RC reasonable, Observed RC low
06/25/2009	0.66	13.6	<2	19.70	3.85	0.0066	0.0013	5.12	0.136	0.067	2.03	Storm 75% of 2 year. Simulated Unitary Q - 2 year, Observed Unitary Q - 20% of 2 year. Simulated RC reasonable, Observed RC low
08/25/2008	4.92	37	2 - 5	27.74	10.17	0.0093	0.0034	2.73	0.479	0.279	1.72	Simulated Unitary Q - 2-5 year, Observed Unitary Q - 60% of 2 year. Simulated RC reasonable, Observed RC low
07/20/2008	23.42	76	10 - 25	22.00	8.76	0.0074	0.0029	2.51	0.440	0.273	1.61	Simulated Unitary Q - almost 5 year, Observed Unitary Q - 55% of 2 year. Simulated RC reasonable, Observed RC low
10/07/2007	31.25	23.75	<2	8.52	1.93	0.0029	0.0006	4.43	0.155	0.043	3.63	Storm 40% of 2 year. Simulated Unitary Q - 50% of 2 year, Observed Unitary Q - 10% of 2 year. Simulated RC reasonable, Observed RC low
08/25/2007	5.75	47	almost 5	45.18	2.99	0.0152	0.0010	15.10	0.458	0.022	20.49	Simulated Unitary Q - almost 10 year due to split hydrograph, Observed Unitary Q - 16% of 2 year. Simulated RC reasonable, Observed RC low
06/19/2007	1.5	22	almost 2	23.55	2.66	0.0079	0.0009	8.86	0.277	0.027	10.09	Storm 90% of 2 year. Simulated Unitary Q 2-5 year, Observed Unitary Q - 10% of 2 year. Simulated RC reasonable, Observed RC low
05/16/2007	11.5	36.25	<2	13.41	2.19	0.0045	0.0007	6.14	0.319	0.083	3.83	Storm 80% of 2 year. Simulated Unitary Q 75% of 2 year, Observed Unitary Q - <10% of 2 year. Simulated RC reasonable, Observed RC low
10/19/2006	14.75	53.25	almost 5	22.58	14.06	0.0076	0.0047	1.61	0.483	0.335	1.44	Simulated Unitary Q almost 5 year, Observed Unitary Q - 80% of 2 year. Simulated RC reasonable, Observed RC low
10/05/2006	7.75	43.25	almost 5	26.73	8.35	0.0090	0.0028	3.20	0.491	0.257	1.91	Simulated Unitary Q - 5 year, Observed Unitary Q - <50% of 2 year. Simulated RC reasonable, Observed RC low
07/29/2006	4.5	30.75	almost 2	28.27	1.89	0.0096	0.0006	15.11	0.509	0.120	4.23	Simulated Unitary Q - 5 year due to 9.5 mm 24 hrs before event, Observed Unitary Q - 10% of 2 year. Simulated RC reasonable, Observed RC low
07/23/2006	3.5	28	almost 2	21.18	3.31	0.0071	0.0011	6.39	0.433	0.057	7.61	Storm 90% of 2 year. Simulated Unitary Q just over 2 year, Observed Unitary Q - >15% of 2 year. Simulated RC reasonable, Observed RC low

Date	Duration	Depth	Storm	Peak Flows (m^3/s)	Peak Flows (m^3/s)	Unitary Flows ($m^3/s/ha$)	Unitary Flows ($m^3/s/ha$)	Unitary Flows Ratios	Runoff Coefficient	Runoff Coefficient	Runoff Coefficient Ratios	Comments
	(Hrs)	(mm)	Frequency	Simulated	Observed	Simulated	Observed	Sim / Obs	Simulated	Observed	Sim / Obs	
07/13/2006	11.75	67.25	10 - 25	45.14	8.93	0.0152	0.0030	5.06	0.646	0.197	3.28	Simulated Unitary Q - 10-25 year, Observed Unitary Q - 50% of 2 year. Simulated RC reasonable, Observed RC low
06/30/2006	7	38.5	>2	38.22	2.74	0.0128	0.0009	13.97	0.557	0.025	22.21	Storm just over 2 year. Simulated Unitary Q 10 year due to 21 mm less than 24 hours before event, Observed Unitary Q - >15% of 2 year. Simulated RC reasonable, Observed RC low
05/17/2006	21.5	28.5	<2	10.82	3.99	0.0036	0.0013	2.71	0.200	0.253	0.79	Storm 60% of 2 year. Simulated Unitary Q 60% of 2 year, Observed Unitary Q >20% of 2 year. Simulated RC reasonable, Observed RC reasonable
05/11/2006	15.75	32.5	<2	6.82	1.83	0.0023	0.0006	3.73	0.147	0.077	1.89	Storm 75% of 2 year. Simulated Unitary Q 40% of 2 year due to storm formation, Observed Unitary Q 10% of 2 year. Simulated RC reasonable, Observed RC low
04/23/2006	23.5	40	<2	9.56	0.28	0.0032	0.0001	34.02	0.316	0.215	1.47	Storm 75% of 2 year. Simulated Unitary Q 40% of 2 year due to storm formation, Observed Unitary Q <5% of 2 year. Simulated RC reasonable, Observed RC low
10/07/2005	3.75	22.75	<2	11.84	1.56	0.0040	0.0005	7.58	0.267	0.029	9.21	Storm 70% of 2 year. Simulated Unitary Q 65% of 2 year, Observed Unitary Q <10% of 2 year. Simulated RC reasonable, Observed RC low
09/26/2005	17.25	45.5	2	14.08	3.56	0.0047	0.0012	3.96	0.356	0.050	7.19	Simulated Unitary Q -80% of 2 year due to storm formation, Observed Unitary Q 20% of 2 year. Simulated RC reasonable, Observed RC low
08/31/2005	10.25	50	2 - 5	30.45	4.82	0.0102	0.0016	6.31	0.492	0.060	8.22	Simulated Unitary Q - 5 year, Observed Unitary Q - 25% of 2 year. Simulated RC reasonable, Observed RC low
08/02/2005	2.5	13.25	<2	10.54	2.21	0.0035	0.0007	4.76	0.136	0.037	3.65	Storm 45% of 2 year. Simulated Unitary Q - 60% of 2 year, Observed Unitary Q - 12% of 2 year. Simulated RC reasonable, Observed RC low
07/26/2005	24.75	69	5 - 10	80.66	9.36	0.0271	0.0031	8.62	0.505	0.030	16.65	Simulated Unitary Q - 100 year, Observed Unitary Q - 60% of 2 year. Simulated RC reasonable, Observed RC low
07/17/2005	20.75	38	<2	11.30	1.47	0.0038	0.0005	7.67	0.150	0.030	5.01	Storm 80% of 2 year. Simulated Unitary Q -65% of 2 year. Observed Unitary Q <10% of 2 year. Simulated RC reasonable, Observed RC low
06/13/2005	2.75	29.25	2	23.56	3.17	0.0079	0.0011	7.43	0.481	0.023	20.91	Storm >90% of 2 Year. Simulated Unitary Q just above 2 year. Observed Unitary Q <20% of 2 year. Simulated RC reasonable, Observed RC low
04/23/2005	55.75	62.5	<2	4.83	5.23	0.0016	0.0018	0.92	0.167	0.194	0.86	Storm >50% of 2 Year. Simulated Unitary Q > 25% of 2 year. Observed Unitary Q >25% of 2 year. Simulated RC reasonable, Observed RC reasonable
10/30/2004	1.25	14.25	<2	3.85	0.84	0.0013	0.0003	4.58	0.062	0.016	3.79	Storm >60% of 2 Year. Simulated Unitary Q >20% of 2 year due to storm formation. Observed Unitary Q <5% of 2 year. Simulated RC reasonable, Observed RC unreasonable
10/15/2004	3.75	15.75	<2	6.28	1.61	0.0021	0.0005	3.90	0.067	0.026	2.63	Storm >50% of 2 Year. Simulated Unitary Q 35% of 2 year. Observed Unitary Q <10% of 2 year. Simulated RC reasonable, Observed RC unreasonable
08/03/2004	0.5	12.75	<2	12.33	2.15	0.0041	0.0007	5.74	0.148	0.043	3.42	Storm >65% of 2 Year. Simulated Unitary Q >60% of 2 year. Observed Unitary Q <10% of 2 year. Simulated RC reasonable, Observed RC unreasonable
07/31/2004	9.5	18.75	<2	4.56	1.47	0.0015	0.0005	3.10	0.124	0.042	2.94	Storm >45% of 2 Year. Simulated Unitary Q - 20% of 2 year. Observed Unitary Q <10% of 2 year. Simulated RC reasonable, Observed RC unreasonable

Date	Duration	Depth	Storm	Peak Flows (m^3/s)	Peak Flows (m^3/s)	Unitary Flows ($m^3/s/ha$)	Unitary Flows ($m^3/s/ha$)	Unitary Flows Ratios	Runoff Coefficient	Runoff Coefficient	Runoff Coefficient Ratios	Comments
	(Hrs)	(mm)	Frequency	Simulated	Observed	Simulated	Observed	Sim / Obs	Simulated	Observed	Sim / Obs	
07/14/2004	4	45.75	almost 10	57.22	8.76	0.0192	0.0029	6.53	0.592	0.051	11.67	Simulated Unitary Q - just under 25 year. Observed Unitary Q 50% of 2 year. Simulated RC reasonable, Observed RC unreasonable
06/18/2004	5.5	31.75	2	18.78	7.29	0.0063	0.0025	2.58	0.442	0.133	3.34	Simulated Unitary Q - 2 year, Observed Unitary Q - 40% of 2 year. Simulated RC reasonable, Observed RC low
06/14/2004	0.75	13.75	<2	13.24	1.15	0.0044	0.0004	11.54	0.229	0.031	7.42	Storm >65 % of 2 Year. Simulated Unitary Q >70% of 2 year, Observed Unitary Q <10% of 2 year. Simulated RC reasonable, Observed RC low
05/22/2004	13.5	22.75	<2	13.08	2.47	0.0044	0.0008	5.30	0.356	0.075	4.75	Storm 50% of 2 Year. Simulated Unitary Q >70% of 2 year, Observed Unitary Q- >10% of 2 year. Simulated RC reasonable, Observed RC low
04/18/2004	1.25	20	<2	17.51	4.39	0.0059	0.0015	3.99	0.306	0.132	2.32	Storm 85% of 2 Year. Simulated Unitary Q >85% of 2 year, Observed Unitary Q 25% of 2 year. Simulated RC reasonable, Observed RC low
Minimum	0.50	12.75	<2	3.85	0.28	0.00	0.00	0.92	0.06	0.02	0.79	
Maximum	55.75	76.00	NA	80.66	14.06	0.03	0.00	34.02	0.65	0.36	22.21	
Average	10.05	33.92	>100	22.77	5.07	0.01	0.00	6.14	0.35	0.11	5.54	

Table 3.8: Summary of May 2000 Results

Location	Observed High Water Elevation (m)	Simulated Water Surface Elevation (m)	Difference in Water Surface Elevations (m)	Simulated Peak Flow (m^3/s)
Speers Road	96.00 - 96.50	96.97	0.47	89.50
Bridge Road	92.00 - 92.50	92.68	0.18	89.56
Warminster Upstream	90.50 - 91.00	90.43	-0.07	90.44
Warminster Drive Downstream	89.50	89.93	0.43	90.44

3.1.4 PCSWMM Model Revisions and Re-validation

In 2017, WSP was provided documentation from the Town of Oakville, pertaining to existing on-line structures located upstream of the QEW, requiring additional PCSWMM model revisions and re-validation.

Background Information

The following information was received by WSP as provided by the Town:

Glen Abbey Phase 3 Stages 2 and 3 and Phase 4 Stage 1, Detention Requirements on East Branch of Fourteen Mile Creek, Andrew Brodie Associates Inc., May 6, 1986

The report outlines the design of the Abbeywood Drive control structure. The report provides dimensions of the outlet control structure.

Glen Abbey Community, Genstar Phase 3, Stages 2 and 3, Hydraulic Grade Line Analysis, Andrew Brodie Associates Inc., dated July 4, 1986

The report provides a hydraulic grade-line analysis for storm sewers discharging to the Abbeywood Drive tributary of the Fourteen Mile Main Branch.

Glen Abbey Community, Phase 3, Stage 2, Re-alignment of the East Branch of the Fourteen Mile Creek, UMA Engineering Ltd., dated February 27, 1986

The report outlines a preliminary design of a realignment of the Abbeywood Drive tributary between Abbeywood Drive and Third Line, to facilitate the development of a residential subdivision.

Glen Abbey Stage 3, Phase 4, Stormwater Management Analysis of Portion South of Pilgrims Way, Andrew Brodie Associates Inc., dated December 9, 1985

The report outlines the design of a control structure for a development draining to a tributary of the former McCraney Creek system.

Glen Abbey Stormwater Management Review, Andrew Brodie Associates Inc., dated February 14, 1983

The report provides a feasibility assessment of on-line control structures to control runoff from upstream development lands.

Drawings

- Abbey Wood Drive – Culvert & Details, prepared by UMA Engineering Ltd., January 14, 1987
- Glen Abbey Community, Storm Drainage Areas, UMA Engineering Ltd., January 14, 1987
- Glen Abbey Community, Storm Outfalls, prepared by UMA Engineers Ltd., August 25, 1986
- Glen Abbey Community, Pilgrims Way, UMA Engineers Ltd., August 21, 1986
- Glen Abbey Community, Storm Drainage Plan, Underwood McLellan (1977) Ltd., June 18, 1981
- Glen Abbey Community – Concrete Box Culvert Details, Underwood McLellan (1977) Ltd., December 1979
- Glen Oaks Creek West – Cross Section of Dam and Drainage Structure, Underwood McLellan (1977) Ltd., November 1979
- Glen Oaks Creek East – Drainage Structure Upstream Section, Underwood McLellan (1977) Ltd., November 1979
- Glen Oaks Creek East – Drainage Structure Downstream Section, Underwood McLellan (1977) Ltd., November 1979
- Glen Oaks Creek East – Stormwater Management Pond, Underwood McLellan (1977) Ltd., November 1979
- Glen Oaks Creek West – Stormwater Management Pond, Underwood McLellan (1977) Ltd., November 1979

Excerpts from the documentation and mapping determined to be of most utility are provided in **Appendix C**.

Fieldwork

WSP conducted site visits (Spring 2017) to each of the on-line control structures to verify dimensions provided by the documentation and mapping and fill gaps accordingly. The field verification work determined that several of the control structure dimensions measured in the field differ from the design information. Although the differences in measurements were not substantial, the field measurements have nevertheless been used in the model updates. Furthermore, WSP noted that two control structures, namely *Nottinghill Gate* and *Old Abbey Lane*, contained orifice plates, which were not noted on the documentation and mapping provided. The orifice plates were attached to the first stage control on the structures and were noted to be restricting flows entering the structures during the site visits. The field measurements and photographs are provided in **Appendix C**. Details of the control structure dimensions incorporated into the hydrologic model are discussed in the next section.

Model Updates

The *Abbeywood Drive*, *Pilgrims Way*, and *Nottinghill Gate* control structures are comprised of three stages of controls, while the *Old Abbey Lane* control structure is comprised of two stages of controls. The on-line structure and culvert dimensions incorporated into the PCSWMM model are provided in **Table 3.9**.

Table 3.9: On-line Control Structure Dimensions Incorporated into Hydrologic Model

Structure / Creek	Control # 1	Control # 2	Control # 3	Culvert Dimensions
Abbeywood Drive / Abbeywood Drive Tributary	Square Orifice (0.85 m high x 1.06 m wide)	Rectangular Weir (1.80 m high x 1.75 m wide)	Open Square Top (4.0 m x 4.0 m)	2.35 m high x 2.40 m wide
Pilgrims Way / Former McCraney Creek	Circular Orifice (0.75 m dia.)	Rectangular Weir (1.25 m high x 1.55 m wide)	Open Square Top (3.10 m x 2.25 m)	1.85 m high x 3.05 m wide
Nottinghill Gate / Taplow Creek	Circular Orifice (0.324 m dia.)[1]	Rectangular Weir (0.50 m high x 3.30 m wide)	Open Square Top (3.30 m x 2.75 m)	1.80 m high x 3.05 m wide
Old Abbey Lane / Glen Oak Creek	Square Orifice[2] (0.60 m high x 0.60 m wide)	Rectangular Weir (1.20 m high x 3.00 m wide)	N/A	1.50 m high x 3.05 m wide

[1]. Orifice plate observed in field, covering an estimated 2/3 of the circular orifice opening. Effective diameter calculated and incorporated into model.

[2] Square orifice plate observed in field. Dimensions were estimated as they could not be directly measured.

Other updates to the PCSWMM model have included minor subcatchment re-discretization (to refine drainage areas controlled by on-line structures).

Modelling Results

In order to determine the impacts to peak flows attributable to incorporating the on-line control structures, two scenarios have been modelled in PCSWMM. The first scenario included only the culverts associated with the on-line control structures (i.e. without on-line control structures incorporated into the model). The second scenario included the culverts with the on-line control structures in place. The hydrologic model was executed for the 2 – 100 year and Regional Storm events, and the results analyzed at subject nodes along the Fourteen Mile and McCraney Creeks systems (ref. Drawing 2 in Appendix H for flow nodes). The subject flow nodes were selected at the on-line control structures (i.e. Nodes FM1, FM3, MC1 and MC3), at the QEW (i.e. Nodes FM2, FM4, MC2 and MC4), at the CNR (i.e. Nodes FM5 and MC5), and at the creek's outlets to Lake Ontario (i.e. Nodes FM6 and MC6). The results are provided in **Tables 3.10** to **3.13**.

Table 3.10: Fourteen Mile Creek – Simulated Peak Flows (m^3/s) – 2 & 5 Year

Flow Node	2 Year			5 Year		
	On-Line Structure Culverts Only	On-Line Structures & Associated Controls	% Difference	On-Line Structure Culverts Only	On-Line Structures & Associated Controls	% Difference
FM1 – Upstream of Abbeywood Drive Structure	7.90	7.90	-	12.76	12.76	-
FM1 - Downstream of Abbeywood Drive Structure	5.88	2.74	-53%	8.89	3.35	-62%
FM2 - Fourteen Mile Main Branch @ QEW	19.99	20.01	0%	37.36	38.30	3%
FM3 - Upstream of Pilgrims Way Structure	8.56	8.56	-	13.67	13.67	-
FM3 - Downstream of Pilgrims Way Structure	7.91	1.89	-76%	12.00	3.91	-67%
FM4 - Former McCraney Creek @ QEW	9.67	4.72	-51%	15.20	7.60	-50%
FM5 - Fourteen Mile Main Branch @ CNR	25.88	22.52	-13%	42.37	42.63	1%
FM6 - Fourteen Mile Main Branch @ Lake Ontario	27.66	24.85	-10%	47.94	42.67	-11%

Table 3.11: Fourteen Mile Creek – Simulated Peak Flows (m^3/s) – 10 & 25 Year

Flow Node	10 Year			25 Year		
	On-Line Structure Culverts Only	**On-Line Structures & Associated Controls**	**% Difference**	**On-Line Structure Culverts Only**	**On-Line Structures & Associated Controls**	**% Difference**
FM1 – Upstream of Abbeywood Drive Structure	16.23	16.23	-	21.12	21.12	-
FM1 - Downstream of Abbeywood Drive Structure	10.84	5.16	-52%	13.23	7.95	-40%
FM2 - Fourteen Mile Main Branch @ QEW	50.53	51.69	2%	68.94	70.64	2%
FM3 - Upstream of Pilgrims Way Structure	17.27	17.27	-	22.30	22.30	-
FM3 - Downstream of Pilgrims Way Structure	14.67	5.47	-63%	17.99	8.60	-52%
FM4 - Former McCraney Creek @ QEW	18.68	9.51	-49%	22.93	12.06	-47%
FM5 - Fourteen Mile Main Branch @ CNR	55.25	57.40	4%	75.30	78.16	4%
FM6 - Fourteen Mile Main Branch @ Lake Ontario	60.11	57.26	-5%	75.12	77.61	3%

Table 3.12: Fourteen Mile Creek Simulated Peak Flows (m^3/s) – 50 & 100 Year

Flow Node	50 Year			100 Year		
	On-Line Structure Culverts Only	On-Line Structures & Associated Controls	% Difference	On-Line Structure Culverts Only	On-Line Structures & Associated Controls	% Difference
FM1 – Upstream of Abbeywood Drive Structure	24.79	24.79	-	28.40	28.40	-
FM1 - Downstream of Abbeywood Drive Structure	14.96	9.94	-34%	16.78	12.23	-27%
FM2 - Fourteen Mile Main Branch @ QEW	82.47	84.51	2%	96.69	99.05	2%
FM3 - Upstream of Pilgrims Way Structure	26.04	26.04	-	29.69	29.69	-
FM3 - Downstream of Pilgrims Way Structure	19.05	10.75	-44%	20.19	12.99	-36%
FM4 - Former McCraney Creek @ QEW	24.75	13.90	-44%	26.28	15.66	-40%
FM5 - Fourteen Mile Main Branch @ CNR	89.82	93.02	4%	103.90	107.20	3%
FM6 - Fourteen Mile Main Branch @ Lake Ontario	88.78	91.94	4%	103.30	106.70	3%

Table 3.13: Fourteen Mile Creek – Simulated Peak Flows (m^3/s) – Regional Storm

Flow Node	Regional Storm		
	On-Line Structure Culverts Only	On-Line Structures & Associated Controls	% Difference
FM1 – Upstream of Abbeywood Drive Structure	29.46	29.46	-
FM1 - Downstream of Abbeywood Drive Structure	29.42	36.57	24%
FM2 - Fourteen Mile Main Branch @ QEW	224.60	222.70	-1%
FM3 - Upstream of Pilgrims Way Structure	27.66	27.66	-
FM3 - Downstream of Pilgrims Way Structure	27.58	27.93	1%
FM4 - Former McCraney Creek @ QEW	30.85	31.25	1%
FM5 - Fourteen Mile Main Branch @ CNR	258.10	257.00	0%
FM6 - Fourteen Mile Main Branch @ Lake Ontario	268.60	268.40	0%

Peak flow results presented in **Tables 3.10 – 3.13** indicate that the on-line control structures reduce peak flows immediately downstream of the control structures (Nodes FM1 and FM3), as well as at the QEW on the former McCraney Creek branch (Node FM4). A minor increase in peak flows with the on-line control structures in place is predicted to occur along the Fourteen Mile Main Branch (Nodes FM2, FM5, and FM6). It is noted that the simulated increase in peak flows is a result of the detention of flows by the on-line control structures (i.e. timing effects). The influence of timing effects has been confirmed through a review of runoff response hydrographs at the subject flow nodes. Hydrographs are provided in **Appendix C** for review.

Table 3.13 indicates a minor simulated increase in peak flows immediately downstream of the Abbeywood Drive control structure (Node FM1). It is noted that this control structure causes overtopping of the roadway during the Regional Storm event, while the model without the control structure in place does not, thus resulting in a reported peak flow increase at the subject flow node. The minor peak flow increase of 0.43 m^3/s (2%) noted at Node FM3 is counter initiative (i.e. On-Line control structures are expected to slightly reduce Regional Storm flows). Given the small difference in peak flows, though the noted increase is likely due to the computational limitations of the PCSWMM model. The peak flow increase noted at Node FM4 is a result of the minor increase at Node FM3 carried forward.

The results for the McCraney Creek system analysis are provided in **Tables 3.14 – 3.17**.

Table 3.14: McCraney Creek – Simulated Peak Flows (m^3/s) – 2 & 5 year

Flow Node	2 Year			5 Year		
	On-Line Structure Culverts Only	On-Line Structures & Associated Controls	% Difference	On-Line Structure Culverts Only	On-Line Structures & Associated Controls	% Difference
MC1 – Upstream of Nottinghill Gate Structure	5.40	5.40	-	8.68	8.68	-
MC1 - Downstream of Nottinghill Gate Structure	5.27	1.95	-63%	8.50	4.53	-47%
MC2 - Taplow Creek @ QEW	5.54	1.96	-65%	9.04	4.57	-49%
MC3 - Upstream of Old Abbey Lane Structure	10.52	10.52	-	14.69	14.69	-
MC3 - Downstream of Old Abbey Lane Structure	9.62	2.36	-75%	13.35	4.93	-63%
MC4 - Glen Oak Creek @ QEW	12.19	6.56	-46%	17.61	9.86	-44%
MC5 - McCraney Creek @ CNR	17.89	13.51	-24%	25.64	20.32	-21%
MC6 - McCraney Creek @ Lake Ontario	22.63	18.00	-20%	33.69	28.67	-15%

Table 3.15: McCraney Creek – Simulated Peak Flows (m^3/s) – 10 & 15 year

Flow Node	10 Year			25 Year		
	On-Line Structure Culverts Only	On-Line Structures & Associated Controls	% Difference	On-Line Structure Culverts Only	On-Line Structures & Associated Controls	% Difference
MC1 – Upstream of Nottinghill Gate Structure	11.00	11.00	-	14.21	14.21	-
MC1 - Downstream of Nottinghill Gate Structure	10.84	6.36	-41%	14.10	9.18	-35%
MC2 - Taplow Creek @ QEW	11.39	6.42	-44%	14.50	9.22	-36%
MC3 - Upstream of Old Abbey Lane Structure	17.31	17.31	-	18.76	18.76	-
MC3 - Downstream of Old Abbey Lane Structure	14.53	7.00	-52%	16.07	12.16	-24%
MC4 - Glen Oak Creek @ QEW	20.06	12.09	-40%	24.31	15.10	-38%
MC5 - McCraney Creek @ CNR	30.25	24.64	-19%	37.05	31.01	-16%
MC6 - McCraney Creek @ Lake Ontario	40.61	35.44	-13%	49.61	43.83	-12%

Table 3.16: McCraney Creek – Simulated Peak Flows (m^3/s) – 50 & 100 year

Flow Node	50 Year			100 Year		
	On-Line Structure Culverts Only	On-Line Structures & Associated Controls	% Difference	On-Line Structure Culverts Only	On-Line Structures & Associated Controls	% Difference
MC1 – Upstream of Nottinghill Gate Structure	16.15	16.15	-	17.63	17.63	-
MC1 - Downstream of Nottinghill Gate Structure	15.90	11.12	-30%	17.24	13.02	-24%
MC2 - Taplow Creek @ QEW	17.14	11.22	-35%	18.65	13.12	-30%
MC3 - Upstream of Old Abbey Lane Structure	20.07	20.07	-	21.26	21.26	-
MC3 - Downstream of Old Abbey Lane Structure	17.11	16.12	-6%	18.19	19.82	9%
MC4 - Glen Oak Creek @ QEW	27.57	18.62	-32%	29.99	22.73	-24%
MC5 - McCraney Creek @ CNR	41.77	35.66	-15%	46.19	40.55	-12%
MC6 - McCraney Creek @ Lake Ontario	56.16	50.18	-11%	63.50	56.04	-12%

Table 3.17: McCraney Creek – Simulated Peak Flows (m^3/s) – Regional Storm

Flow Node	Regional Storm		
	On-Line Structure Culverts Only	On-Line Structures & Associated Controls	% Difference
MC1 – Upstream of Nottinghill Gate Structure	33.91	33.91	-
MC1 - Downstream of Nottinghill Gate Structure	33.90	37.16	10%
MC2 - Taplow Creek @ QEW	35.27	38.45	9%
MC3 - Upstream of Old Abbey Lane Structure	30.47	30.47	-
MC3 - Downstream of Old Abbey Lane Structure	30.56	31.68	4%
MC4 - Glen Oak Creek @ QEW	36.45	37.99	4%
MC5 - McCraney Creek @ CNR	77.09	81.76	6%
MC6 - McCraney Creek @ Lake Ontario	104.50	108.70	4%

As indicated in **Tables 3.14– 3.16**, the on-line control structures reduce peak flows at all nodes along the McCraney Creek system, with the exception of the 100-year peak flow, reported immediately downstream of the Old Abbey Lane control structure. The increase in peak flow in this location is due to the control structure resulting in an overtopping of the roadway, similar to that determined for the Abbeywood Drive control structure. **Table 3.17** indicates minor increases in peak flows at all nodes along the McCraney Creek system. Similar to the results for the Abbeywood Drive control structure, the increase in peak flows immediately downstream of the control structures (Nodes MC1 ad MC3) are considered a result of overtopping of the roadway. The increase in peak flows along the remainder of the McCraney Creek system are a result of the increases at Node MC1 and MC3 carried forward.

Model Re-validation

Given the influence on simulated peak flows along the Fourteen Mile and McCraney Creeks systems resulting from the existing on-line control structures, the initial reported results produced by the PCSWMM hydrologic model have required re-validation. The PCSWMM model had been “pseudo-calibrated” for the May 2000 storm event, and simulated water surface elevations were compared to observed values at specific locations along the Fourteen Mile Creek system. The observed water surface elevations were obtained from Conservation Halton’s June 2000 report to the Town of Oakville. The simulated water surface elevations associated with the previous modelling, had an average deviation of 0.25 m from the observed water surface elevations, and based on this finding, the model was considered adequately parameterized for use in this study at that time.

In addition to the model updates (on-line structures and minor subcatchment re-discretization), further model updates have been completed as part of the re-validation exercise. The updates have been conducted as part of a re-calibration exercise in order to produce results similar to those reported in the June 2000 report from Conservation Halton, as well as the initial modelling results. The following model updates have thus been completed:

— Entrance loss coefficients for all bridges and culverts have been adjusted (0.4 to 0.05 – 0.9). The adjusted entrance loss coefficients are considered reasonable and fall within the acceptable range per PCSWMM modelling documentation (Frost, W.H., 2006. “Minor Loss Coefficients for Storm Drain modelling with SWMM” *Journal of Water Management Modelling*) and the HEC-RAS reference manual.

— Exit loss coefficients for all bridges and culverts have been adjusted (0.4 to 0.5 – 1). Similarly, the exit loss coefficients are considered reasonable and fall within the acceptable range per PCSWMM modelling documentation[1] and the HEC-RAS reference manual.

— Minor channel slope and geometry changes have been made to remove oscillations from the receding limb of hydrographs at three locations.

As a form of model validation, the revised PCSWMM model with on-line control structures in-place has been executed for the May 2000 event. These results have been compared with those from the original modelling from May 2013 (ref. **Table 3.18**).

Table 3.18: Summary of May 2000 Storm Modelled Results

Location	Observed High Water Elevation (m)	June 2017 Results		May 2013 Results	
		Simulated Water Surface Elevation (m)	Simulated Peak Flow (m^3/s)	Simulated Water Surface Elevation (m)	Simulated Peak Flow (m^3/s)
Speers Road	96.00 - 96.50	96.95	91.05	96.97	89.50
Bridge Road	92.00 - 92.50	92.75	91.33	92.68	89.56
Warminster Drive Upstream	90.50 - 91.00	90.44	91.85	90.43	90.44
Warminster Drive Downstream	89.50	89.94	91.85	89.93	90.44

As indicated in **Table 3.18**, the results of the June 2017 execution are similar to those from the May 2013 assessment. The peak flows are generally within 2% (+/-) of the previous model condition. Furthermore, the simulated water surface elevations are within 1 - 7 cm of the May 2013 results. The average deviation from the observed high-water elevation for the June 2017 results is 0.30 m. As such, the performance of the revised PCSWMM hydrologic model with on-line control structures in-place is considered reasonable, and the model considered suitable to complete the alternative assessment.

Design Flows

It is noteworthy that as per Provincial requirements, the hydrologic modelling does not account for the attenuation effects of on-line culverts. This condition (with culverts removed) is typically referred to as the “design” condition, since reliance on man-made culverts for downstream flood protection implies that the culverts are part of the overall formal control for the system. In order to define the “benefit” to existing controls vs. the more conservative design conditions, the re-validated PCSWMM model has been revised to remove all culverts, and a comparison has been completed between this model, and the model used in the previously completed (December 7, 2016) Supplemental Alternative Assessment.

The hydrologic model was executed for the 2 – 100 year and Regional Storm events, and the results analyzed at the same subject nodes along the Fourteen Mile (FM1 – FM6) and McCraney Creek (MC1 – MC6) systems. The results are provided in **Tables 3.19– 3.22**.

Table 3.19: Fourteen Mile Creek – Simulated Peak Flows (m^3/s) – 2 & 5 year

Flow Node	2 Year			5 Year		
	December 7, 2016 Model – No Culverts	Current Model – On-Line Structures Only	% Difference	December 7, 2016 Model – No Culverts	Current Model – On-Line Structures Only	% Difference
FM1 - Downstream of Abbeywood Drive Structure	7.58	2.78	-63%	12.01	3.45	-71%
FM2 - Fourteen Mile Main Branch @ QEW	19.99	20.01	0%	37.35	38.32	3%
FM3 - Downstream of Pilgrims Way Structure	8.30	1.89	-77%	13.30	3.92	-71%
FM4 - Former McCraney Creek @ QEW	9.71	4.66	-52%	15.31	7.55	-51%
FM5 - Fourteen Mile Main Branch @ CNR	28.16	22.53	-20%	46.95	42.66	-9%
FM6 - Fourteen Mile Main Branch @ Lake Ontario	29.51	24.67	-16%	51.96	42.70	-18%

Table 3.20: Fourteen Mile Creek – Simulated Peak Flows (m^3/s) – 10 & 25 year

Flow Node	10 Year			25 Year		
	December 7, 2016 Model – No Culverts	Current Model – On-Line Structures Only	% Difference	December 7, 2016 Model – No Culverts	Current Model – On-Line Structures Only	% Difference
FM1 - Downstream of Abbeywood Drive Structure	15.32	5.23	-66%	20.01	8.10	-60%
FM2 - Fourteen Mile Main Branch @ QEW	50.52	51.71	2%	68.82	70.61	3%
FM3 - Downstream of Pilgrims Way Structure	16.76	5.49	-67%	21.67	8.60	-60%
FM4 - Former McCraney Creek @ QEW	18.92	9.47	-50%	24.20	12.03	-50%
FM5 - Fourteen Mile Main Branch @ CNR	59.47	57.44	-3%	75.80	78.18	3%
FM6 - Fourteen Mile Main Branch @ Lake Ontario	65.88	57.29	-13%	83.95	77.62	-8%

Table 3.21: Fourteen Mile Creek – Simulated Peak Flows (m^3/s) – 50 & 100 year

Flow Node	50 Year			100 Year		
	December 7, 2016 Model – No Culverts	Current Model – On-Line Structures Only	% Difference	December 7, 2016 Model – No Culverts	Current Model – On-Line Structures Only	% Difference
FM1 - Downstream of Abbeywood Drive Structure	23.51	10.12	-57%	27.00	12.23	-55%
FM2 - Fourteen Mile Main Branch @ QEW	82.24	84.53	3%	96.34	99.10	3%
FM3 - Downstream of Pilgrims Way Structure	25.34	10.76	-58%	28.91	13.02	-55%
FM4 - Former McCraney Creek @ QEW	28.74	13.87	-52%	33.14	15.62	-53%
FM5 - Fourteen Mile Main Branch @ CNR	89.13	93.07	4%	104.60	107.20	2%
FM6 - Fourteen Mile Main Branch @ Lake Ontario	96.20	91.94	-4%	109.10	106.80	-2%

Table 3.22: Fourteen Mile Creek – Simulated Peak Flows (m^3/s) – Regional Storm

Flow Node	Regional Storm		
	December 7, 2016 Model – No Culverts	**Current Model – On-Line Structures Only**	**% Difference**
FM1 - Downstream of Abbeywood Drive Structure	36.75	36.24	-1%
FM2 - Fourteen Mile Main Branch @ QEW	220.00	221.60	1%
FM3 - Downstream of Pilgrims Way Structure	28.90	28.51	-1%
FM4 - Former McCraney Creek @ QEW	32.28	31.86	-1%
FM5 - Fourteen Mile Main Branch @ CNR	254.60	256.10	1%
FM6 - Fourteen Mile Main Branch @ Lake Ontario	267.40	267.70	0%

Similar to the results presented in **Tables 3.10– 3.12**, peak flow results presented in **Tables 3.19 – 3.21** indicate that the on-line control structures reduce peak flows immediately downstream of the control structures (Nodes FM1 and FM3), as well as at the QEW on the former McCraney Creek branch (Node FM4). Generally speaking, the peak flow reductions remain, while reducing in relative magnitude along the Fourteen Mile creek system. The exception is subject node FM5 where the current model produces minor increases in the 25 – 100-year storm events. It is noted that the simulated increase in peak flows is considered a result of the detention of flows by the on-line control structures (i.e. timing effects).

Table 3.22 presents minor increases and decreases along the Fourteen Mile creek system. The results are consistent with those presented in **Table 3.13**.

The results for the McCraney Creek system are provided in **Tables 3.23 – 3.26.**

Table 3.23: McCraney Creek – Simulated Peak Flows (m^3/s) – 2 & 5 year

Flow Node	2 Year			5 Year		
	December 7, 2016 Model – No Culverts	Current Model – On-Line Structures Only	% Difference	December 7, 2016 Model – No Culverts	Current Model – On-Line Structures Only	% Difference
MC1 - Downstream of Nottinghill Gate Structure	5.35	1.95	-63%	9.12	4.54	-50%
MC2 - Taplow Creek @ QEW	5.51	1.97	-64%	9.39	4.58	-51%
MC3 - Downstream of Old Abbey Lane Structure	10.54	2.35	-78%	16.63	4.94	-70%
MC4 - Glen Oak Creek @ QEW	14.03	6.54	-53%	22.41	9.83	-56%
MC5 - McCraney Creek @ CNR	18.49	13.50	-27%	28.91	20.31	-30%
MC6 - McCraney Creek @ Lake Ontario	22.97	17.99	-22%	35.48	28.65	-19%

Table 3.24: McCraney Creek – Simulated Peak Flows (m^3/s) – 10 & 25 year

Flow Node	10 Year			25 Year		
	December 7, 2016 Model – No Culverts	Current Model – On-Line Structures Only	% Difference	December 7, 2016 Model – No Culverts	Current Model – On-Line Structures Only	% Difference
MC1 - Downstream of Nottinghill Gate Structure	11.68	6.37	-46%	15.37	9.18	-40%
MC2 - Taplow Creek @ QEW	12.28	6.43	-48%	16.49	9.23	-44%
MC3 - Downstream of Old Abbey Lane Structure	20.80	7.02	-66%	26.41	12.05	-54%
MC4 - Glen Oak Creek @ QEW	28.40	12.05	-58%	36.03	15.06	-58%
MC5 - McCraney Creek @ CNR	36.14	24.62	-32%	45.51	30.99	-32%
MC6 - McCraney Creek @ Lake Ontario	43.65	35.42	-19%	56.00	43.80	-22%

Table 3.25: McCraney Creek – Simulated Peak Flows (m^3/s) – 50 & 100 year

Flow Node	50 Year			100 Year		
	December 7, 2016 Model – No Culverts	Current Model – On-Line Structures Only	% Difference	December 7, 2016 Model – No Culverts	Current Model – On-Line Structures Only	% Difference
MC1 - Downstream of Nottinghill Gate Structure	18.61	11.13	-40%	21.76	13.03	-40%
MC2 - Taplow Creek @ QEW	19.47	11.22	-42%	22.29	13.12	-41%
MC3 - Downstream of Old Abbey Lane Structure	30.10	16.21	-46%	34.03	20.22	-41%
MC4 - Glen Oak Creek @ QEW	41.14	18.54	-55%	46.62	22.71	-51%
MC5 - McCraney Creek @ CNR	52.20	35.63	-32%	58.78	40.52	-31%
MC6 - McCraney Creek @ Lake Ontario	64.76	50.12	-23%	73.05	55.97	-23%

Table 3.26: McCraney Creek – Simulated Peak Flows (m^3/s) – Regional Storm

Flow Node	Regional Storm		
	December 7, 2016 Model – No Culverts	Current Model – On-Line Structures Only	% Difference
MC1 - Downstream of Nottinghill Gate Structure	37.25	36.21	-3%
MC2 - Taplow Creek @ QEW	38.58	37.57	-3%
MC3 - Downstream of Old Abbey Lane Structure	31.29	31.66	1%
MC4 - Glen Oak Creek @ QEW	37.52	37.93	1%
MC5 - McCraney Creek @ CNR	84.02	82.44	-2%
MC6 - McCraney Creek @ Lake Ontario	111.70	110.20	-1%

Similar to the results presented in **Tables 3.14 – 3.16**, peak flow results presented in **Tables 3.23 – 3.25** indicate that the on-line control structures reduce peak flows at all nodes along the McCraney Creek system. **Table 3.26** presents minor decreases and increases in peak flows at all nodes along the McCraney Creek system.

3.1.5 Summary of Findings

The following provides a summary of findings for the hydrologic assessment.

- The on-line control structures result in potentially significant impacts to the simulated peak flows on both the Fourteen Mile and McCraney Creeks systems. For the Fourteen Mile Creek, locally (FM1 and FM3) peak flows decrease substantially for all events up to the 100-year. That said, due to timing effects, the introduction of the on-line control facilities actually increases peak flows for larger storm events on the main branch of Fourteen Mile Creek (FM5 and FM6). For the McCraney Creek, peak flows up to and including the 100-year storm event are reduced.
- Minor peak flow increases downstream of the on-line control structures are considered a result of runoff response timing effects and control structure hydraulics.
- The PCSWMM hydrologic model with on-line control structures has been revalidated using the May 2000 storm event observed high water surface elevations and is considered suitable for use in the assessment of alternatives. It is notable that the May 2000 event is equivalent to a 50-to-100-year storm, hence the attenuative influence of the on-line control structures is somewhat less due to timing effects.
- The Regional Storm unitary peak flows are within the expected range of values. As such the Regional Storm peak flows used for hydraulic modelling would be considered adequate.

3.2 Hydraulics

3.2.1 Background

Hydraulics provides insight into the conveyance capacity associated with sewers, creeks, culverts, bridges, etc. It provides an indication of the velocity and depth associated with various flow rates. For this study the hydraulic analyses have been completed to evaluate the existing flow conveyance capacity of the creek systems for the purpose of developing a better understanding of extent and frequency of flooding and the effectiveness of various flood reduction alternatives.

The 1985 Fourteen Mile Creek / McCraney Creek Flood Damage Reduction Program involved the preparation of hydraulic modelling of both creek systems for the purpose of developing Regulatory Floodplain mapping. The hydraulic modelling was conducted using HEC-2, for the FDRP frequency and Regional Storm peak flows, later to be updated in 1992 using the peak flows from the GAWSER hydrologic modelling.

Conservation Halton has since partially updated the hydraulic modelling for both creek systems based on the 2002 digital elevation model using HEC-geoRAS. The peak flows within the hydraulic modelling are still based on the 1992 GAWSER hydrologic modelling. The peak flows used are the 2 to 100-year existing land use peak flows and the future land use Regional Storm peak flows. Conservation Halton has assumed that development that has occurred after 1992 provided post to pre-development flow controls, resulting in future land use condition peak flows matching existing. The Regional Storm peak flows represent future land use conditions and Regional Storm controls have not been provided south of Dundas Street. The 1992 Triton Study ultimate land use condition represents the full watershed development. Future development north of Dundas Street will be required to control the Regional Storm, as such only the Future land use peak flows for the Regional Storm have been used in the hydraulic modelling.

3.2.2 Methods

The hydraulic modelling for this current study has been developed using the HEC-RAS model based on the 2002 digital elevation model. The 2009 digital elevation model has been provided by Conservation Halton and has been used to compare to 2002 hydraulic model. The hydraulic structures in the 2002 HEC-RAS hydraulic model provided by Conservation Halton were estimated based on the topography and aerial photography; as such the structures have been updated in the modelling using available information such as the HEC-2 modelling, background reports and field reconnaissance.

There are a number of discrepancies between the 2002 and 2009 digital elevation model (DEM). In some cases, channel elevations are different between the 2002 and 2009 DEMs by 2 m. In addition, channel alignments may not be the same between the two DEMs. Another concern is that 2009 DEM channel alignment and hydraulic cross-sections may not line up with the 2009 property fabric made available with the Town of Oakville. Based on the foregoing it was determined that there would be a significant amount of effort required to update the 2002 hydraulic model to the 2009 topographic conditions with potentially limited benefits. As such, the 2002 DEM was used for subsequent analyses.

The steady state peak flows (2-100 year and Regional Storm) from the final calibrated PCSWMM modelling described in Section 3.1 have been applied as inputs to the HEC-RAS hydraulic modelling. The manning's 'n' used were consistent across multiple reaches and were based on typical values used in the HEC-RAS manual. The downstream boundary conditions for the overall project boundary were based on the average water surface elevation for the Lake Ontario. Other boundary conditions were based on the normal depth per DEM.

3.2.3 Results

The HEC-RAS cross-sections locations and Regional storm floodplains for both creek systems have been provided in Drawing 3, Drawing 4 and Drawing 5 (Appendix D). A summary of the hydraulic structures has also been prepared for each creek as shown in **Table 3.27**. Based on the hydraulic modelling results there are 38 structures that would be overtopped by various storm frequencies. Maximum flooding depths and flow velocities across structures have been provided in **Table 3.28**.

Crossings within **Table 3.28** that have flooding depths greater than 0.3 m are of concern as vehicle passage would be impeded (notwithstanding, MNR 2002 guidelines indicate that a depth of 0.4 to 0.6 m would “be sufficient to reach the distributor or plugs of most private vehicles”). Emergency vehicle passage would potentially be feasible for fire trucks with flow depths of 0.9 to 1.2 m as per the MNR 2002 guidelines, however in practicality, emergency services are typically not willing to operate vehicles across flood depths of that magnitude.

Table 3.27: Hydraulic Structure Summary

Crossing Location	Culvert Observation (Yes / No)	Size of Opening (span x rise) (m x m)	Inverts (m)		Culvert Length (m)	Flow Capacity (m^3/s)	Flow Frequency
			Upstream	Downstream			
Fourteen Mile Creek- Reach1							
West Oak Trails Boulevard	N	13 m x 3.0 m Conc. Arch Culvert	141.45	141.55	42.2	8.8	100
Upper Middle Road West	N	10 m x 1.5 m Conc. Arch Culvert	136	135.5	16.5	31	Regional
PostMaster Drive	N	5.0 m x 2.0 m Box Culvert	134	134	15.6	11	100
Merchant's Gate	N	5.0 m x 1.5 m Box Culvert	133.5	133	16.2	11	100
Third Line south of Glen Abbey Gate	N	3.09 m x 1.85 m Box Culvert	132.3	132.15	7.3	11	100
Abbeywood Drive	N	3.0 m x 2.5 m Box Culvert	118.02	117	15.6	31	Regional
Third Line north of QEW	N	3.7 m x 2.6 m Box Culvert	113.26	112.25	11.3	11	100
Fourteen Mile Creek-Main Reach							
Bronte Road	N	2.44 m x 1.22 m Box Culvert	125.09	124.86	42.1	17	50
Upper Middle Road	N	2 x 4.267 m x 3.04 8m Box Culvert	122	121.74	24.7	94.8	Regional
QEW	N	9.0 m x 4.5 m Ellip. Culvert	103.3	102.7	106	42.6	100
Third Line	N	13.0 m x 2.50 m Concrete Box	100.52	100.2	13.1	42.6	100
Ramp to QEW	N	11.0 m x 2.0 m Concrete Box	100	100	22.9	42.6	100
CNR	Y	12 m x 6 m Box Culvert	96.26	96.15	13.3	212	Regional
Speers Road	Y	11.0 m span Bridge	97.40	97.40	15	72.4	100
Bridge Road	Y	14 m x 3.0 m Box Culvert	90.15	89.84	10.7	72.4	100
Warminster Drive	N	25 m x 2.0 m Box Culvert	88.54	88.52	10	73.3	100
Rebecca Street	Y	17 m x 2.5 m Box Culvert	83.33	83.39	18.2	73.3	100
Lakeshore Road	Y	15.0 m x 3.0 m Box Culvert	77.15	77.5	16.1	74	100
Fourteen Mile Creek – East Branch							
West Oaks Trail Blvd	N	7.3 m x 2.9 m Box Culvert	141	140	10	29.1	Regional
Upper Middle Road West	N	4.0 m x 1.0 m Box Culvert	131.5	131.44	19.1	11	100
Lower McCraney Creek							
CNR	Y	3.5 m x 2.4 m Bridge	100.87	100.69	15.7	28.2	10
Speer's Road	Y	6.16 m x 1.40 m Concrete Box	98.44	98.31	26.2	37	50
Pinegrove Road	Y	3.6 m x 3.0 m Concrete Box	95.19	95	17.7	24.2	5
Wildewood Drive	Y	5.0 m x 1.8 m Box Culvert	93.99	93.57	16	24.2	5
Rebecca Street	Y	9.16 m x 4.0 m Concrete Box	81.06	80.53	16.9	89.7	Regional
Lakeshore Road West	N	5.4 m x 2.9 m Concrete Box	79.76	78.81	19.3	43.9	100
Upper McCraney Creek							
Springdale Road	N	3.0 m x 1.5 m Concrete Box	145.90	145.86	9	3.56	100
Third Line	N	3.0 m x 1.7 m Concrete Box	145	144.5	8.5	3.56	100
West Oak Trails Blvd	N	4.0 m x 1.0 m Concrete Box	143.5	143.5	13.6	3.56	100
Sandpiper Road	N	3.0 m x 1.8 m Concrete Box	141.5	141	9.6	3.56	100
Upper Middle Road	N	2.4 m Conc. Circ. Culvert	138	137.83	35.4	3.56	100
Pilgrim's Way north	N	3.0 m x 2.0 m Box Culvert	133.67	133.48	14.6	3.56	100
Pilgrim's Way south	N	3.0 m x 2.0 m Box Culvert	116.5	114.74	20.6	34.3	Regional
QEW	N	4.27 m x 2.00 m Concrete Box	108	105.99	83.4	11.6	100
Glen Oaks Creek							
West Oak Trails Blvd	N	5.0 m x 1.5 m Box Culvert	145.02	144.01	14.6	24.1	Regional
Sandpiper Road	N	4.88 m x 1.83 m Concrete Box	140.5	140.5	9	24.1	Regional
Upper Middle Road	N	1.8 m x 1.4 m Box Culvert	139.47	138	71.6	24.1	Regional

Crossing Location	Culvert Observation (Yes / No)	Size of Opening (span x rise) (m x m)	Inverts (m)		Culvert Length (m)	Flow Capacity (m^3/s)	Flow Frequency
			Upstream	Downstream			
Monastery Drive	N	3.6 m x 1.7 m Box Culvert	133	131.68	15	5.11	100
Monk's Passage	N	3.0 m x 2.5 m Box Culvert	125	124.08	9.3	24.1	Regional
Montrose Abbey Drive	N	3.0 m x 2.5 m Box Culvert	121	121	9.2	5.11	100
Old Abbey Lane	N	3.1 m x 1.5 m Box Culvert	116.53	115	14.6	5.11	100
QEW	N	4.27 m x 2.00 m Concrete Box	110	109	80.6	16.6	100
Private Property DS of QEW	N	3.6 m x 1.2 m Concrete Box	107.85	107.55	5	10.9	25
Wyecroft Road	N	6.10 m x 0.95 m Concrete Box	105.01	104.95	16.9	12.2	50
Taplow Creek							
West Oak Trails Blvd	N	3.7 m x 1.2 m Box Culvert	145	144.03	15	5.1	100
Sandpiper Road	N	3.0 m x 1.5 m Box Culvert	141	140.5	9.6	5.1	100
Upper Middle Road	N	3.5 m x 1.5 m Box Culvert	137.68	137.71	35.2	22.4	Regional
Pilgrims Way North	N	7.0 m x 2.0 m Box Culvert	135.53	135.3	19.5	22.4	Regional
Pilgrim's Way South	N	4.0m x 2.0m box culvert	121	120	14.3	22.4	Regional
Private Crossing West of Nottinghile Gate	N	3.0 m x 1.5 m Box Culvert	114	113	12.2	22.4	Regional
North Service Road	N	3.0 m x 2.58 m Box Culvert	108.7	108.3	9.5	11.2	100
QEW	N	3.0 m x 1.8 m Box Culvert	108.5	107.9	38.3	11.2	100
South Service Road West	N	Twin 3.0 m x 1.8 m Box Culvert	103.75	103.58	58.4	33.7	Regional
Fourth Line	N	5.4 m x 1.0 m Box Culvert	101.71	101.69	16	5.11	2

Table 3.28: Hydraulic Structure Overtopping Summary

Crossing Location	Maximum Flooding Depth (m)	Maximum Flooding Velocity (m/s)	Maximum Depth-Velocity Product
Fourteen Mile Creek- Reach1			
West Oak Trails Boulevard	0.15	1.49	0.22
PostMaster Drive	0.48	1.04	0.50
Merchant's Gate	0.04	0.83	0.03
Third Line south of Glen Abbey Gate	0.75	1.30	0.98
Third Line north of QEW	0.03	1.12	0.03
Fourteen Mile Creek-Main Reach			
Bronte Road	0.92	0.30	0.28
QEW	0.72	1.27	0.91
Third Line	0.62	1.67	1.04
Ramp to QEW	0.80	1.30	1.04
Speers Road	1.10	3.28	3.61
Bridge Road	0.10	3.69	0.37
Warminster Drive	0.48	2.00	0.96
Rebecca Street	0.20	4.34	0.87
Lakeshore Road	0.32	1.97	0.63
Fourteen Mile Creek – East Branch			
Upper Middle Road West	0.46	0.38	0.17
Lower McCraney Creek			
CNR	0.27	0.55	0.15
Speer's Road	0.70	3.52	2.46
Pinegrove Road	0.77	2.63	2.03
Wildewood Drive	1.07	2.24	2.40
Lakeshore Road West	0.10	1.06	0.11
Upper McCraney Creek			
Springdale Road	0.19	0.49	0.09
Third Line	0.15	1.84	0.28
West Oak Trails Blvd	0.51	1.13	0.58
Sandpiper Road	0.35	0.71	0.25
Upper Middle Road	0.30	0.48	0.14
Pilgrim's Way north	0.23	0.75	0.17
QEW	0.04	0.28	0.01
GlenOaks Creek			
Monastery Drive	0.26	0.96	0.25
Montrose Abbey Drive	0.14	0.56	0.08
Old Abbey Lane	0.25	0.50	0.13
QEW	0.30	2.21	0.66
Private Property DS of QEW	0.67	0.74	0.50
Wyecroft Road	0.20	1.49	0.30
Taplow Creek			
West Oak Trails Blvd	0.35	0.77	0.27
Sandpiper Road	0.25	0.55	0.14
North Service Road	0.30	0.39	0.12

Crossing Location	Maximum Flooding Depth (m)	Maximum Flooding Velocity (m/s)	Maximum Depth-Velocity Product
QEW	0.69	0.27	0.19
Fourth Line	1.00	0.59	0.59

Based on the updated HEC-RAS hydraulic modelling, the creek systems result in flooding of both private and public property south of the QEW. North of the QEW, flooding is generally not a concern due to more modern flood management land use planning policies in place, including set back from the creeks using buffers to mitigate any potential flooding risks. However, there is a section north of the QEW where homes located north of Sandpiper Road on Taplow Creek experience flooding during Regional Storms due to backwater effects from the downstream road crossing. Although the likelihood of flooding in this area is low, during the infrastructure renewal of the Sandpiper Road crossing, it is recommended that the town explore opportunities to improve water conveyance to mitigate backwater impacts during Regional Storm conditions.

South of the QEW development encroaches into the creek systems and the creeks have been reduced in width, as such the creek's flow conveyance capacities are typically not capable of conveying the Regional Storm flows and in various locations private property is flooded during more frequent storm events.

The 2008 Town of Oakville Town-wide Flood Study identified reaches (Sites 5 to 12) on both Fourteen Mile Creek and McCraney Creek where flooding was a concern based on Conservation Halton's Regional Storm floodplain. As the hydraulic modelling has been updated for this current study, these sites have been reassessed. Reference Figures are included in **Appendix D** and provide the updated Regional Storm floodplain for Sites 5 to 12, with the findings provided for each site provided below.

Site 5: Fourteen Mile Creek (CNR to Speers Road)

This reach was designated as a medium priority in the Town of Oakville Town-wide Flood Study due to the potential flooding of industrial property west of the creek block during the 100-year storm and Regional Storm. Flooding mechanisms include the backwater from the Speers Road culvert and more significantly the creek block's 2-year storm flow in the vicinity of 1439 Speers Road. The update to the hydraulic modelling has resulted in the flooding area remaining the same apart from additional flooding on Speers Road.

Site 6: Fourteen Mile Creek (Upstream of Bridge Road)

This creek reach has a very low flood potential with only 1319 Bridge Road located within the Regional Storm floodplain. The flooding mechanism is primarily encroachment. With the update to the hydraulic modelling the Regional Storm floodplain would remain mostly the same.

Site 7: Fourteen Mile Creek (Sumerlea Street to Rebecca Street)

This site was noted in the Town-wide study as having most rear yards in the 100-year storm floodplain and 10 homes with basement flooding potential during the Regional Storm. Flooding mechanisms include the backwater from the Rebecca Street crossing and the encroachment of development into the floodplain. Based on the updated hydraulic modelling at least seven additional homes would be within the Regional Storm floodplain.

Site 9: Glen Oak Creek and Taplow Creek (QEW to CNR)

This reach is in an industrial area that is flood-prone during the Regional Storm, however flooding of buildings would commence at the 25-year storm. Flooding mechanisms include the restrictive flow capacity of the CNR crossing and both of the Wyecroft Road culverts. The creek blocks have a flow capacity equivalent to the 5-year storm, before flooding commences on private property. There are no significant changes to the Regional Storm area based on the updated hydraulic modelling.

Site 10: McCraney Creek (Speers Road to Pinegrove Road)

As noted in the Town-wide Flood Study, the residential area on the north side of Pinegrove Road starts to experience flooding at approximately the 10-year storm event and has seven homes in the Regional Storm floodplain, this has not changed based on the updated modelling. The formative flood mechanism relates to the restrictive flow capacity of the Pinegrove Road culvert with a Regional Storm backwater of 1.2 m (+/-) and development encroachment into the floodplain.

Site 11: McCraney Creek (Pinegrove Road to Wildwood Drive)

The Regional Storm flooding along this differs from that documented in the Town-wide Flood Study, from two homes to potentially four homes at flooding risk. Earlier work to replace the culvert at Wildwood Drive has only maintained the previous flood elevations due to creek block width limitations.

Site 12: McCraney Creek (Wildwood Drive to Rebecca Street)

This reach of McCraney Creek as documented within the Town-Wide Study is by far the most flood-prone in the Town of Oakville, with basement flooding of four homes during a 2-year storm and first floor flooding of two homes in the 10-year storm event. Flooding during the Regional Storm within the Town-Wide Study identified 29 homes (+/) noted in the floodplain with updated modelling now showing approximately 37 homes located within the floodplain. The flooding in this reach is significant, mainly due to the restrictive floodplain capacity and development encroachment.

3.2.4 Summary of Findings

Regional Storm flooding limits for both Fourteen Mile Creek and McCraney Creek south of the QEW have not significantly changed from those provided in the 2006 Town-wide Flood Study. With the additional flooding investigation and hydraulic modelling for both creeks north of the QEW, three primary sites have been identified where flooding during the Regional Storm impacts homes. In addition to flooding on private properties, there are 38 road crossings that overtop during various storm events. Of these, 16 structures experience such high flow depths and velocities that they prevent vehicle ingress and egress.

3.3 Natural Areas Inventory

A desktop review of available information on soils, terrestrial and fisheries habitat has been conducted to document general natural environment conditions. Natural Area Inventory information has been included in **Appendix E**.

3.3.1 Soils

Soils background information for both Fourteen Mile Creek and McCraney Creek has been provided previously in the 1992 Fourteen Mile Creek / McCraney Creek Watershed Planning Study and the 2002 Fourteen Mile Creek Main and West Subwatershed Branch Subwatershed Study.

Soils for the study area consist of Oneida, Chinguacousy and Jeddo clay loam soils which are typical of the Halton Till. The Halton Till is a result of glacial depositional process. Isolated areas have sand and gravel deposits. The soils are considered to be moderately to poor draining. In the area of the QEW soils are on red shale plains and the creeks have or will cut down to the red shale.

3.3.2 Terrestrial

Both Fourteen Mile Creek and McCraney Creek are located within significantly urbanized areas with limited vegetation resources. South of the QEW both creek systems have been encroached upon by development with most of the vegetation being located within rear yards and being ornamental in nature.

Vegetation north of the QEW is similar to that south of the QEW, except the creek corridors are wider and are naturally vegetated. Fourteen Mile Creek Valley Environmentally Sensitive Area (ESA), located north of the QEW, is the only ESA in the study area. The 70 ha ESA includes portions of the main and east branch of Fourteen Mile Creek is and between Upper Middle Road and the North Service Road. The area has been designated an ESA as it supports a relatively high number of plant communities, is an area of significant groundwater discharge and contributes to maintaining surface water quality. The ESA has mature mixed forests within the valley feature and is an important migratory staging and wintering area for the saw-whet owl and long eared owl.

North of Upper Middle Road and west of Bronte Road, Fourteen Mile Creek is located within a significant valley feature, which used to be a golf course and has been planted to be re-naturalized as part of the West Oak Trails development.

There are no officially evaluated wetlands within the study area, south of Dundas Street.

3.3.3 Fisheries

Aquatic resources have been documented in the 1992 Fourteen Mile Creek / McCraney Creek Watershed Plan, the 2002 Main and West Branch Fourteen Mile Creek Subwatershed Plan and the 2011 Fourteen Mile Creek Reach 2 Stabilization and Rehabilitation, Draft Environmental Assessment Report.

Fourteen Mile Creek has a mixture of both warmwater and coldwater fisheries habitat but has been designated as a coldwater fishery by the Ministry of Natural Resources and Forestry. McCraney Creek is considered to be warmwater fisheries habitat. South of the QEW the fisheries habitat is considered poor due to the significant creek alteration, bedrock bed, creek lining and fish obstructions. The fish community south of the QEW may include creek chub, sunfish species, white sucker, and common shiner. Under higher flow conditions, migratory coldwater fish species could include rainbow trout and Chinook salmon.

The Ministry of Natural Resources and Forestry has noted Fourteen Mile Creek as habitat for Redside dace (*Clinostomus elongates*). Redside dace has been listed as endangered in 2009 under Ontario’s Endangered Species Act, 2007 (ESA 2007).

Redside Dace was assessed as endangered in Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in April of 2007. Redside Dace observations have been recorded within the Fourteen Mile Creek / McCraney Creek Watershed Planning Study and the Fourteen Mile Creek Main and West Branch Subwatershed Plan. Redside Dace have been noted just north of Lakeshore Road, south of Upper Middle Road on the West Branch, north of Upper Middle and east of Bronte Road and further upstream south of Dundas Street, east of Bronte Road. Due to previous observations of Redside Dace, as recent as 1990, the Ministry of Natural Resources and Forestry reviews proposed works within Fourteen Mile Creek to the protection the species.

3.4 Archaeology and Cultural Heritage Assessment

3.4.1 Cultural Heritage

A review of the Oakville Heritage Register identifies several properties with the 14 Mile Creek/McCraney Creek watershed. The Oakville Heritage register includes the following type of heritage properties:

- Individually designated properties which fall under Part IV of the Ontario Heritage Act (OHA)
- Properties designated within Heritage Conservation Districts which fall under Part V of the OHA
- Properties which are not designated by but believed to be of cultural heritage value or interested (also known as 'listed' properties.

All properties identified in the Oakville Heritage Resister are single residential properties that are designated as 'Heritage Listed' or 'Heritage Part IV'. A list of heritage properties within the study area are presented in **Appendix F**

Through subsequent work as part of the McCraney Creek Bridge Replacement Municipal Class EA (2022), the Town's Heritage Planner confirmed that the bridge has no heritage status under the Ontario Heritage Act. Further Heritage Planning staff visited the site and confirmed that a Cultural Heritage Evaluation Report (CHER) was not required due to substantial changes and modern materials that have modified the structure since its original construction. The town's Heritage Planner added that the property has not been identified as having potential cultural heritage value despite its age and the have not requested any further study.

3.4.2 Archeological

The Criteria for Evaluating Archaeological Potential form was completed as part of the desktop review to identify any known archaeological sites within the Study Area and is provided in **Appendix F**. The review concluded that an Archaeological Assessment should be conducted if any ground disturbance is planned in previously disturbed areas (pre-1960). Most of the Study Area has been significantly disturbed due to past watercourse alterations, as well as residential, industrial, and commercial developments. However, if the preferred alternatives selected are in relatively undisturbed areas within 300 meters of a waterbody, an archaeological assessment is required."

As part of the Lakeshore Road West Class EA (2017) a Stage 1 Archaeological Assessment was completed and covered the area associated with the McCraney Creek Bridge Replacement (as detailed in the McCraney Creek Bridge Replacement Municipal Class EA (2022). The Assessment concluded that the area of the bridge had low archaeological potential.

4 PROBLEM STATEMENT

The Town of Oakville Town-wide Flood Study has identified seven creek reaches on Fourteen Mile Creek and McCraney Creek where flooding of both private and public property has been determined as significant. Flooding mitigation opportunities are being developed within this Municipal Class EA process to protect public safety, private property and municipal infrastructure on Fourteen Mile Creek and McCraney Creek south of Dundas Street to Lake Ontario.

5 ALTERNATIVE ASSESSMENT

5.1 Initial Alternative Assessment

The 2008 Town-wide Flood Study provided the baseline conditions for the existing conditions within the Fourteen Mile Creek and McCraney Creek study area relevant to the identified flooding problems. This Alternative Assessment builds upon the findings from the Town-wide Study and identifies and assesses potential flood and erosion mitigation alternatives, leading to the selection of preliminary preferred alternatives.

5.1.1 Long List of Alternatives

In order to address the identified riverine-based flooding potential within the Fourteen Mile and McCraney Creeks, a long-list of potential remediation alternatives has been established. The long-list of remediation measures has been screened based on evaluation criteria including functional aspects based on engineering principles related to the effectiveness of improving flood protection; environmental and social considerations and economics. The next step involves evaluating the short-listed alternatives in more detail using functional performance, cost / benefit ratios and environmental and social impacts and benefits.

These flooding problems within Fourteen Mile Creek and McCraney Creek occur due to the following mechanisms:

1. Inadequate channel (conveyance system) capacity
2. Inadequate floodplain capacity
3. Spill-prone areas where flow exceeds capacity and moves away from the watercourse
4. Limited culvert / bridge flow capacity
5. Lack of stormwater control *(considered to be a flooding cause not a mechanism)*
6. Creek blockages due to debris
7. Obstruction zone (debris/ice)

These flooding mechanisms are considered general and as part of the current assessment of alternatives, a local understanding of mechanisms has been established and refined. The long-list of alternatives for reducing flooding risk has been subdivided into three categories, “Do-Nothing”, Structural / Capital Alternatives and Non-Structural Alternatives as follows:

“Do-Nothing”

Base line condition to compare the technical performance of all other alternatives.

Structural / Capital Alternatives

The following structural / capital flood mitigation alternatives have been listed and described within the “Conservation Ontario Class Environmental Assessment for Remedial Flood and Erosion Control Projects”, January 2002, amended September 2009.

1 Culvert / Bridge Upgrades – Replace / Supplement
2 Floodplain / Channel Improvements
3 Roadway Profile Modifications
4 Flood proofing Buildings
5 Eliminate / Reduce Potential Culvert Blockages
6 Diversions
7 Flood Control via Stormwater Quantity Measures
8 Combinations

Alternative 1: Culvert / Bridge Upgrade – Replace / Supplement: Should a culvert / bridge crossing’s flow capacity restrict conveyance and produce upstream flooding conditions; a mitigation approach could include either replacing or supplementing the capacity of the existing culvert / bridge crossing.

Alternative 2: Floodplain / Channel Improvements: Improve channel and floodplain flow conveyance capacity by widening the channel, local grading improvements, removal of flow obstructions within the channel and the floodplain and possible channel profile improvements.

Alternative 3: Roadway Profile Modifications: Roadway profiles can be modified to reduce the amount and extent of upstream flooding.

Alternative 4: Flood proofing buildings: Buildings can be flood proofed by sealing low openings with various types of construction practices or alternatively local berming and/or flood walls can be constructed to prevent direct flooding to the building.

Alternative 5: Eliminate / Reduce Potential Culvert Blockages: Typically, debris accumulates at the upstream side of a roadway crossing and/or around instream areas. Eliminating or reducing potential culvert and/or creek blockages can reduce the potential for future flooding.

Alternative 6: Diversions: Drainage may be able to be locally diverted from one location to another within the Fourteen Mile Creek or McCraney Creek watershed or to another adjacent watershed such as Bronte Creek to the west to reduce flooding conditions. Drainage diversions are possible within developed areas, however, may be limited by existing infrastructure, development and property ownership and other environmental factors. It should be noted that significant diversions to other drainage networks are typically not supported by Conservation Authorities.

Alternative 7: Flood Control Via Stormwater Quantity Measures (Off-line and On-line Flood Storage, LID): Stormwater quantity controls whether on-line or off-line can reduce flows within watercourses and thereby reduce the extent of flooding. To offset the increase in peak flows on Fourteen Mile Creek due to flow diversions from McCraney Creek, Taplow Creek and potentially GlenOaks Creek, flood storage could be implemented. For flood storage to be the most effective in reducing peak flows, flood storage should be implemented online using existing modified structures or by constructing new control structures within well defined valley systems. Flood controls could be primarily implemented north of the QEW as no significant sites are available south of QEW, due to development encroaching on creek blocks.

Flood storage, equivalent to nominal depths (expressed in mm), can be provided by LID best management measures. Although LID is typically considered for water quality and erosion management, a reduction in peak flows can be achieved particularly for frequent storm events.

Alternative 8: Combinations: Combinations of various alternatives that would reduce flooding conditions may be possible, when a stand-alone alternative does not provide fully adequate flood remediation.

Non-Structural Alternatives

1. Regulation
2. Flood Forecasting and Warning
3. Emergency Preparedness
4. Creek Maintenance Plan
5. Property Acquisition

Alternative 1: Regulation Conservation Halton regulates Fourteen Mile Creek and McCraney Creek and associated flood-prone or natural hazard areas through Ontario Regulations 41/24 (Prohibited Activities, Exemptions and Permits) under the Conservation Authorities Act. The Conservation Authority applies regulations to ensure that flooding conditions are not negatively impacted by creek or floodplain alterations/development.

Alternative 2: Flood Forecasting and Warning: Conservation Halton maintains a Flood Status System that advises Town of Oakville staff of potential flooding conditions within the Conservation Authority's jurisdiction. The Conservation Authority has a working knowledge of the creek systems which they regulate, that assists in the prediction of flood conditions. Conservation Authority staff notifies the Town of Oakville staff of potential flooding conditions, in order that Town staff can mobilize and prepare required emergency planning tasks prior to flooding conditions.

Alternative 3: Emergency Preparedness: Both Conservation Authority staff and Town of Oakville emergency services staff are actively involved before and during, flooding conditions. After forecasting potential flooding and notifying Town of Oakville staff, Conservation Authority personnel monitor flooding conditions as needed, utilizing available staff throughout local watercourses, including Fourteen Mile Creek, McCraney Creek, and the other watersheds within the Town of Oakville limits. This effort helps identify areas where emergency services may be required. Emergency services staff are informed of potential flooding to evacuate citizens in flood-prone areas both before and during flooding.

Alternative 4: Creek Maintenance Plan: A Creek Maintenance Plan would facilitate regular inspection of all creek reaches to determine flooding issues such as debris accumulation and culvert blockages and the subsequent removal of each blockage. The Maintenance Plan would also facilitate observation of on-going or emerging erosion issues. The Town of Oakville currently maintains all town-owned creek blocks within the study area, regularly inspects the channels, and addresses any blockages when alerted to issues

Alternative 5: Property Acquisition: At risk properties that are located within the floodplain, could be acquired and modified (through grading) to improve upstream flooding conditions or to eliminate or reduce the threat to life of persons living or working on the property. Acquisition of property would typically be the last alternative to select, due to the high social and economic considerations involved.

5.1.2 Long List of Alternatives Evaluation Methodology

To screen the long-listed alternatives, a qualitative evaluation system has been developed, using negative, neutral, positive and varied results to assess the suitability of each alternative against appropriate "evaluation factors". The factors include considerations related to a two-tier hierarchy of potential impacts / issues organized by Evaluation Category and supplemented by more detailed and specific Evaluation Criteria. Alternatives that do not improve flooding conditions or are deemed infeasible have been excluded from further consideration. Additionally, alternatives that should be combined with others have been noted.

Evaluation Categories

A broad description of the type of impacts and issues under consideration includes:

— **Functional:** Impacts that the alternative may have on how a system is intended to work as related to flood (and erosion) mitigation.

— **Environmental:** Potential impacts or benefits that alternatives may have on terrestrial and aquatic habitat.

— **Social:** Impacts / issues relating to the interaction of the community / neighbourhood with the implementation of the proposed alternative

— **Economic:** Immediate and future costs and cost-benefit of the alternative including operations and maintenance.

— **Constructability:** Construction considerations related to accessibility for machinery and the potential impact of construction techniques and access on private property.

Evaluation Criteria

Specific evaluation criteria relevant to each Evaluation Category has been summarized in **Table 5.1**.

Table 5.1: Flood Alternatives Evaluation Criteria

Evaluation Category	Evaluation Criteria	Criteria Description
Functional	Potential to reduce flooding	Degree to which each alternative reduces property flooding.
	Potential to reduce erosion	Reflects the degree to which the alternative contributes to long-term, stability of the creek, as well as the potential requirements for future intervention.
	Potential to protect municipal infrastructure	Reflects the degree to which the alternative contributes to the immediate need for protection of municipal infrastructure.
Environmental	Potential to improve Aquatic Habitat	Depending on the alternative, fish habitat may be enhanced or negatively impacted.
	Potential to improve Terrestrial Habitat	Depending on the alternative impacts to the existing terrestrial system may occur.
Social	Ability to Improve Public Safety	Depending on the configuration of the works, the study reaches may be considered safer when flooding potential is reduced.
	Impacts on Private Properties	Relates to the change in flood risk on private lands.
	Impact on Public Lands	Depending on the alternative there are varying degrees of impact to flooding conditions on public lands including parks and roadways.
Economic	Capital Costs	High costs are negative. Low costs are positive.
	Operations and Maintenance Costs	High costs are negative. Low costs are positive.
Constructability	Ease of Construction and Accessibility	Depending on the selected alternative, the machinery and materials required to construct will vary. The more aggressive the construction, the more difficult to construct, since larger and more extensive equipment will be required.
	Expected Temporary Disturbance to Existing Habitats	Depending on the scope of work, existing habitats will be disturbed to a varying degree by in both the short and long-term.

5.1.3 Screening of Long List of Alternatives

The following provides an initial screening of the long list of alternatives; refer to **Table 5.2** for a detailed screening of long-listed alternatives.

Structural / Capital Alternatives

Do Nothing: Although all alternatives have to be compared to the baseline condition as a flood remediation alternative the Do Nothing alternative has been screened.

Alternative 5: Eliminate / Reduce Potential Culvert Blockages: As a standalone solution to the existing flooding problems, elimination or reduction of the culvert and bridge blockages would not resolve flooding potential and risk along Fourteen Mile Creek and McCraney Creek, as it has been noted that the limited flow conveyance capacity of unblocked crossings, such as the CNR crossing, contributes to upstream flooding even without blockage. This alternative should be considered as an operational improvement in conjunction with the preferred solutions.

Non-Structural Alternatives

Alternatives 1 to 4: Non-structural alternatives such as Regulation, Flood Forecasting, Warning and Emergency Preparedness and a Creek Maintenance Plan are required to reduce the threat to life and property but would not reduce existing flooding conditions and risk within the study area. As such these alternatives should be considered as potential areas for operational improvement in conjunction with the preferred solutions.

Table 5.2: Long List Alternatives Screening

Evaluation Category	Evaluation Criteria	Structural / Capital Alternatives								Non-Structural Alternatives				
		Alternative 1: Culvert / Bridge Upgrade	Alternative 2: Floodplain / Channel Improvements	Alternative 3: Roadway Profile Modifications	Alternative 4: Flood Proofing Buildings	Alternative 5: Eliminate / Reduce Potential Culvert Blockages	Alternative 6: Diversions	Alternative 7: Flood Control Via Stormwater Quantity Measures (LID, flood storage)	Alternative 8: Combinations	Alternative 1: Regulation (updated)	Alternative 2: Flood Forecasting and Warning	Alternative 3: Emergency Preparedness	Alternative 4: Creek Maintenance Plan	Alternative 5: Acquisition
Functional	Potential to reduce flooding	Positive	Positive	Positive	Positive	Neutral	Positive	Positive	Varies	Positive	Negative	Negative	Positive	Positive
	Potential to reduce erosion	Neutral	Positive	Neutral	Neutral	Positive	Negative	Positive	Varies	Positive	Negative	Negative	Positive	Neutral
	Potential to protect municipal infrastructure	Positive	Positive	Positive	Negative	Positive	Positive	Positive	Varies	Positive	Negative	Negative	Positive	Neutral
Environmental	Potential to improve Aquatic Habitat	Neutral	Positive	Neutral	Neutral	Positive	Neutral	Neutral	Varies	Neutral	Neutral	Neutral	Positive	Neutral
	Potential to improve Terrestrial Habitat	Neutral	Positive	Neutral	Negative	Neutral	Negative	Varies	Varies	Neutral	Neutral	Neutral	Positive	Neutral
Social	Ability to improve Public Safety	Negative	Positive	Positive	Positive	Positive	Positive	Positive	Varies	Positive	Positive	Positive	Negative	Positive
	Impacts on Private Properties	Negative	Positive	Positive	Positive	Positive	Positive	Positive	Varies	Neutral	Neutral	Neutral	Neutral	Positive
	Impact on Public Lands	Negative	Positive	Positive	Neutral	Positive	Positive	Positive	Varies	Neutral	Neutral	Neutral	Neutral	Neutral
Economic	Capital Costs	Negative	Negative	Negative	Positive	Positive	Negative	Negative	Varies	Positive	Positive	Positive	Positive	Negative
	Operations and Maintenance Costs	Negative	Positive	Negative	Positive	Positive	Negative	Negative	Varies	Positive	Positive	Positive	Negative	Positive
Construct-ability	Ease of Construction and Accessibility	Neutral	Negative	Negative	Negative	Negative	Negative	Negative	Varies	Neutral	Neutral	Neutral	Negative	Positive
	Expected Temporary Disturbance to Existing Habitats	Neutral	Negative	Negative	Negative	Positive	Negative	Negative	Varies	Neutral	Neutral	Neutral	Negative	Negative
Results:		**CF**	**CF**	**CF**	**C**	**S**	**C**	**C**	**C**	**S**	**S**	**S**	**S**	**C**

Legend

Positive | Neutral | Varies | Negative

CF = Carried Forward

S = Screened From Further Consideration

C = Carried Forward with other Alternatives

5.1.4 Short-Listed Flood Mitigation Alternatives

With respect to non-structural alternatives (Alternatives 1 to 4), while these alternatives are required to reduce the threat to life and property, they would not reduce existing flooding conditions and risk within the study area. These alternatives should be considered as potential areas for operational improvement in conjunction with the preferred solution but have not been carried forward for direct evaluation. Alternative 5 (acquisition) has been carried forward for consideration in certain cases.

The following structural alternatives have been short-listed as potential short-term alternatives based on the initial screening results:

— **Alternative 1:** Culvert / Bridge Upgrades – Replace / Supplement
— **Alternative 2:** Floodplain / Channel Improvements
— **Alternative 3:** Roadway Profile Modifications
— **Alternative 4:** Flood Proofing Buildings
— **Alternative 6:** Diversions
— **Alternative 7:** Flood Control via Stormwater Quantity Measures(Off-line and On-line Flood Storage, LID)
— **Alternative 8:** Combinations

Alternative 1: Culvert / Bridge Upgrades – Replace / Supplement

To determine the potential reduction in flood levels due to culvert and bridge upgrades, a preliminary assessment has been conducted by removing hydraulic structures south of the QEW on Fourteen Mile, GlenOaks, Taplow and McCraney Creeks with the HEC-RAS hydraulic models. The resulting flood elevations without crossings in place for the 10 and 100-year storms and Regional Storm Hurricane Hazel have been plotted on Figures included in **Appendix G**, thus representing theoretical 'best' conditions. Examination of the flood areas with and without crossings has determined the approximate number of residential and non-residential buildings removed from the 25 and 100-year storm and Regional Storm flood areas for each creek system (ref. **Table 5.3**).

Table 5.3: Residential and Non-residential Buildings Removed from Floodplains

Creek	Land Use	10-Year	100-Year	Regional Storm
Fourteen Mile Creek	Non-residential	0	0	0
	Residential	3	3	2
Taplow Creek	Non-residential	3	3	3
GlenOaks Creek	Non-residential	2	1	1
McCraney Creek	Non-residential	0	0	0
	Residential	4	5	4

The greatest improvement in flood reduction would occur on McCraney Creek between Pinegrove Road and Rebecca Street where four homes are removed for the 10-year storm event. Based on the preliminary assessment, and the flow capacity of each hydraulic crossing, the following (highlighted) crossings in **Table 5.4** have been assessed to determine potential upgrade requirements.

Table 5.4: Hydraulic Structures

Crossing Location	Size of Opening (span x rise) (m x m)	Current Flow Capacity (m^3/s)	Approx. Flow Capacity (yrs)
Fourteen Mile Creek-Main Reach			
Third Line	13.0 m x 2.50 m concrete box	42.6	50
Ramp to QEW	11.0 m x 2.0 m concrete box	42.6	>100
CNR	12 m x 6 m box culvert	212	Regional
Speers Road	11.0 m span Bridge	72.4	>100
Bridge Road	14 m x 3.0 m box culvert	72.4	>100
Warminster Drive	25 m x 2.0 m box culvert	73.3	>50
Rebecca Street	17 m x 2.5 m box culvert	113.46	>100
Lakeshore Road	15.0 m x 3.0 m Box culvert	118.79	>100
McCraney Creek			
CNR	3.5 m x 2.4 m Bridge	28.2	<10
Speer's Road	6.16 m x 1.40 m concrete box	37	<10
Pinegrove Road	3.6 m x 3.0 m concrete box	24.2	<5
Wildwood Drive	5.18 m x 1.83 m open box culvert	24.2	<5
Rebecca Street	9.16 m x 4.0 m concrete box	84.65	>100
Lakeshore Road West	5.4 m x 2.9 m concrete box	43.9	<25
GlenOaks Creek			
Private Property DS of QEW	3.6 m x 1.2 m concrete box	10.9	<5
Wyecroft Road	6.10 m x 0.95 m concrete box	12.2	<5
Taplow Creek			
South Service Road West	Twin 3.0 m x 1.8 m box culvert	38.4	>Regional
Fourth Line	5.4 m x 1.0 m box culvert	5.10	>2

Alternative 2: Floodplain / Channel Improvements

In the 2008 Town-wide Flood Study, floodplain / channel improvements were generally not recommended except for one site. This was due to significant private property constraints and high improvement costs. Channel improvements were only recommended for McCraney Creek (Flood Site 12) north of Rebecca Street to Wildwood Drive, specifically related to the removal of the drop structure and lowering of the channel by approximately 1 m. The concrete lined channel has been determined to have less than a 2-year flow capacity. Lowering the channel by 1 m for the width of the channel would not significantly reduce flooding for the less frequent storm events, 25-year storm or greater, therefore this approach has been screened from further consideration.

A different approach for channel improvements has been considered by assessing the channel capacity specifically between Rebecca Street and Wildwood Drive for McCraney Creek. The flood reduction benefit of widening the rectangular lined channel by 5 m (+/-) either side has been assessed. For this channel section to be widened, private residential property would have to be purchased by the Town of Oakville.

The cost of purchasing property (1000 m by 15 m at $\$500/m^2$) would be $7,500,000, based on the creek and 5 m either side of the creek being purchased. The cost of creek works could range from $1,200,000 to $1,500,000. Minimum costs for channel widening would be $8,700,000.

To determine the financial benefit of the channel works, the direct damages for this reach have been assessed. The direct damages and annual average damages (AAD) based on the 2008 Town-wide Flood Study for this creek reach are the following:

- 2-year storm: $69,738
- 5-year storm: $111,835
- 10-year storm: $194, 574
- 25-year storm: $373, 047
- 50-year storm: $407,332
- 100-year storm: $484, 006
- Regional Storm: $766,127
- AAD: $78,192, present worth (50 years, 5% Interest) - $1,427,463

The 10 m channel widening would improve the creek reach flow capacity from less than the 2-year to the 2-year storm, with a minimum direct damage reduction of approximately $35,000. Based on such a minimal reduction in direct damages and the significant cost of the project requiring over 200 years to be repaid if all damages were eliminated, the cost significantly outweighs the benefit.

Alternative 3: Roadway Profile Modifications

Modifying roadway profiles can improve upstream flooding conditions by lowering the road profile to allow more flow across the roadway, but this must be balanced with maintaining vehicle ingress and egress. A review of each creek system south of the QEW determined that the only hydraulic structure capable of conveying the Regional Storm and potentially benefiting from a lowered roadway profile is the South Service Road on Taplow Creek. However, since there are no buildings within the Regional Storm floodplain upstream of the South Service Road, lowering the road profile would offer no benefit. Therefore, this alternative has been screened from further consideration.

Alternative 4: Flood Proofing Buildings

Flood proofing buildings can include berming to protect the building from flooding and/or relocating or removing low openings to the building. Typically flood proofing consists of building a berm around a property or a group of properties. The 2008 Town-wide Flood Study recommended the following flood proofing:

— Fourteen Mile Creek (Site 6) - 1379 Bridge Road
— Fourteen Mile Creek (Site 7) – two homes between Rebecca Street and Willowbrook Road
— McCraney Creek (Site 11) – 565 and 568 Pinegrove Road
— McCraney Creek (Site 12) – approximately 25 homes but noted that not each home may be possible due to flooding around certain homes.

"Based on the assessment of updated floodplain areas for the 10-year, 100-year and the Regional Storm, the 2008 study has been revised to include the following properties for potential flood proofing. This revision is based on Regional Storm flooding being less than 1 meter at the creek side and not surrounding the properties. Further assessment based on detailed topography, structures, vegetation etc. may result in further revision to the property listed below:

Fourteen Mile Creek: (13 homes)

— 1349, 1353, 1357, 1356, 1350 and 1346 Pinegrove Road
— 1179 and 1217 Willowbrook Drive
— 274 Spring Garden Road
— 213, 239, 241, 243 Willowridge Court

McCraney Creek: (11 homes)

- 346, 354 and 360 Burton Road (north of Wildwood Drive)
- 560 Wildwood Drive
- 308, 314 and 320 Burton Road (south of Wildwood Drive)
- 255 Weldon Avenue
- 539 Oriole Drive
- 571 Patricia Drive
- 184 Shanley Terrace

Note that this list prompted a detailed review of berming options for flood control, for which a dedicated cost-benefit analysis was undertaken. The methods and findings of that alternative have been discussed further in subsequent sections.

Alternative 6: Flow Diversions:

The 2008 Town-wide Flood Study established a baseline for flooding conditions within Fourteen Mile Creek and McCraney Creek, which have been updated herein. One of the main alternatives considered within the 2008 study was to implement a flow diversion from McCraney Creek to Fourteen Mile Creek and implement flood storage upstream of the QEW on Fourteen Mile Creek to offset the influence of the diversion. The diversion and flood storage recommendation were based on a recommendation from the 1985 FDRP study.

A high-level review of potential sites for flow diversion has determined five sites that could be further assessed as part of the flood mitigation alternative assessment (refer to Figures included in **Appendix G**). The main criterion for selecting diversion sites has been available lands and positive grade. Open space is required to construct a diversion channel and there needs to be a positive grade with a slope of about 0.10% (if possible) or greater. Two of the diversions would be closed conduits, therefore requiring adequate inlet capacity and grade to convey diverted flow.

Diversion One (Taplow Creek to Fourteen Mile Creek)

The first potential flow diversion location is from Taplow Creek at Fourth Line to Fourteen Mile Creek to the west, just north of the CNR tracks. The total length of the flow diversion would be approximately 1000 m. An existing flow diversion channel west of Fourth Line has a base width of 1.83 - 2.13 m, a height of 1.83 - 2.13 m with 1.5:1 side slopes, a secondary overbank area on each side with a width of 1.83 - 2.13 m and a height of 1.83 - 2.13 m with 2:1 slopes. The existing flow diversion has a capacity of 25.6 m^3/s to 28.9 m^3/s, based on a 0.11 % longitudinal slope.

The existing diversion channel would need to be extended to the east 200 m to the west side of Fourth Line (ref. Figure 5 (Flow Diversion 'D1' in Appendix G). The existing diversion channel has a Regional Storm peak flow of 39.47 m^3/s, which is above the maximum flow capacity of 28.91 m^3/s. To facilitate adequate flow conveyance for the Regional Storm and allow for additional flow to be diverted from Taplow Creek, the existing 1500 m (+/-) diversion channel would have to be retrofitted to a 3 m base, 4.15 m deep channel with 1:1.5 side slopes at a longitudinal slope of 0.11%. The existing grass lined channel top width is 14.9 m, while the retrofitted channel would require 15.5m. The retrofitted channel flow capacity would be 60.1 m^3/s, which would allow for 20 m^3/s flow diversion from Taplow Creek to Fourteen Mile Creek.

A flow diversion of 20 m^3/s from Taplow Creek to Fourteen Mile Creek would reduce McCraney Creek Regional Storm peak flows from 82.86 m^3/s to 62.4 m^3/s, equivalent of the 50-year storm peak flow.

To determine the benefit of reduced McCraney Creek peak flows, flood damage curves versus peak flows (at Lake Ontario) have been developed using data from the 2008 Town-wide Flood Study (refer to **Chart 5-1**). Direct damages would be reduced from $1,446,789 to $974,675, a 33% reduction. The cost for the 1000 m channel works would be approximately $1,200,000, however off-setting flood storage would be required.

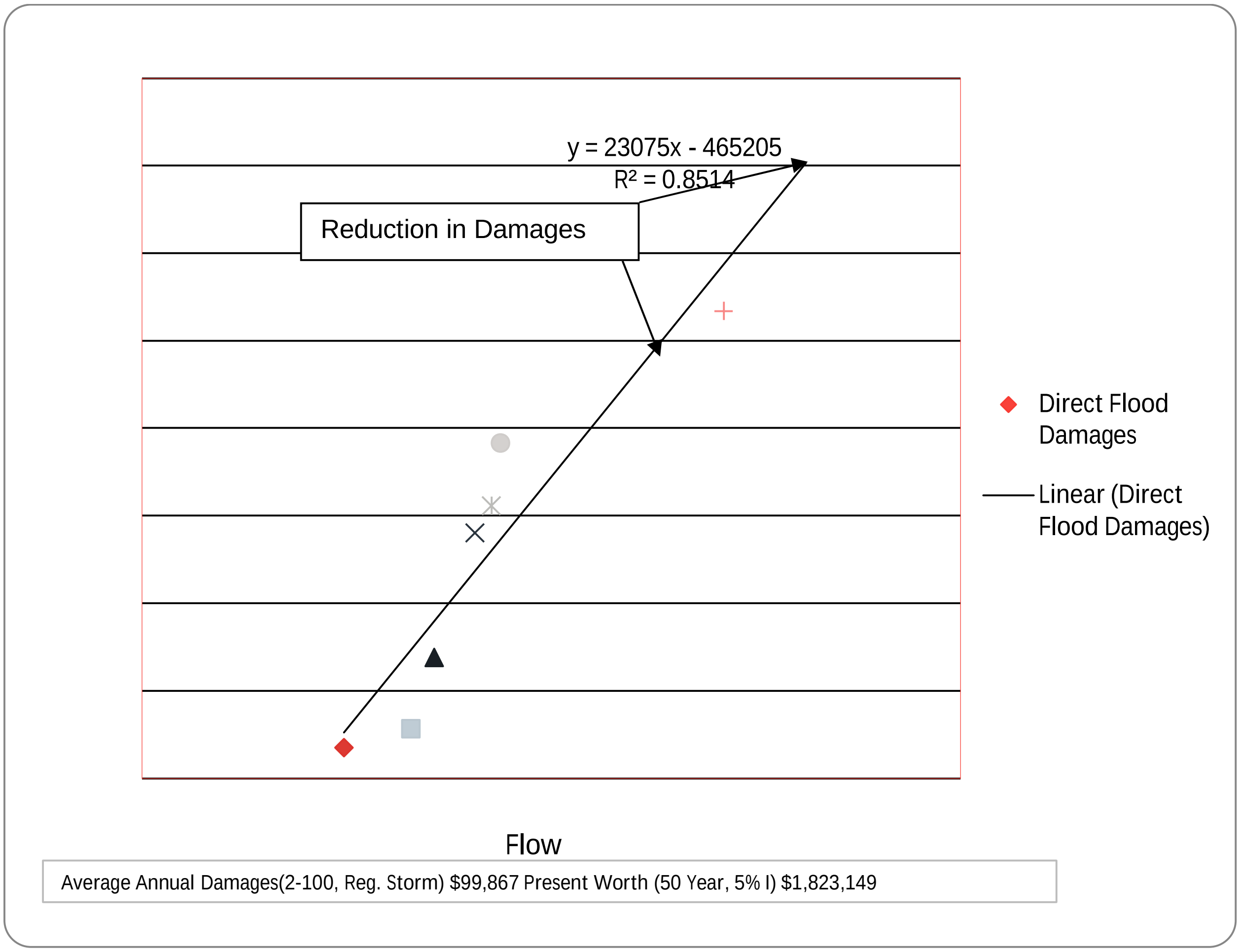


Chart 5-1: McCraney Creek Flow versus Direct Flood Damages

Diversion Two (Taplow Creek to Fourteen Mile Creek)

The second diversion location is also from Taplow Creek north of the QEW at Fourth Line to Fourteen Mile Creek (refer to Figure 6 – Flow Diversion ‘D2” in **Appendix G**). The flow diversion would be located within Town of Oakville controlled lands but would require Indian Ridge Trail to be relocated and an existing treed area to be rehabilitated. The flow diversion would be approximately 800 m in length and would be a 2 m base width with 3:1 side slope, and 2 m grass deep lined channel that would require a 14 m strip of land plus additional lands to match existing grades. The flow capacity of the channel would be approximately 16.60 m^3/s based on a 0.25 % longitudinal slope. Based on the flow reduction to McCraney Creek downstream, direct flood damages would be reduced from $1,446,789 to $1,063,744, a 26% reduction. The cost for the channel works would be approximately $960,000. Refer to **Chart 5-2** for details.

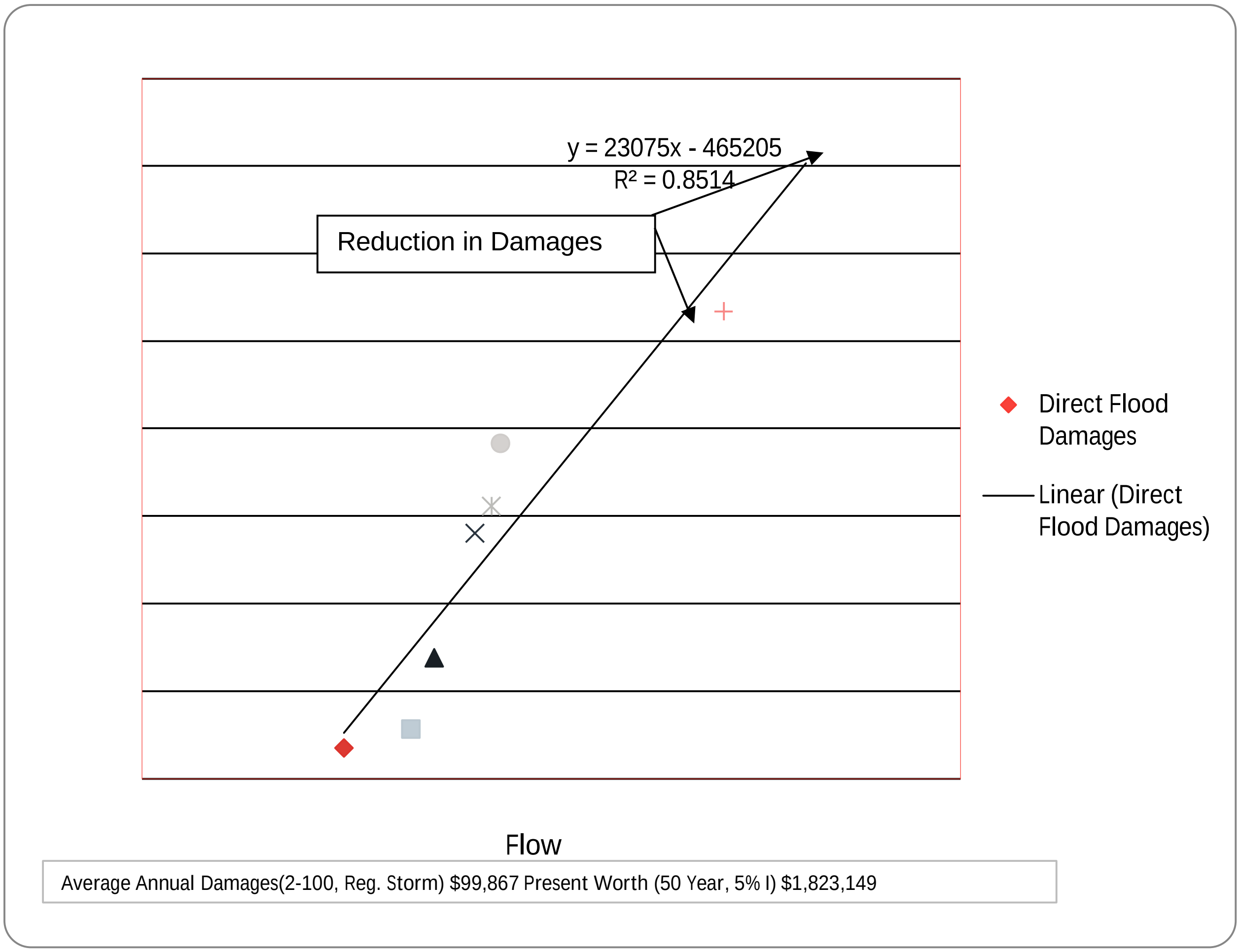


Chart 5-2: McCraney Creek Flow versus Direct Flood Damage

Diversion Three (Taplow Creek to Fourteen Mile Creek)

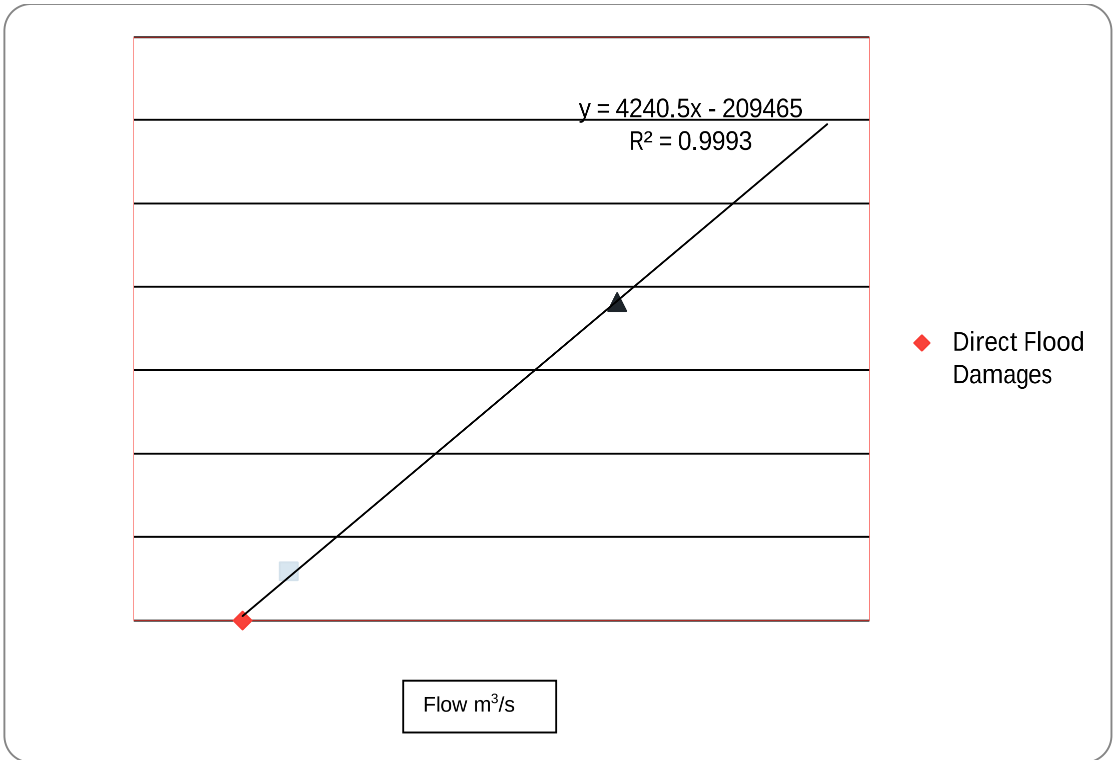
A flow diversion could exist from Taplow Creek to Fourteen Mile Creek along the north side of Upper Middle Road (ref. Figure 7 – Flow Diversion 'D3' in **Appendix G**) using the open space along the roadway. The flow diversion would be limited by the available space and could only have a 15 m top width. The flow diversion would be approximately 500 m in length and would have a 2 m base width with 3:1 side slope and a 2 m deep grass lined channel. The flow capacity of the channel would be approximately 16.60 m^3/s based on a 0.25 % longitudinal slope. A 25 m long, 3 m by 2.4 m box culvert would have to be placed under Bloomfield Drive to facilitate the diversion channel. The direct flood damages would be reduced from $1,446,789 to $1,063,744, a 26% reduction. The cost for the channel works would be approximately $500,000 and $300,000 for the culvert.

The possibility of a diversion from GlenOaks Creek to Taplow Creek at the same location could be investigated, once feedback has been provided from the Town of Oakville on the Taplow Creek diversion. It is understood that Upper Middle Road is being assessed for widening from 4 lanes to 6 lanes and that significant utilities exist within the Upper Middle Road rights-of-way, which may preclude this diversion from further consideration.

Diversion Four (Internal within Fourteen Mile Creek)

The fourth diversion location is actually the existing piped outlet from the Mid Halton WWTP. The 1200 / 1350 mm diameter pipe that outlets at Lake Ontario is going to be abandoned in the short-term and could be used as a flow diversion conduit for Fourteen Mile Creek. The flow capacity of the existing piped outlet is 3.5 m^3/s, based on documentation within the Mid Halton Wastewater Treatment Plant Phase IV and V Expansion, Class Environmental Assessment, April 2010, Hatch Mott McDonald.

Flood damages based on the 2008 Town-wide Study only occur for the 100-year and Regional Storm. The 3.5 m^3/s should it be diverted during a 100-year storm event or greater would reduce direct flood damages only nominally approximately $14,850. Although the reduction in flood damages is not considered significant the 3.5 m^3/s reduction could be implemented for more frequent storm events to help offset part of the potential 20 m^3/s that would be diverted to Fourteen Mile Creek from Taplow Creek. Costs would involve the construction of the inlet systems only. Refer to the damage curve provided as **Chart 5-3.**



Average Annual Damages (100, Reg. Storm) $4,892, Present Worth (50 Year, 5% I) $90,946

Chart 5-3: 14 Mile Creek Flow versus Direct Flood Damages

Diversion Five (Fourteen Mile Creek to Bronte Creek)

Diversion Five would be from Fourteen Mile Creek to Bronte Creek within the Merton Lands, north of the QEW and south of Upper Middle Road. Flow above the 5-year flood elevation of 116.91 m (+/-) would be diverted to Bronte Creek through a 960 m long twin 3 m by 1.8 m box culverts (or equivalent) at a slope of 2%. The diversion would be capable of conveying approximately 16 m^3/s. The diversion flow capacity is restricted due to the 1.5 m (+/-) head at the Fourteen Mile Creek inlet. The outlet to Bronte Creek would be through a drop structure with inverts 97.8 m and 95.5 m. The Bronte Creek valley floor at this location has an elevation of 95 m. The diversion culverts would have a cover of approximately 10 m within the Merton land, which is considered well below any future underground infrastructure. The cost for the diversion would be approximately $20,000,000 (based on 2* 960 m * $3425/m *3 for installation), while the reduction in direct flood damages would be less than $100,000. Not considering the cost, the diverted flow from Fourteen Mile Creek would almost equal and balance the diverted flow from Taplow Creek to Fourteen Mile Creek.

Alternative 7: Flood Control via Stormwater Quantity Measures (Off-line and On-line Flood Storage, LID)

Flood storage could be implemented to offset the increase in peak flows on Fourteen Mile Creek due to potential flow diversions from McCraney Creek, Taplow Creek and potentially GlenOaks Creek or as standalone measures in the absence of diversion over control (within North of 5 lands). Flood controls would need to be implemented north of the QEW as no sites are available south of QEW due to development encroaching on creek blocks.

To offset the flow diversions, peak flows within Fourteen Mile Creek would have to be reduced accordingly, as such flood storage would have to reduce flows (approximately) from a minimum of 16.60 m^3/s to maximum of 52.6 m^3/s. Flood storage scenarios have been developed as per the following:

— **Scenario 1:** On-line Regional Storm to 100-year flood storage along Dundas Street

— **Scenario 2:** On-line flood storage on Fourteen Mile Creek upstream of the QEW and downstream of Upper Middle Road

— **Scenario 3**: On-line flood storage on the east and west branches of Fourteen Mile Creek at Upper Middle Road

— **Scenario 4:** Off-line flood storage locations at various locations within Fourteen Mile Creek, GlenOaks and Taplow Creek

— **Scenario 5:** Scenario 2 with LID applied to catchments within Fourteen Mile Creek south of Dundas Street

— **Scenario 6:** Flood storage through utilization of valley storage upstream of existing culverts

Scenario One: Flood storage locations receive drainage from Fourteen Mile catchments 215, 112 and 184, GlenOaks and Taplow Creek catchment 447. Flood storage at the north side of Dundas Street for the existing land use condition has been notionally sized to reduce the Regional Storm peak flows through over control to the 100-year storm peak flows. To determine the impact of the flood storage on the downstream system, the flood storage has been, for this preliminary assessment, applied to all storm events (2- to 100-year) although only peak flows above the 25-year storm event would be controlled. Depth for each facility has been based on creek system formation and topography. **Table 5.5** provides the results of the Scenario One assessment. The McCraney Creek Regional Storm peak flows at Lake Ontario are not significantly reduced due to the Regional Storm to 100-year peak flows (12.98 m^3/s vs. 12.31 m^3/s) being almost the same at Dundas Street. The Fourteen Mile Creek

Regional Storm peak flows at Lake Ontario are almost reduced 5% to 14 m^3/s by the three flood storage locations.

Based on a reduction of 14 m^3/s in the Regional Storm peak flow, direct flood damages would be reduced by approximately $60,000 with a combined total flood storage volume of approximately 226,875 m^3 (ref. **Chart 5-4**).

Scenario Two: Consists of two separate online flood storage locations upstream of the QEW within the Merton Lands (refer to Figure 1 in **Appendix G**). The 1985 14 Mile Creek – McCraney Creek System Flood Control Study by Philips Planning & Engineering Limited provided the two locations. The first location is immediately downstream of the confluence of the east and west branches (North flood storage area) while the second is approximately 100 m north of the QEW (South flood storage area). Each flood storage location has been tested independently as the 1985 study determined that peak flows were not further reduced by placing both storage locations in series.

Using the data from the 1985 study, the northern flood storage location had a depth of 9.5 m from elevations 114.5 m to 125.0 m. Flood storage was only considered within the defined valley limits as to not impact table lands. The flood storage was applied above the 5-year storm for fisheries passage considerations. The maximum storage determined for the northern storage site is approximately 600,000 m^3, with three 2.35 m diameter pipes (or equivalent) as an outlet, with the result of reducing the Regional Storm peak flow at the storage location from 223 m^3/s to 140 m^3/s and from 269 m^3/s to 222 m^3/s at Lake Ontario (ref. **Table 5.6**). The reduction in direct flood damages, with this system in-place, would be approximately $199,000 (ref. **Chart 5-5**).

The South flood storage area would have a volume of approximately 480,000 m^3 with a maximum depth of 9.1 m. The outlet would consist of three 2.80 m diameter pipes (or equivalent). Regional Storm peak flows would be reduced from 223 m^3/s to 139 m^3/s at the outlet and 269 m^3/s to 204 m^3/s at Lake Ontario (ref. **Table 5.7**), with a reduction in direct flood damages of $275,262.

Table 5.5: Flood Storage Scenario One – Regional Storm to 100-year Flood Storage along Dundas Street Peak Flows (m^3/s)

Location	Creek	2-Year		5-Year		10-Year		25-Year		50-Year		100-Year		Regional Storm	
		Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage
Dundas Street West - Trib Area 215	14 Mile Creek	7.90	7.90	7.90	7.90	20.73	20.73	28.61	28.61	34.58	31.38	40.75	33.30	48.23	38.02
Dundas Street West - Trib Area 112	14 Mile Creek	6.43	6.43	6.43	6.43	16.32	16.32	23.00	22.93	28.32	25.38	33.72	26.45	39.88	30.14
Dundas Street West - Trib Area 184	14 Mile Creek	2.60	2.60	2.60	2.60	6.98	6.98	9.57	9.33	11.54	9.92	13.78	10.22	30.63	13.54
Dundas Street West - Trib Area 447	GlenOaks / Taplow Creeks	2.31	2.31	2.31	2.31	6.29	6.29	8.67	8.67	10.49	10.14	12.31	11.46	12.98	12.23
QEW - Trib Area 107	14 Mile Creek	21.22	21.22	21.22	21.22	56.48	56.48	77.19	77.23	92.15	91.91	107.27	102.72	223.04	199.43
QEW - Trib Area 154	Upper McCraney Creek	10.68	10.68	10.68	10.68	21.00	21.00	26.99	26.99	31.48	31.48	35.94	35.94	32.24	32.24
QEW - Trib Area 441	Taplow Creek	4.89	4.89	4.89	4.89	11.64	11.64	16.22	16.22	19.27	19.27	22.33	22.33	38.53	37.82
QEW - Trib Area 410	Glen Oaks Creek	26.35	26.35	26.35	26.35	53.86	53.86	70.54	70.54	84.71	84.71	96.07	96.06	73.35	73.26
CNR - Trib Area 106	14 Mile Creek	32.25	32.25	32.25	32.25	62.44	62.44	84.63	84.66	100.71	100.29	126.11	121.03	257.46	241.29
CNR - Trib Area 440	Taplow Creek	5.32	5.32	5.32	5.32	12.18	12.18	16.84	16.84	20.01	20.01	23.16	23.16	40.68	39.98
CNR - Trib Area 404	GlenOaks Creek	17.88	17.88	17.88	17.88	34.43	34.43	42.41	42.41	48.70	48.70	54.87	54.87	45.53	45.53
CNR - Trib Area 402	Lower McCraney Creek	21.71	21.71	21.71	21.71	42.49	42.49	54.32	54.32	63.57	63.57	72.45	72.45	82.86	82.69
Lake Ontario - Trib Area 101	14 Mile Creek	31.78	31.78	31.78	31.78	67.45	67.45	85.35	85.35	98.34	98.22	113.96	111.42	269.42	255.20

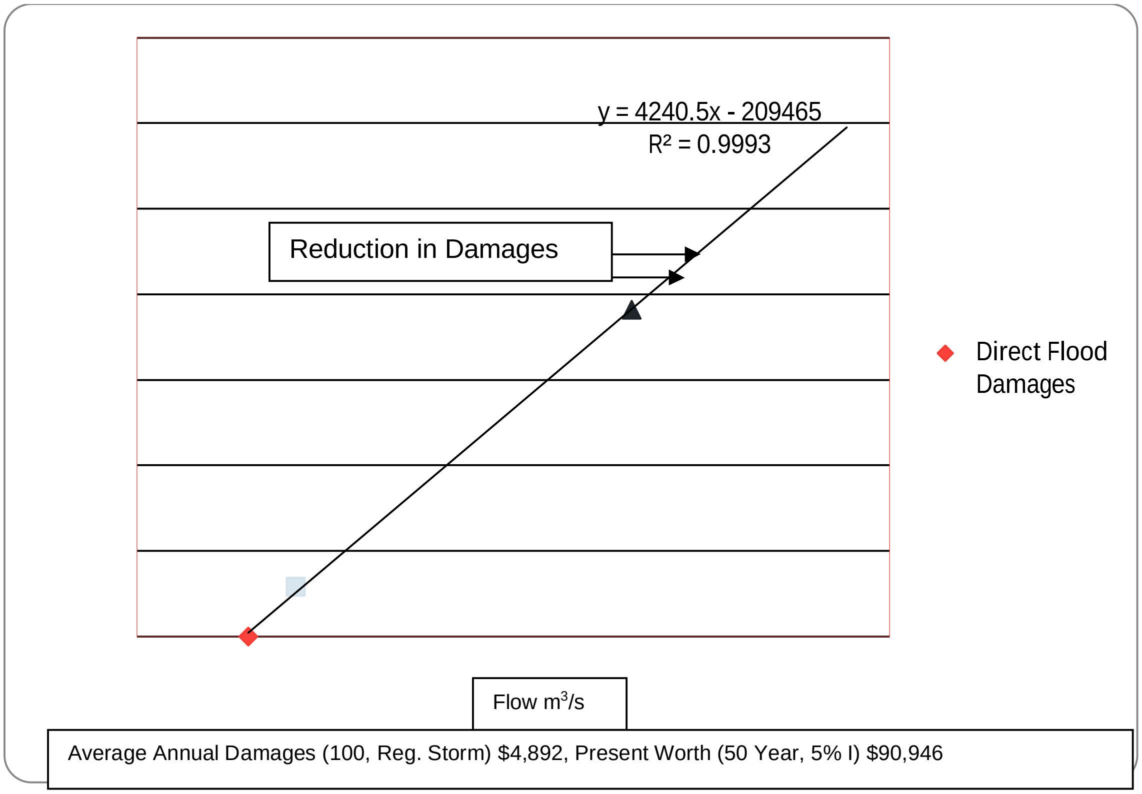


Chart 5-4: Fourteen Mile Creek Flow versus Direct Flood Damages

Table 5.6: Scenario Two – North Storage Area Peak Flows (m^3/s)

Location	Creek	2-Year		5-Year		10-Year		25-Year		50-Year		100-Year		Regional	
		Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage
QEW - Trib Area 107	14 Mile Creek	21.22	20.33	41.31	36.35	56.48	45.76	77.19	55.91	92.15	62.03	107.27	67.74	223.04	140.42
CNR - Trib Area 106	14 Mile Creek	32.25	32.25	49.87	49.87	62.44	61.63	84.63	77.10	100.71	88.72	126.11	104.20	257.46	192.11
Lake Ontario - Trib Area 101	14 Mile Creek	31.78	31.78	53.02	53.02	67.45	67.45	85.35	85.35	98.34	97.69	113.96	111.42	269.42	221.53

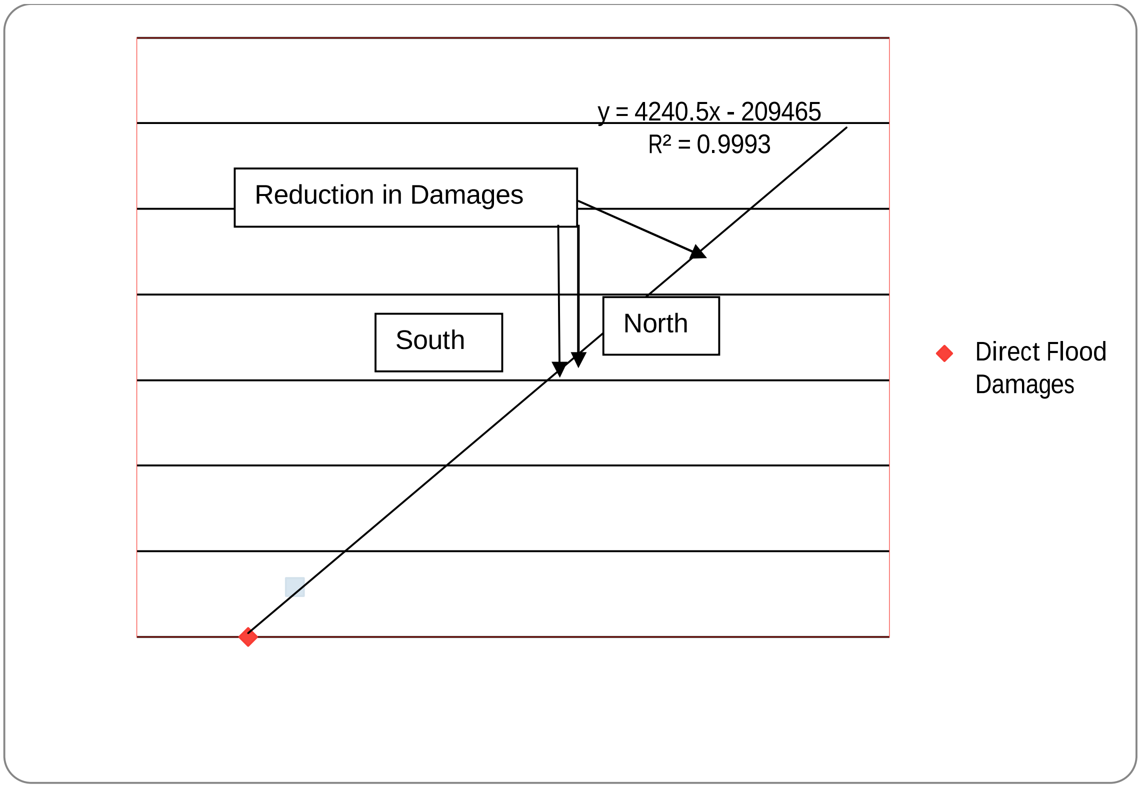


Chart 5-5: Fourteen Mile Creek versus Direct Flood Damages

Table 5.7: Scenario Two – South Storage Area Peak Flows (m^3/s)

Location	Creek	2-Year		5-Year		10-Year		25-Year		50-Year		100-Year		Regional	
		Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage
QEW - Trib Area 107	14 Mile Creek	21.22	20.90	41.31	39.36	56.48	51.54	77.19	64.96	92.15	73.21	107.27	80.85	223.04	139.06
CNR - Trib Area 106	14 Mile Creek	32.25	30.17	49.87	46.58	62.44	57.37	84.63	71.66	100.71	82.22	126.11	93.14	257.46	181.41
Lake Ontario - Trib Area 101	14 Mile Creek	31.78	31.37	53.02	51.32	67.45	65.17	85.35	81.33	98.34	92.81	113.96	103.93	269.42	204.06

Scenario Three: Consists of the following two locations along Upper Middle Road.

— **Site A: Fourteen Mile Creek West Branch north of Bronte Road**: The west branch is located within a well-defined valley system, within the West Oak Trails development. There are a number of stormwater management facilities located within the valley system and potential impacts to the existing stormwater infrastructure would have to be assessed. The existing culvert under Bronte Road is a 2.44 m by 1.22 m box culvert and has a flow capacity of 15.37 m^3/s and a Regional Storm peak flow of 29.1 m^3/s with approximately 1 m of overtopping the roadway.

— **Site B: Fourteen Mile Creek east of Bronte Road upstream of Upper Middle Road:** This site has a valley feature which is well vegetated, with residential and open spaces located adjacent to the valley. The valley feature does not have the depth of the west branch and would therefore not provide the same magnitude of flood storage. The existing culvert is a 4 m by 1 m box culvert and has a flow capacity greater than 14.42 m^3/s for the 100-year storm and the Regional Storm peak flow is 30.2 m^3/s. The culvert is overtopped during the Regional Storm by 0.77 m.

Based on review of the 1985 14 Mile Creek – McCraney Creek System Flood Control Study, each of these locations had been determined to not provide adequate flood storage and/or reduction in peak flows. Both the Bronte Road and Upper Middle Road culverts have significant overtopping during the Regional Storm and could be upgraded in the future, reducing available flood storage upstream of the crossings, as such each site has been removed from further consideration.

Scenario Four: Includes three locations for offline flood storage. A search for locations yielded six locations as shown in **Table 5.8** and Figure 1 in **Appendix G**. The first three locations in **Table 5.8** have been eliminated from further consideration as the flood storage available at each location is considered minimal for Regional Storm benefits. The other three locations have been shown on Figures 2 to 4 in **Appendix G**.

Table 5.8: Potential Off-line Flood Storage Locations

Creek	Location	Catchment # / Drainage Area (ha)	Available Area (m^2)	Storage Depth (m)	Available Storage (m^3)	Comments
McCraney	Westgate Park (Nearest Int.: Fourth Line & Rebecca St)	# 403 111.65 ha	1,445	1.5	2,168	– Minimal tree removal required – Impractical due to available storage (~39m^3/imp. ha)
GlenOaks	Montrose Park (Nearest Int.: Old Abbey Lane & Montrose Abbey Drive)	# 410 (partial) 9.83 ha	1,712	1.5	2,568	– Feasible due to available storage (~522m^3/imp. ha) – Minimal tree removal required
GlenOaks	Old Abbey Park (Nearest Int.: Old Abbey Lane & Parkridge Crescent)	# 410 (partial) 18.23 ha	3,353	2.0	6,706	– Feasible due to available storage (~552m^3/imp. ha) – Minimal tree removal required – Small playground reinstatement
Taplow	Nottinghill Park (Nearest Int.: Nottinghill Gate & Springbrook Crescent)	# 442 (partial) 10.33 ha	22,441	1.5	33,662	– Feasible due to available storage (~6,517m^3/imp. ha) – Moderate tree removal required – Playground, baseball diamond, soccer field reinstatement – Available Area can be reduced to 3,443m^2 to achieve 1,000m^3/imp. ha
14 Mile	Fourteen Mile Creek Trail (East of Langtry Park) (Nearest Int.: Brays Lane & Langtry Drive)	# 162 (partial) 8.95 ha	13,877	1.5	20,816	– Feasible due to available storage (~4,652m^3/imp. ha) – Moderate tree removal required – Baseball diamond, reinstatement – Available Area can be reduced to 2,983m^2 to achieve 1,000m^3/imp. ha
GlenOaks	Past Oakville Transit Facility (Nearest Int.: Fourth Line & Wyecroft Road)	# 404 71.05 ha	17,345	1.5	26,018	– Feasible due to available storage (~732m^3/imp. ha) – Demolition / lost use of existing building

The first flood storage location would be at the previous Town of Oakville Transit Facility. A 50 m wide weir on the west creek bank would allow flow above the 5-year storm to enter the offline storage area. The maximum peak flow into the storage area would be 4.3 m^3/s for the Regional Storm while the peak outflow could be controlled to 0.10 m^3/s through a 250 mm diameter pipe outlet, requiring a storage volume of 17,345 m^3. Due to the minimal reduction in peak flows (34.33 m^3/s to 33.95 m^3/s for 10-year and 45.53 m^3/s to 41.93 m^3/s for the Regional Storm at the McCraney Creek CNR crossing) and the need to remove the existing building to facilitate the storage area, this storage location has been removed from further consideration.

The second storage location would be at the Nottinghill Park near the intersection of Nottinghill Gate and Springbrook Crescent. The park provides over 2.2 ha of open space which could be used for above ground and/or underground storage. The flood storage would intercept a drainage area of 10.33 ha for the 100-year storm. For the preliminary assessment, underground storage has been considered due to the recreational use of the park. A flood storage depth of 1.41 m and area of 3443 m^2 would allow 4855 m^3 of storage. The Taplow Creek 100-year peak flow would be reduced from 23.2 m^3/s to 21.2 m^3/s.

The third location for offline flood storage would be just east of Langtry Park along the Fourteen Mile Creek Trail system. The drainage area would be 8.95 ha, with a storage depth of 1.38 m, area of 2,983 m^2, volume of 4117 m^3 and reduction of the 100-year storm peak flow from 114.4 m^3/s to 114 m^3/s at Lake Ontario.

The results from the off-line assessment are in **Table 5.9**. The 100-year peak flows would not be reduced significantly and actually could increase on Fourteen Mile Creek due to timing effects. As such, the offline storage locations have not been considered further.

Table 5.9: Scenario Four Offline Flood Storage Peak Flows (m^3/s)

Location	Creek	2-Year		5-Year		10-Year		25-Year		50-Year		100-Year		Regional	
		Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage	Ex	Storage
QEW - Trib Area 441	Taplow Creek	4.89	4.39	8.48	7.72	11.64	10.33	16.22	14.58	19.27	17.39	22.33	20.09	38.53	NA-
CNR - Trib Area 106	14 Mile Creek	32.25	31.69	49.87	49.02	62.44	62.52	84.63	84.70	100.71	100.78	126.11	122.20	257.46	NA
CNR - Trib Area 440	Taplow Creek	5.32	4.90	9.16	8.49	12.18	11.09	16.84	15.36	20.01	18.43	23.16	21.19	40.68	NA
CNR - Trib Area 404	GlenOaks Creek	17.88	17.88	27.88	27.88	34.43	33.95	42.41	39.81	48.70	45.18	54.87	53.44	45.53	41.93
CNR - Trib Area 402	Lower McCraney Creek	21.71	21.67	33.98	33.86	42.49	41.82	54.32	51.00	63.57	58.98	72.45	69.85	82.86	79.23
Lake Ontario - Trib Area 101	14 Mile Creek	31.78	31.33	53.02	52.26	67.45	66.54	85.35	84.21	98.34	98.42	113.96	114.42	269.42	NA
Lake Ontario - Trib Area 401	Lower McCraney Creek	25.82	25.76	40.77	40.58	51.27	50.61	65.49	63.41	75.08	72.02	84.66	82.76	109.93	106.38

Scenario Five: Consists of applying an aggressive amount of source control uniformly across the tributary watershed (15 mm of rainfall abstraction) for both pervious and non pervious surfaces for the Fourteen Mile Creek catchments south of Dundas Street in combination with the North and South flood storage areas separately. As PCSWMM uses the Green Ampt Equation for infiltration, which does not use an initial abstraction as per the SCS method, depression storage has been used as a surrogate. The results of the assessment in **Tables 5.10** and **5.11** demonstrate that LID measures applied globally in combination with the North and South flood storage areas would have a moderate reduction of peak flows for less frequent storm events such as the 10-year storm and greater, as such LID best management practices should be considered as retrofits in existing developed areas whenever possible.

Scenario Six: Considers the flood storage that exists upstream of hydraulic crossings for the 2- to 100-year storm events. In determining peak flows using hydrologic models, unless hydraulic crossings are official stormwater management facilities the flood storage upstream of crossings is not considered. The PCSWMM model has been executed with hydraulic structures in place and the results provided in **Table 5.12**. Fourteen Mile Creek 100-year storm peak flows from the QEW to the Lake are reduced 14 to 40% (equivalent 100-year to a 50-year storm), while McCraney Creek 100-year storm peak flows are reduced 36% (equivalent 100-year to a 10-year storm) at Lake Ontario. The accumulative flood storage provided upstream of existing hydraulic structures is considered to be significant, specifically for McCraney Creek.

Alternative 8: Combinations

Based on the numerous combinations of alternatives, for the current short-list assessment, the combination of using Alternative 7 Fourteen Mile Creek On-line North flood storage location and Alternative 6 diversion from Fourteen Mile Creek to Bronte Creek has been assessed. To convey a diverted peak flow of 23.5 m^3/s during the Regional Storm, a 960 m long, 2.1 m diameter pipe at a 2.1% slope has been used. The upstream invert elevation would be 117.5 m and a downstream invert elevation would be 97 m. Results of the combined flood storage and diversion pipe are provided within **Table 6.13**.

The online flood storage would be reduced from 606,454 m^3 to 478,207 m^3 at a depth of 9.08 m. Peak flows at Lake Ontario would be reduced from 269 m^3/s to 217 m^3/s compared to 240 m^3/s when only the standalone flood storage is applied. Direct flood damages would be reduced from $931,229 to $710,723 a reduction of $220,506. The 960 m long diversion pipe would cost approximately $6,000,000 instead of $20,000,000.

Table 5.10: LID with North Flood Storage Area Peak Flows (m^3/s)

Location	Creek	2-Year			5-Year			10-Year			25-Year			50-Year			100-Year			Regional	
		Ex	Storage	Storage & LID	Ex	Storage	Storage & LID	Ex	Storage	Storage & LID	Ex	Storage	Storage & LID	Ex	Storage	Storage & LID	Ex	Storage	Storage & LID	Ex	Storage
QEW - Trib Area 107	14 Mile Creek	21.22	20.33	10.44	41.30	36.34	21.46	56.47	45.75	32.12	77.18	55.91	44.711	92.14	62.02	51.97	107.27	67.74	58.62	223.03	140.42
CNR - Trib Area 106	14 Mile Creek	32.24	32.24	18.18	49.86	49.86	35.05	62.44	61.63	46.05	84.62	77.09	60.91	100.70	88.72	72.11	126.10	104.20	83.26	257.46	192.10
Lake Ontario - Trib Area 101	14 Mile Creek	31.783	31.78	30.55	53.02	53.02	35.00	67.44	67.44	47.43	85.34	85.34	66.71	98.34	97.68	79.48	113.96	111.417	92.41	269.41	221.52

Table 5.11: LID with South Flood Storage Area Peak Flows (m^3/s)

Location	Creek	2-Year			5-Year			10-Year			25-Year			50-Year			100-Year			Regional	
		Ex	Storage	Storage & LID	Ex	Storage	Storage & LID	Ex	Storage	Storage & LID	Ex	Storage	Storage & LID	Ex	Storage	Storage & LID	Ex	Storage	Storage & LID	Ex	Storage
QEW - Trib Area 107	14 Mile Creek	21.22	20.90	8.065	41.31	39.36	21.99	56.48	51.54	33.96	77.19	64.96	50.06	92.15	73.21	59.54	107.27	80.85	68.38	223.04	139.06
CNR - Trib Area 106	14 Mile Creek	32.257	30.179	16.91	49.87	46.589	32.75	62.44	57.37	42.89	84.63	71.66	56.88	100.71	82.22	67.186	126.11	93.14	77.42	257.46	181.41
Lake Ontario - Trib Area 101	14 Mile Creek	31.78	31.37	30.56	53.02	51.32	34.31	67.45	65.17	47.47	85.35	81.33	64.29	98.34	92.81	77.65	113.96	103.93	88.07	269.42	204.06

Table 5.12: Existing Land Use Peak Flows (m^3/s) With and Without Hydraulic Crossings

Location	Creek	Node	Area (ha)	2 Yr		5 Yr		10 Yr		25 Yr		50 Yr		100 Yr		Regional[1]
				With Culverts	No Culverts	With Culverts	No Culverts	With Culverts	No Culverts	With Culverts	No Culverts	With Culverts	No Culverts	With Culverts	No Culverts	
Dundas	14 Mile CK, East	3.2	299	2.60	2.60	5.13	5.13	6.98	6.98	9.57	9.57	11.54	11.54	13.78	13.78	30.63
Upper Middle	14 Mile CK, East Trib	749.08	401	2.57	2.59	5.52	5.56	7.65	7.63	10.77	10.84	12.85	13.22	14.45	14.72	38.30
Upper Middle	14 Mile CK, Trib-2	3135.52	191.2	0.60	0.60	3.46	3.45	5.71	5.67	8.75	8.69	11.02	11.01	13.43	13.41	25.40
Upper Middle	McCraney Ck	3361.22	178.3	1.60	1.67	3.73	4.07	5.24	5.65	7.38	7.93	8.87	10.05	10.27	12.31	19.75
Upper Middle	Taplow Ck	3802.9	204.7	2.38	2.48	3.69	4.01	5.17	5.31	7.55	7.65	9.17	9.30	10.66	10.83	25.80
Upper Middle	GlenOaks Ck	5839.625	101.9	1.03	1.07	2.12	2.38	2.62	3.13	3.30	4.14	4.46	4.87	5.32	5.65	8.38
QEW	14 Mile CK,	4248.377	2380.9	20.26	21.22	34.16	41.31	42.62	56.49	52.42	77.20	58.93	92.17	65.23	107.30	223.03
QEW	McCraney Ck	674.6	298	10.95	10.95	17.16	17.17	21.54	21.54	27.69	27.68	32.25	32.25	36.78	36.78	32.24
QEW	Taplow Ck	819.9957	321.6	5.17	5.10	9.10	9.09	11.77	12.03	15.47	16.53	17.86	19.62	20.41	22.60	38.54
QEW	GlenOaks Ck	3099.031	298.1	14.13	13.78	20.57	22.38	24.80	27.67	29.16	35.30	33.10	41.73	37.25	47.88	37.08
Speers	14 Mile CK,	2902.731	2876.5	32.16	33.00	48.88	52.05	59.82	63.52	73.81	84.87	86.00	101.26	95.02	166.19	259.26
Speers	East McCraney Ck	2230.806	711.3	17.09	21.66	23.17	33.83	25.98	42.35	28.72	54.19	33.45	62.40	38.81	70.46	82.59
Rebecca	14 Mile CK,	895.8482	3153.9	33.05	33.24	57.56	60.81	71.73	78.49	98.30	104.65	107.36	125.89	114.10	134.36	269.37
Lakeshore	14 Mile CK,	OF100	3183.6	32.67	32.69	53.99	54.73	66.65	69.35	82.75	88.44	95.56	103.68	104.64	118.79	270.24
Lakeshore	East McCraney Ck	OF400	970.5	22.01	25.82	29.63	40.77	33.79	51.27	40.08	65.49	46.73	75.08	53.54	84.65	109.88

[1]Flows reported without culverts

Table 5.13: Combined Fourteen Mile Creek Online North Flood Storage Location and Bronte Creek Diversion Peak Flows (m^3/s)

Location	Creek	2-Year		5-Year		10-Year		25-Year		50-Year		100-Year		Regional	
		Ex	Storage and Diversion	Ex	Storage and Diversion	Ex	Storage and Diversion	Ex	Storage and Diversion	Ex	Storage and Diversion	Ex	Storage and Diversion	Ex	Storage and Diversion
QEW - Trib Area 107	14 Mile Creek	21.22	20.33	41.31	36.35	56.48	45.38	77.19	54.94	92.15	60.84	107.27	66.37	223.04	136.57
CNR - Trib Area 106	14 Mile Creek	32.25	32.25	49.87	49.87	62.44	61.63	84.63	77.10	100.71	88.72	126.11	104.20	257.46	188.14
Lake Ontario - Trib Area 101	14 Mile Creek	31.78	31.78	53.02	53.02	67.45	67.45	85.35	85.35	98.34	97.69	113.96	111.42	269.42	217.59
Diversion Tunnel	14 Mile Creek	-	0.00	-	0.00	-	1.37	-	3.73	-	5.31	-	6.86	-	23.50

5.1.5 Summary of Short-listed Alternatives

A preliminary summary of the short-listed alternatives has been provided within **Table 5.14**.and includes the following list of alternatives to be carried forward for further assessment:

- Alternative 1: Culvert / Bridge Upgrades – Replace / Supplement
- Alternative 4: Flood Proofing Buildings (Berming)
- Alternative 6: Flow Diversions
- Alternative 7: Offline and Online Flood Storage and LID
- Alternative 8: Combinations

Table 5.14 presents preliminary costs and benefits, while it is acknowledged that further refined cost-benefit analysis is provided in **Section 5.4**.

Table 5.14: Short-listed Alternatives Assessment Summary

Alternative	Location	Description	Benefit	Cost	Recommendation
Alternative 1: Culvert / Bridge Upgrades – Replace / Supplement	McCraney Crk –CNR	Upgrade from 3.5 m x 2.4 m Bridge	3,3,3 non-residential buildings removed from 10-year storm, 100-year storm and Regional Storm respectively on Taplow Creek 2,1,1 non-residential buildings removed from 10-year storm, 100-year storm and Regional Storm respectively on Glen Oak Creek	To be determined	Carried forward for further assessment. Impacted by McCraney Creek Speers Road culvert and Taplow Creek Fourth Line Culvert
	McCraney Crk –Speers Road	Upgrade from 6.16 m x 1.40 m concrete box	Has to be considered with CNR culvert	To be determined	To be assessed in conjunction with McCraney Creek CNR culvert upgrade
	McCraney Crk –Pinegrove Road	Upgrade from 3.6 m x 3.0 m concrete box	No apparent benefit	Not determined	Screened from further consideration
	McCraney Crk –Wildwood Drive	Upgrade from 5.18 m x 1.83 m open box culvert (not feasible)	0,1,2 residential buildings removed from 10-year storm, 100-year storm and Regional Storm respectively	Not determined	Screened from further consideration. Culvert has been maximized in size based on creek width
	McCraney Crk –Lakeshore Road	Upgrade from 5.4 m x 2.9 m concrete box culvert	0,0,0 non-residential buildings removed from 10-year storm, 100-year storm and Regional Storm respectively	To be determined	Carried forward for further assessment
	GlenOaks Crk – Private property DS of QEW	Upgrade from 3.6 x 1.2 m concrete box culvert	No apparent direct benefit	. Not determined	Screened from further consideration (note that culvert is on private property)
	GlenOaks Crk – Wyecroft Road	Upgrade from 6.10 x 0.95 m concrete box culvert	2,1,1 non-residential buildings removed from 10-year storm, 100-year storm and Regional Storm respectively	. Not determined	Screened from further consideration
	Taplow Crk – Fourth Line	Upgrade from 5.4 x 1.0 m concrete box culvert	Has to be considered with CNR Culvert	To be determined	To be assessed in conjunction with McCraney Creek CNR culvert upgrade
Alternative 2: Floodplain / Channel Improvements	McCraney Creek – Wildwood Drive to Rebecca Street	Lower channel 1 m +/-	No measurable benefit	Not determined	Screened from further consideration
	McCraney Creek – Wildwood Drive to Rebecca Street	Widen channel by 10 m. Requires land purchase	Channel flow capacity from <2-year to 2-year	$8,700,000	Screened from further consideration due to high cost and low benefit
Alternative 3: Roadway Profile Modifications	Taplow Creek - South Service Road	Lower road profile	No measurable benefit	Not determined	Screened from further consideration

<table>
<tr><th>Alternative</th><th>Location</th><th>Description</th><th>Benefit</th><th>Cost</th><th>Recommendation</th></tr>
<tr><td rowspan="2">Alternative 4: Flood Proofing Buildings (Berming)</td><td>Fourteen Mile Creek</td><td>1 m +/- Berm at:
– 1349, 1353, 1357, 1356, 1350 and 1346 Pinegrove Road
– 1179 and 1217 Willowbrook Drive
– 274 Spring Garden Road
– 213, 239, 241, 243 Willowridge Court</td><td>13 homes removed from Regional Storm floodplain</td><td>Estimated at: $130,000 (13 homes at 40 m each at $250/m berm) (excludes land and landscaping)</td><td>Carried forward for further assessment. Based on detailed topography, structures, vegetation etc. may result in further revision to location of berms and affected properties.</td></tr>
<tr><td>McCraney Creek</td><td>1 m +/- Berm at:
– 346, 354 and 360 Burton Road (north of Wildwood Drive)
– 560 Wildwood Drive
– 308, 314 and 320 Burton Road (south of Wildwood Drive)
– 255 Weldon Avenue
– 539 Oriole Drive
– 571 Patricia Drive
– 184 Shanley Terrace</td><td>11 homes removed from Regional Storm floodplain</td><td>Estimated at: $110,000 (11 homes at 40 m each at $250/m berm) (excludes land and landscaping)</td><td>Carried forward for further assessment. Based on detailed topography, structures, vegetation etc. may result in further revision to location of berms and affected properties.</td></tr>
<tr><td rowspan="4">Alternative 6: Flow Diversions</td><td>Diversion One: Taplow Creek upstream of the CNR</td><td>Diversion from Taplow Creek to Fourteen Mile Creek along CNR. Existing diversion channel to be modified and extended for a total length of 1000 m.</td><td>McCraney Creek flow reduction of 20 m^3/s (Regional Storm peak flow reduced to equivalent of 50-year storm peak flow). Direct flood damages reduced from $1,446,789 to $974,675. Approximately 20 homes removed from floodplain.</td><td>$1,200,000</td><td rowspan="4">Carried forward for further assessment.</td></tr>
<tr><td>Diversion Two: Taplow Creek north of the QEW</td><td>800 m diversion along the Indian Ridge Trail from Taplow Creek to Fourteen Mile Creek</td><td>McCraney Creek flow reduction of 16.6 m^3/s Direct flood damages reduced from $1,446,789 to $1,063,744. Approximately 15 to 17 homes removed from floodplain</td><td>$960,000</td></tr>
<tr><td>Diversion Three: Taplow Creek to Fourteen Mile Creek along Upper Middle Road</td><td>500 m diversion along north side of Upper Middle Road</td><td>McCraney Creek flow reduction of 16.6 m^3/s Direct flood damages reduced from $1,446,789 to $1,063,744. Approximately 15 to 17 homes removed from floodplain</td><td>$800,000</td></tr>
<tr><td>Diversion Four: Fourteen Mile Creek north of the QEW</td><td>Diversion using abandoned Mid Halton WWTP 1200 / 1350 mm diameter pipe</td><td>Fourteen Mile Creek 100-year storm and Regional Storm peak flows reduced by 3.5 m^3/s. Direct flood damages reduced by $14,850</td><td>Estimated less than $100,000 for inlet structures</td></tr>
</table>

Alternative	Location	Description	Benefit	Cost	Recommendation
	Diversion Five: Fourteen Mile Creek within Merton land (north of QEW and south of Upper Middle Road)	Diversion using 960 m long twin 3 m by 1.8 m box culverts.	Fourteen Mile Creek Regional Storm peak flows reduced by 16 m^3/s. Reduction in direct flood damages of $66,000. Potentially 2 +/- homes removed from floodplain	$20,000,000	
Alternative 7: Offline and Online Flood Storage and LID	Scenario 1: Over control for North of 5 lands at Fourteen Mile Creek, Taplow Creek and Glen Oak Creek along north side of Dundas Street	Catchments 215, 112 and 184. Flood storage applied to reduce Regional Storm peak flows to 100-year storm peak flows. Total storage of 226,875 m^3.	Fourteen Mile Creek Regional Storm peak flows reduced by 14 m^3/s (5%) at Lake Ontario resulting in $60,000 in reduced direct flood damages.	Estimated at $13,626,000 Based on $60/$m^3$ of storage	**Carried forward for further assessment.**
	Scenario 2: Online North Storage Site north of the QEW at confluence of East and West Branches	660,000 m^3 of online storage	Regional Storm peak flows reduced by 47 m^3/s at Lake Ontario resulting in $199,000 in reduced direct flood damages	Cost to be determined	
	Scenario 2: Online South Storage Site north of the QEW at confluence of East and West Branches	480,000 m^3 of online storage	Regional Storm peak flows reduced by 65 m^3/s at Lake Ontario resulting in $275,262 in reduced direct flood damages	Cost to determined	
	Scenario 3: Sites A and B at West and East Branches of Fourteen Mile Creek at Upper Middle Road	Online flood storage upstream of hydraulic structures	Benefit not assessed as sites not considered appropriate for online flood storage	Not determined	
	Scenario 4: McCraney Creek Westgate Park	2168 m^3 underground flood storage for 111.65 ha drainage area	Impractical due to limited available flood storage	Not determined	
	Scenario 4: Glen Oaks Creek at Montrose Park	2,568 m^3 of underground flood storage for less than 9.6 ha drainage area	Impractical due to limited available flood storage	Not determined	
	Scenario 4: Glen Oaks Creek at Old Abbey Park	6,706 m^3 of underground flood storage for less than 18 ha drainage area	Impractical due to limited available flood storage	Not determined to	
	Scenario 4: Taplow Creek, Nottinghill Park north of the QEW	4,855 m^3 for 10.33 ha drainage area	100-year flow reduced from 23.2 m^3/s to 21.2 m^3/s	$300,000 to $486,000	
	Scenario 4: Fourteen Mile Creek, north of QEW, east of Langtry Park	4,117 m^3 for 8.95 ha drainage area	100-year peak flow reduced from 114.4m^3/s to 114 m^3/s	$247,000 to $412,000	
	Scenario 4: Glen Oak Creek, abandoned Town of Oakville Transit Facility on Wyecroft Road	17,345 m^3 of offline flood storage	Regional Storm peak flows reduced from 45.53 m^3/s to 41.93 m^3/s	$1,040,700 (without land and building costs)	
	Scenario 5: Fourteen Mile Creek	Fourteen Mile Creek LID BMPs (15 mm abstraction) applied with online North Site flood storage	100-year storm peak flows reduced from 111.4 m^3/s to 92.41 m^3/s at Lake Ontario (both peak flows based on North Site flood storage being applied)	Cost not determined	LID BMPs retrofits should be applied whenever possible

Alternative	Location	Description	Benefit	Cost	Recommendation
	Scenario 5: Fourteen Mile Creek	Fourteen Mile Creek LID BMPS (15 mm abstraction) applied with online South Site flood storage	100-year storm peak flows reduced from 103.93 m^3/s to 88.07 m^3/s at Lake Ontario (both peak flows based on South Site flood storage being applied)	Cost not determined	LID BMPs retrofits should be applied whenever possible
	Scenario 6: Fourteen Mile Creek, Taplow Creek, Glen Oak Creek and McCraney Creek	Flood storage upstream of hydraulic structures with controllable gate system	McCraney Creek 100-year peak flows reduced from 84.65 m^3/s to 53.54 m^3/s (equivalent to a 10-year peak flow). Fourteen Mile Creek peak flows reduced from 118.79 m^3/s to 104.64 m^3/s (just above 50-year peak flow equivalent)	No cost (based on existing hydraulics)	**Carried forward for further assessment.** To be discussed with Town of Oakville
Alternative 8: Combinations	Fourteen Mile Creek north of QEW at confluence of East and West Branches	478,207 m^3 of online storage (North site) and diversion using 960 m long 2.1 m diameter pipe	Regional Storm peak flows reduced from 269 m^3/s to 217 m^3/s, reduction of 52 m^3/s at Lake Ontario. Direct flood damages reduced from $931,229 to $710,723. Regional Storm peak flows reduced an additional 5 m^3/s with combined flood storage and diversion vs. at standalone flood storage. Direct flood damages reduced additional $22,000 with combined alternative versus standalone flood storage.	Diversion $6,000,000 Storage cost to be determined	**Carried forward for further assessment.**

5.2 Supplemental Alternative Assessment

As noted in the previous section, the preliminary short-listed alternatives include:

- **Alternative 1:** Culvert / Bridge Upgrades – Replace / Supplement
- **Alternative 4:** Flood Proofing Buildings (Berming)
- **Alternative 6:** Flow Diversions
- **Alternative 7:** Offline and Online Flood Storage and LIDs
- **Alternative 8:** Combinations

Alternatives 1 and 4 have been carried forward to the cost-benefit analysis exercise. However, Alternatives 6, 7, and 8 have been modified based on feedback from Conservation Halton (March 18, 2016) and the Ministry of Natural Resources and Forestry (MNRF) (March 17, 2016) on the preliminary short-listed alternatives identified.

During the April 2016 meeting with the Town, both the MNRF and Conservation Halton expressed concerns that key aspects of the preliminary short-listed alternatives do not align with current policy. The main issue is the diversion from McCraney Creek to Fourteen Mile Creek. Although this diversion would be 'permanent' and reduce flood risk areas downstream on McCraney Creek, the mitigation of these diverted flows and the over-control linked to the proposed online structure on Fourteen Mile Creek are not supported by policy. As a result, this would lead to an increase in Regulatory flows on Fourteen Mile Creek, increasing the Regulatory floodplain limits for properties downstream of the diversion.

As such, a modified list of alternatives was assessed as part of the Supplemental Alternatives Assessment and was conducted based on the June 10, 2016 Supplemental Scope Work Plan. The Work Plan outlined an agreed-upon approach involving an assessment of various supplemental alternatives, considered in response to the review and commentary from Conservation Halton and the MNRF

On the basis of the foregoing, the December 2016 Supplemental Assessment assessed the following alternatives:

1. **1** Storage Tanks
2. **2** Off-setting Flow Diversions
3. **3** Refinement / Optimization of Existing Roadway Crossings
4. **4** Over-control North of Dundas
5. **5** Combinations

Further, the regulators (MNRF and Conservation Halton) raised concerns regarding the environmental impacts associated with the various supplemental alternatives being considered and had therefore requested additional natural environment assessments to review and examine the potential natural system impacts associated with the plan recommendations. To this end, C. Portt and Associates (Fisheries) and Dougan & Associates (now Dougan Ecology; Terrestrial Ecology) had been retained by the Town for the December 2016 Supplemental Assessment to explicitly examine the existing natural systems which may be altered as part of the plan, in order to better define the potential impacts and provide insights into appropriate mitigation. The fisheries and terrestrial assessments have been provided for this updated assessment (refer to **Appendix E**).

5.2.1 Long list of Alternatives

Storage Tanks

The off-line storage analysis conducted as part of the earlier alternative assessment considered storage in public spaces (parks) with gravity capture and discharge. In order to fully explore the potential effectiveness and scale of a more aggressive storage approach, through discussion with Town staff, large underground tanks have been considered which would capture and store water below the outlet stage, which would inherently require a pumping system to drain. The objective and salient difference with this option is that the tanks could be much larger and could therefore potentially provide a much greater level of control, albeit at considerably higher costs.

Through this supplemental analysis, the sites for storage tanks have been maximized and evaluated in terms of their efficacy in addressing off-site flood risk on both Fourteen Mile Creek and McCraney Creek. While MNRF and Conservation Halton may not support any off-site reduction in Regulatory flows, through the use of the tanks, the targeted flood risk for this study is inherently for the more frequent storms in the range of a 10- to 25-year event, notwithstanding any reduction in the less frequent storm events (i.e. 100-year) has also been considered through this analysis. It should be noted that this management strategy is not being considered for managing the

Regulatory event, hence there would be no expectation of a reduction in Regulatory flood limits on either system.

A review of Town-owned properties along Fourteen Mile Creek, Taplow Creek and Glen Oak Creek north of the QEW has been conducted (refer to Figures included in **Appendix H**; locations T-1, GO-1, 14M-1, MC-1). The storage capacity for each tank location has been based on the available area and a designated depth of 5 m (Note: While clearly tank depths can be greater than 5 m, this has been considered a reasonable depth for the purpose of storage and constructability. Depths greater than 5 m would potentially involve significant construction requirements and potentially encounter bedrock). Flood storage tank details are summarized in **Table 5.15.**

Table 5.15: Off-line Flood Storage

Tank No.	Location	Area (m^2)	Estimated Volume (m^3)
1	Nottinghall Gate Park (Taplow Creek)	13,500	67,500
2	Old Abbey Lane Park (Glen Oak Creek)	8,500	42500
3	Montrose Abbey Park (Taplow Creek)	NA_1	NA_1
4	Langtry Park (Fourteen Mile Creek)	19,000	95,000
5	Aldercrest Park (McCraney Creek)	8,000	40,000
6	Windrush Park (McCraney Creek)	6,500	32,500
7	Glen Abbey Park (McCraney Creek)	24,000	120,000

Note: $_1$ Tank location not assessed due to lack of available area

Each of the flood storage tank locations has been assessed as to the ability of the locational characteristics (creek water levels and valley configuration) to capture creek flow, commencing between the 5- and 10-year storm events [Note: Flows below the 5- and 10-year level would be assumed to continue to flow as currently in the respective watercourses, hence there would be no expected impacts to the natural system function (i.e. aquatic habitat and stream morphology)].

Notionally, the flow capture mechanics for each tank were considered to be comprised of an inlet system which maximized capture on the basis of relatively low head (i.e. through a series of low rise box culverts). In an effort to increase head at each tank to fully utilize the tank storage volume during the 100-year storm event, overbank grading (valley forming) had been proposed, resulting in a modified head condition. Based on the lack of peak flow control provided by existing head conditions only the modified head condition has been assessed.

Tank No. 2 Old Abbey Lane Park (Glen Oak Creek) proposed to be located immediately upstream of the control structure on Old Abbey Lane Park, would benefit from an increase in available head to the tank inlets, that said would still require a modified head condition to be optimized. The available head for the 25-year, 100-year and Regional Storm has been provided in **Table 5.16**, with the modified head condition representing the condition assessed for the tanks.

Table 5.16: Available Head / Modified Head (m)

Tank No.	25 Year	100 Year	Regional Storm
1	0.74/0.85	0.79/0.90	1.06/1.56
2[1]	1.99/1.99	2.07/2.07	2.31/2.31
4	2.15/2.17	2.36/2.38	3.29/3.33
5	0.89/0.92	0.94/0.98	1.21/1.31
6	0.83/0.87	0.91/0.95	1.03/1.13
7	0.83/0.92	0.90/0.98	1.0/1.12

Note: 1. Tank # 2 was not modified as available head was adequate based on downstream on-line control structure.

For Tanks 2 and 4, the locally generated 100-year flow (combination of local minor and major drainage systems) from drainage catchments 410-2 (24.39 ha) and 162-1 (9.3 ha) have been assumed to discharge directly to the tanks. Local drainage capture opportunities have also been considered for the other tank locations, however due to the configuration of the local drainage systems in those areas, drainage capture is either not feasible or not considered beneficial. The peak inflow into each tank and the flood storage (base / modified due to head / available) for each storm event is summarized in **Table 5.17**.

Table 5.17: Inflow (m^3/s) / Modified Storage / Available[1] (m^3)

Tank No.	25 Year	100 Year	Regional Storm
1	4.88 / 35,289	7.59 / 57,402 (67,500)	9.20 / 67,500
2[2]	3.65 / 21,896	9.84 / 42,500 (42,500)	1.35 / 42,500
4	8.99 / 31,673	22.62 / 95,000 (95,000)	52.99 / 95000
5	3.26 / 18,960	5.53 / 35,376 (40,000)	15.89 / 40,000
6	2.78 / 13,013	6.05 / 28,672 (32,500)	11.72 / 32,500
7	5.57 / 35,064	9.13 / 55,080 (120,000)[3]	13.00 / 120,000

Notes: 1. Available storage provided in brackets (Objective to use full tank capacity for the 100-year storm event +/-)

2 Tank #2 was not modified as available head was adequate based on downstream on-line control structure

3 Tank 7 is not fully utilized in the 100-year storm as the available storage is greater than the hydrograph volume.

The benefit (i.e. reduction in peak flows) resulting from the implementation of Tanks 1, 2, 5 - 7 is considered to be insufficient as it would not result in an appreciable reduction in flood risk downstream. The potential reduction in peak flows at key locations resulting from the implementation of Tank 4 is summarized in **Table 5.18**. Tank 2 at the Old Abbey lane showed appreciable reduction in the flood risk downstream in the previous assessment. However, in this assessment, since there is an on-line control structure downstream of the tank, the timing of the peak flow in the main channel has shifted such that the benefit of the tank in reducing peak flow is muted by the external flow coming into the system by local subcatchments 410_1 and 404. Although peak flow reduction is achieved at the QEW, by the time flow recaches the CNR crossing, the benefits are offset by flows from local subcatchments. This diminishes the effectiveness of the tank in managing peak flows downstream of CNR, rendering it insignificant.

The flood storage tanks are targeted towards the provision of flow reduction for the more frequent storm events (i.e. 10, 25, and 50-year). The reduction in the 25-year and 100-year storms of approximately 9% to 17% of the peak flow falls into this expectation as does the minimal reduction in Regional Storm peak flows, since the flood storage tanks are unable to have a significant impact on the larger Regional Storm runoff volumes.

Table 5.18: Peak Flows at Key Nodes (m^3/s)

Tank No.	25 Year Existing/ Modified Head Tank				100 Year Existing/ Modified Head Tank				Regional Storm Existing/ Modified Head Tank			
14 Mile Creek												
	Existing	**Langtry Park**	**Windrush Park**	**Glen AbbeyPark**	**Existing**	**Langtry Park**	**Windrush Park**	**Glen AbbeyPark**	**Existing**	**Langtry Park**	**Windrush Park**	**Glen AbbeyPark**
QEW west branch	70.61	62.71	-	-	99.1	78.59	-	-	221.6	222.1	222.1	222.1
QEW east branch	12.03	-	11.57	11.57	15.62	-	15.19	15.19	31.86	30.33	30.04	19.04
CNR	78.18	70.77	77.84	75.76	107.2	89.84	105.7	103.3	256.1	255.7	255.5	243.8
Lake Ontario	77.62	70.63	77.31	75.25	106.8	88.94	105.5	103.1	267.7	267.6	267.2	255.5
McCraney Creek												
	Existing	**Nottinghill Gate Park**	**Old Abbey Lane Park**	**Aldercrest Park**	**Existing**	**Nottinghill Gate Park**	**Old Abbey Lane Park**	**Aldercrest Park**	**Existing**	**Nottinghill Gate Park**	**Old Abbey Lane Park**	**Aldercrest Park**
QEW west branch	15.06	15.04	14.94	15.04	22.71	-	19.32	-	37.93	37.6	37.85	37.62
QEW east branch	9.225	5.076	9.415	6.509	13.12	8.151	-	8.697	37.57	30.04	37.64	37.64
CNR	30.99	30.97	30.88	30.97	40.52	40.51	40.41	40.51	82.44	76.91	82.25	82.31
Lake Ontario	43.8	43.77	43.67	43.77	55.97	55.91	55.7	55.91	110.2	104.9	110	110.1

Off-setting Flow Diversions

Fourteen Mile Creek to Bronte Creek

A diversion during high water events (i.e. greater than 10 to 25-year) has been proposed from the McCraney Creek system to Fourteen Mile Creek. Conservation Halton and MNRF have commented on this management approach in terms of the implications to the flood risk associated with lands downstream of the diversion point on Fourteen Mile Creek (ref. correspondence March 17 and 18, 2016 from MNRF and CH respectively). While it is understood that online storage solutions are by policy not recognized in terms of reducing Regulatory floodlines due to the diversion, off-setting diversions in the receiving watercourse would be supportable. It is on this basis that another off-setting diversion has been considered, from Fourteen Mile Creek to the Bronte Creek system.

Due to the depth and the size of the Bronte Creek system (i.e. hydrograph timing effects) and the nature of the receiving valley, diversions to this system are deemed to be inconsequential in terms of any tangible impact on either peak flows or ecology downstream of the diversion point.

In order to be supportable by the Regulators, the amount of the diversion from Fourteen Mile Creek to Bronte Creek needs to have a net impact such that flow rates would be the same or less downstream of the diversion discharge point from McCraney Creek (i.e. upstream of CNR). In terms of Provincial Policy, this would, as discussed earlier, result in a net decrease in the Regulated flood limits on McCraney Creek and would likely have a near zero net impact on the Fourteen Mile Creek Regulated flood limits.

In establishing the preferred location (refer to Figure 11 in **Appendix H**) and form of the flow diversion from Fourteen Mile Creek to Bronte Creek several factors have been considered:

— Minimize length of the diversion between Fourteen Mile Creek and Bronte Creek.

— Look for potential intake locations to minimize the need to create an online valley structure to increase backwater at the diversion inlet, thereby selecting a location with maximum attainable head.

— Place the diversion inlet at / or above the 10-year flood elevation to eliminate any potential for natural system impacts (stream morphology and aquatic habitat).

— Align the diversion conduit to reduce tree removal within both Fourteen Mile Creek and Bronte Creek. The diversion outlet to Bronte Creek would also have to be aligned to minimize stream morphological impacts.

In an effort to eliminate the need for an online structure to create increased backwater and head at the diversion inlet on Fourteen Mile Creek, while maximizing the available inlet flow area, an inlet capture system (notionally sized as 2.4 by 1.2 m box culvert or equivalent such as a Morning Glory inlet) has been adopted as the diversion system inlet. The 1.2 m culvert rise has been selected due to the low flow depths within the creek valley. The box culverts would transition to a 920 m (+/-) long, 2.1 m diameter pipe after 210 m, which through a drop structure would outlet to Bronte Creek via a 70 m long, 2.1 m diameter pipe. The box culvert length has been minimized by transitioning to a 2.1 m diameter pipe just beyond the Fourteen Mile Creek Valley.

The flow diversion configuration as dimensioned would be capable of diverting peak flows for storm events commencing at the 25-year storm frequency (+/-). Diverted flow rates are provided in **Table 5.19**. The influence of the flow diversion has been comprehensively modelled in PCSWMM, with the downstream peak flow results provided in **Table 5.20**. The 25-year to 100-year and Regional Storm peak flows have been reduced to at, or below, existing conditions.

Based on the limited head within Fourteen Mile Creek at the flow diversion inlet, it would be recommended to construct a 'hydraulic bump' in the overbank area (beyond bankfull creek zone) to locally raise water levels to improve capture during events more frequent than the Regional Storm. The results presented in **Tables 5.19** and **5.20** are reflective of the 'hydraulic bump' conditions.

Table 5.19: Fourteen Mile Creek Diversion to Bronte Creek Peak Flows

Location	25	50	100	Regional Storm
Creek Flow	61.72	74.40	87.84	182.00
Diversion Flow	2.92	6.29	10.01	17.21
Downstream Flow of Diversion	58.74	68.17	77.67	165.60

Table 5.20: Fourteen Mile Creek with Diversion Peak Flows – (Existing / Proposed)

Culvert	25	50	100	Regional Storm
QEW	70.61 / 64.55	84.53 / 75.07	99.10 / 85.94	221.60 / 200.80
CNR	78.18 / 71.97	93.07 / 83.50	107.2 / 95.73	256.10 / 234.40
Lake Ontario	77.62 / 71.88	91.94 / 83.17	106.80 / 95.41	267.70 / 245.7

McCraney Creek (Taplow Creek) to Fourteen Mile Creek (Combined with Fourteen Mile Creek Diversion to Bronte Creek)

As noted in the initial alternative assessment, the McCraney Creek to Fourteen Mile Creek flow diversion has been advanced as the preferred alternative based on its ability to reduce flood risk on downstream flood prone reaches along the McCraney Creek.

The flow diversion as proposed would commence immediately west of Fourth Line and would be located just north of the CNR tracks. The total length of the flow diversion would be approximately 1500 m (+/-). The existing channel west of Fourth Line has a base width of 1.8 to 2.1 m (+/-) with 1.5:1 side slopes, and a secondary overbank area on each side with 2:1 slopes (refer to Figures 9 and 10 in **Appendix H**). The existing flow capacity of this system is 25.6 m^3/s to 28.9 m^3/s based on a 0.11% longitudinal slope premised on free flow conditions.

In order to be functional, the existing channel would need to be extended easterly 200 m (+/-) to the west side of Fourth Line (refer to Figure 9 in **Appendix H**). The existing channel has previously been reported as receiving Regional Storm peak flow 39.5 m^3/s, which is above the estimated maximum flow capacity of 28.9 m^3/s. In order to provide adequate flow conveyance for the Regional Storm and allow for additional flow to be diverted from Taplow Creek, the existing 1500 m (+/-) diversion channel would have to be retrofitted to a 3 m base, 3.66 - 4.15 m deep channel with 1:1.5 side slopes at a longitudinal slope of 0.25%. The existing grass lined channel top width is 14.9 m, while the retrofitted channel would require 21.4 m +/-.

The flow diversion based on this configuration has been incorporated in the updated PCSWMM model and set such that the diversion would accept flow above the Taplow Creek 10-year flood elevation of 103.51 m at the stormwater management facility adjacent to Fourth Line.

The analysis has indicated that peak flows for the 2-year to the 100-year storm events on the McCraney Creek downstream of the CNR tracks would not be reduced by the proposed flow diversion. Rather, the controlling 2-year to 100-year storm event hydrographs (peak flows) for the McCraney Creek are governed by the Glen Oak Creek, located west of Fourth Line, with the diversion in place. As such, for the 2- to 100-year storm events peak flows to be reduced within McCraney Creek, flows from Glen Oak Creek upstream of the CNR would either have to be diverted to Taplow Creek or flows within Glen Oak Creek would have to be reduced upstream of the CNR through alternate means.

Both the Fourteen Mile Creek to Bronte Creek Diversion and the Taplow Creek to Fourteen Mile Creek Diversion are necessary to reduce Regional Storm peak flows within McCraney Creek and to at least maintain or reduce these peak flows within Fourteen Mile Creek downstream of the CNR tracks. The Fourteen Mile Creek to Bronte Creek flow diversion would offset the diverted flow from Taplow Creek to Fourteen Mile Creek for storm events ranging from 25-year to 100-year and the Regional Storm. **Table 5.21** provides existing and proposed peak flows at key locations resulting from the Taplow Creek to Fourteen Mile Creek Diversion.

Table 5.21: Peak Flow Results with both Diversion in Place

Location	25	50	100	Regional
Taplow Creek Upstream of Diversion	(9.273)	(11.43)	(13.39)	(39.73)
Diversion Channel	2.42	3.43	4.35	15.59
McCraney Creek at CNR	(30.99)[1] 30.99	(35.63) 35.63	(40.52) 40.52	(82.44) 68.43
McCraney Creek at Lake Ontario	(43.8) 43.8	(50.12) 50.12	(55.97) 55.97	(110.2) 96.55
Fourteen Mile Creek at CNR	(78.18) 74.27	(93.07) 86.75	(107.2) 99.5	(256.1) 251.4
Fourteen Mile Creek at Lake Ontario	(77.62) 74.12	(91.94) 86.25	(106.8) 99.56	(267.7) 263.6

Note: [1] Flows in brackets represent existing conditions

Reinforce / Optimize Existing Roadway Embankments and Crossings

As discussed with Town staff, many of the at-risk locations in the Town, particularly along the Lower McCraney Creek, have not experienced flooding to the frequency and extent that is currently predicted by the modelling. The underlying rationale for this observation has been supported through more detailed forensic analysis in that several of the existing hydraulic crossings (culverts / embankments) on both the McCraney Creek and Fourteen Mile Creek systems have significant attenuative effects which reduce downstream flood flow rates. While this occurs in practice, it has no influence on the Regulatory flow condition downstream, by way of Provincial Policy. Notwithstanding, these hydraulic structures (road embankments and culverts) while providing a tangible benefit in terms of reducing downstream flood risk, remain at risk of failure, similar to the failure of the Finch Avenue structure in the City of Toronto in 2005 (shown in the photos below).

In an effort to provide added resiliency and protection to residents downstream of these hydraulic crossings, particularly those that provide the most important or significant benefit, the crossings could be constructed to be more robust and stable (under flood stage), in terms of their geotechnical and hydraulic stability, and potentially optimized in terms of their configuration (by adjusting their size or overtopping elevations). Appropriately retrofitted, these existing roadway embankments and crossings can be designed to function in a manner to best meet off-site objectives in terms of flood management and local hydraulic performance of the crossings.

As noted earlier, it is considered that MNRF and Conservation Halton will be supportive of this measure in that there is no expectation that there would be any adjustment to downstream Regulatory floodplain limits. Further, given that the hydraulic crossings are currently at a higher risk of failure (since they were not constructed as purpose-built water retention systems), modifying their configuration and providing them with a higher level of physical integrity, should not bring forth a requirement of the Province and Conservation Halton to assess dam break impacts and associated contributions to increased off-site peak flows; however, this perspective remains an uncertainty.

Culvert crossings have been selected upstream of, or at, the QEW (ref. **Table 5.22**) that are considered to be the most restrictive in terms of flow capacity and would produce the greatest attenuation of peak flows for each of the following creeks (Fourteen Mile Creek, McCraney Creek, and Taplow Creek), while receiving sufficient contributing drainage areas. Based on the online structure location on Glen Oak Creek located just upstream of the QEW, no culvert has been selected for Glen Oak Creek. Culvert crossings located just upstream of the QEW typically have the largest contributing drainage areas for each creek, prior to the creek confluences downstream of the QEW.

Details of the selected culverts have been provided in **Table 5.22**. Selected culverts have been modified as part of optimization to improve/maintain hydraulic performance while enhancing benefits from flow attenuation; selected locations where this has been considered have been noted herein.

Without any modifications to the existing culvert configuration, the culverts have been incorporated into the 'no-culvert' model to determine the flow attenuation at the crossings and downstream along each creek (ref. **Table 5.23**). Peak flow results with the subject four culverts in-place have been compared to the peak flows with all culverts in place (ref. **Table 5.23**).

Based on the 2008 Ministry of Transportation (MTO) Highway Drainage Design Standards, design flow for return period for bridges and culverts, the crossings are, as a minimum, required to convey the following storm events with a suitable freeboard.

— Fourteen Mile Creek North - Service Road / QEW: 100-year
— Upper McCraney Creek - North Service Road / QEW: 50-year
— Taplow Creek - North Service Road: 25-year

In order to demonstrate the 'optimized' flow attenuation for each of the selected culverts, the flow area for each culvert has been modified by reducing the rise and maintaining the span, while still meeting the 2008 MTO crossing performance requirements. The details of the optimized culverts are as per the following:

— Fourteen Mile Creek Main Branch: North Service Road / QEW: 9 m span HE arch, rise reduced from 4.5 m to 1.5 m
— Upper McCraney Creek: North Service Road / QEW: 4.27 m span by 2 m rise box, reduced to 3 m span by 0.55 m rise box
— Taplow Creek: North Service Road: 3 m span box, rise reduced from 2.58 m to 0.50 m

The reduced peak flows resulting from the optimized culverts and associated flow attenuation have been provided in **Table 5.23**. The results in **Table 5.23** demonstrate that the 10-year to 100-year storm event peak flows are moderately reduced downstream of the optimized culverts.

Additional detailed assessment of each crossing would be required to determine a refined configuration that would optimize flow attenuation potential, while not impacting downstream and upstream properties and roadway overtopping conditions.

Table 5.22: Hydraulic Structure Analysis Summary including Culvert Sizing Optimization

Crossing Location	Size of Opening (span x rise) (m x m)	Inverts (m)		Top of Road / Culvert Length (m)	Flow Capacity (m^3/s)	Flow Frequency related to Capacity
		Upstream	Downstream			
Fourteen Mile Creek- Reach 1						
West Oak Trails Boulevard	1.8 m x 1.2 m Box Culvert	141.45	141.55	14 / 42.2	7.87	100
Upper Middle Road West	10 m x 1.5 m Conc. Arch Culvert	136	135.5	32.7 / 83.3	25.31	Regional
PostMaster Drive	5.0 m x 2.0 m box culvert	134	134	28.6 / 53	13.05	100
Merchant's Gate	4.9 m x 1.85 m box culvert	133.5	133	30 / 61	25.12	Regional
Third Line south of Glen Abbey Gate	3.09 m x 1.85 m box culvert	132.3	132.15	32.57 / 31.6	7.9	2
Abbeywood Drive	2.4 m x 2.35 m box culvert	118.02	117.1	29.4 / 63.5	29.8	100
Third Line north of QEW	3.7 m x 2.6 m box culvert	113.26	112.25	34 / 55	25.78	50
Fourteen Mile Creek-West Branch						
Bronte Road	2 x 4.2 m x 2.8 m box culvert	125.09	124.86	10.9 / 42.1	133.60	Regional
Upper Middle Road	7.3 m x 2.7 m box culvert	122	121.74	34 / 39.5	80.72	100
Fourteen Mile Creek-Main Reach						
North Service Road / QEW	9.0 m x 4.5 m Ellip. Culvert	103.3	102.73	105 / 125	99.07	100
Fourteen Mile Creek – East Branch						
West Oaks Trail BLVD	7.3 m x 2.9 m box culvert	140.6	140.41	6.5 / 10	38.64	Regional
Upper Middle Road West	4.2 m x 2.4 m box culvert	131.5	131.44	33.9 / 40	14.42	100

Crossing Location	Size of Opening (span x rise) (m x m)	Inverts (m)		Top of Road / Culvert Length (m)	Flow Capacity (m^3/s)	Flow Frequency related to Capacity
		Upstream	Downstream			
Upper McCraney Creek						
Springdale Road	3.0 m x 1.5 m concrete box	145.90	145.86	9 / 32.3	12.53	100
Third Line	3.0 m x 1.7 m concrete box	145	144.5	8.5 / 45.2	19.89	100
West Oak Trails Blvd	4.0 m x 1.0 m concrete box	143.5	143.5	13.6 / 40	8.38	25
Sandpiper Road	3.0 m x 1.8 m concrete box	141.5	141	9.6 / 41	12.53	100
Upper Middle Road	2.4 m Conc. Circ. Culvert	138	137.83	39 / 88.5	11.73	100
Pilgrim's Way north	3.0 m x 2.0 m box culvert	133.67	133.48	26 / 35.1	11.61	100
Pilgrim's Way south	3.05 m x 1.85 m box culvert	116.08	114.74	30.8 / 91.6	31.86	Regional
North Service Road / QEW	4.27 m x 2.00 m concrete box	108	105.99	90.4 / 98	14.66	100
Glen Oak Creek						
West Oak Trails Blvd	5.0 m x 1.5 m box culvert	145.02	144.01	14.6 / 39.2	8.38	Regional
Sandpiper Road	4.88 m x 1.83 m Conspan Arch	140.5	140.5	9 / 31.2	8.38	Regional
Upper Middle Road	1.8 m x 1.4 m box culvert	139.47	138	81.6 / 93.4	3.13	10
Monastery Drive	3.6 m x 1.7 m box culvert	133	131.68	28.5 / 48.3	21.66	Regional
Monk's Passage	3.0 m x 2.5 m box culvert	125	124.08	19.4 / 36.9	21.66	Regional
Montrose Abbey Drive	3.0 m x 2.5 m box culvert	121	121	13.9 / 28	12.8	10

Crossing Location	Size of Opening (span x rise) (m x m)	Inverts (m)		Top of Road / Culvert Length (m)	Flow Capacity (m^3/s)	Flow Frequency related to Capacity
		Upstream	Downstream			
Old Abbey Lane	3.05 m x 1.5 m box culvert	116.1	115	24 / 46.7	32.8	25
North Service Road / QEW	4.27 m x 2.00 m concrete box	110	109	86.8 / 93.64	32.8	25
Taplow Creek						
West Oak Trails Blvd	3.7 m x 1.2 m box culvert	145	144.03	15 / 40	10.77	100
Sandpiper Road	3.0 m x 1.5 m box culvert	141	140.5	9.6 / 40	10.77	100
Upper Middle Road	3.5 m x 1.5 m box culvert	137.68	137.71	56.2 / 90.8	10.77	100
Pilgrims Way North	3.0 m x 2.0 m box culvert	135.53	135.3	33.2 / 45.1	15.14	100
Pilgrim's Way South	4.0 m x 2.0 m box culvert	121	120	24.2 / 32.2	15.14	100
Private Crossing West of Nottinghill Gate	3.05 m x 1.8 m box culvert	113.5	113	3.5 / 38.1	13.15	100
North Service Road	3.0 m x 2.58 m box culvert	108.7	108.3	28 / 28	13.15	100
QEW	3.0 m x 1.8 m box culvert	108.5	107.9	53.86 / 60.27	9.23	25

Table 5.23: Peak Flow Attenuation (m^3/s) with Culvert Crossings in Place (No Culverts / Culverts / Optimized Culverts)

Location	25	50	100	Regional Storm
Fourteen Mile Creek				
North Service Road (Fourteen Mile Main Branch-Culvert 3)	70.61 / 70.40 / 68.28	84.53 / 84.03 / 80.76	99.10 / 98.49 / 92.36	221.60 / 213.90 / 214.10
North Service Road (Upper McCraney Creek-Culvert 10)	12.03 / 12.15 / 7.29	13.87 / 13.95 / 7.91	15.62 / 15.68 / 8.34	31.86 / 31.86 / 31.85
CNR	78.18 / 77.91 / 76.53	93.07 / 92.66 / 89.71	107.20 / 106.50 / 101.40	256.10 / 246.30 / 246.80
Lake Ontario	77.62 / 77.47 / 76.53	91.94 / 91.58 / 89.10	106.80 / 106.30 / 102.20	267.70 / 257.30 / 257.80
McCraney Creek				
North Service Road (Taplow Creek-Culvert 7)	9.23 / 9.25 / 8.42	11.22 / 11.22 / 9.36	13.12 / 13.13 / 11.70	37.57 / 37.53 / 37.55
CNR	30.99 / 30.97 / 31.00	35.63 / 35.61 / 35.65	40.52 / 40.51 / 40.54	82.44 / 82.13 / 81.83
Lake Ontario	43.80 / 43.79 / 43.81	50.12 / 50.12 / 50.14	55.97 / 55.96 / 55.99	110.20 / 109.90 / 109.50

Combinations

The various standalone flood risk reduction alternatives considered in this supplementary assessment demonstrate mixed results with respect to reducing peak flows (and associated flood risk) downstream. The two off-setting flow diversions would provide reduced Regional Storm peak flows within the McCraney Creek downstream of the CNR tracks, while slightly reducing Regional Storm peak flows on Fourteen Mile Creek downstream of the CNR tracks. Under the 10-year to 100-year storm events, the Fourteen Mile flow diversion reduces peak flows downstream of the CNR tracks between 4% to 7%, while the Taplow Creek flow diversion does not reduce peak flows in the McCraney creek system at any location downstream of the CNR tracks.

The off-line storage tanks have been determined to be largely ineffective in reducing peak flows for the more frequent storm events south of the QEW, due primarily to the tanks locations, and the significant runoff response from the downstream contributing drainage areas which tend to control peak flows downstream of the QEW and CNR. The exception to the foregoing, is the Langtry Park storage tank with a targeted volume of 95,000 m^3, which would reduce the 25-year to 100-year Fourteen Mile Creek peak flows at the CNR by 10% to 17% respectively.

The reinforcement and optimization of existing roadway crossings at two out of the three locations for the purpose of flow attenuation and reduction of flows downstream within each creek, has shown to be effective when optimizing crossing flow areas. However, the Langtry Park storage tank provides a greater reduction in flows than the optimized culverts (i.e. 17% vs. 5% at the CNR)

Based on the foregoing, the following set of combined alternatives has been assessed for combined effectiveness in addressing the area's flood risk:

- Fourteen Mile Creek Flow Diversion to Bronte Creek
- Taplow Creek Flow Diversion to Fourteen Mile Creek
- Langtry Park Off-line Storage Tank

The results in **Table 5.24** demonstrate reductions in peak flows for all events (25-year to 100-year, Regional Storm) within the critical flooding areas within Fourteen Mile Creek and reductions in peak flows for the Regional Storm within McCraney Creek downstream of the CNR.

Table 5.24: Peak Flow Results (Existing/ Proposed) with Combined Alternatives (m^3/s)

Location	25	50	100	Regional
Taplow Creek Downstream of QEW	9.23 / 9.23	11.22 / 11.22	13.12 / 13.12	37.57 / 37.57
Taplow Creek Upstream of Fourth Line	9.28 / 9.41	11.44 / 11.47	13.39 / 13.41	39.73 / 39.73
Taplow Diversion Channel	- / 2.42	- / 3.43	- / 4.35	- / 15.59
Taplow Creek at Confluence with Glen Oak Creek	9.23 / 6.95	11.40 / 8.02	13.36 / 9.05	39.74 / 24.15
Glen Oak Creek Downstream of QEW	15.06 / 15.06	18.54 / 18.54	22.72 / 22.71	37.93 / 37.93
Glen Oak Creek at Confluence with Taplow	30.42 / 30.42	35.14 / 35.14	39.04 / 39.04	46.82 / 46.82
McCraney Creek at CNR	30.99 / 30.99	35.63 / 35.63	40.52 / 40.52	82.44 / 68.43
McCraney Creek at Lake Ontario	43.80 / 43.80	50.12 / 50.12	55.97 / 55.97	110.20 / 96.55

Location	25	50	100	Regional
Upper McCraney Creek Downstream of QEW	12.03 / 12.03	13.87 / 13.87	15.62 / 15.62	31.86 / 31.86
Fourteen Mile Creek Upstream of Diversion	65.98 / 65.98	79.47 / 79.47	93.52 / 93.52	184.10 / 184.10
Fourteen Mile Creek Diversion	- / 2.92	- / 6.28	- / 10.05	- / 16.84
Fourteen Mile Creek Downstream of Diversion	66.03 / 58.74	79.31 / 68.17	93.38 / 77.67	184.10 / 165.60
Fourteen Mile Creek Downstream of QEW	70.61 / 59.61	84.53 / 66.03	99.10 / 72.35	221.60 / 202.40
Fourteen Mile Creek downstream at CNR	78.18 / 69.56	93.07 / 78.29	107.20 / 87.39	256.10 / 254.10
Fourteen Mile Creek at Lake Ontario	77.62 / 69.56	91.94 / 78.37	106.80 / 87.40	267.70 / 266.60

5.2.2 Summary of Scoped Environmental Studies

In addition to the hydrologic and hydraulic technical assessment of the supplemental alternatives, there has been additional ecological field work conducted to address some of the issues cited by Conservation Halton and the MNRF in their review of the Fourteen Mile Creek Flood Mitigation Study (Draft). While it was recognized by the Town and WSP, that a study area-wide ecological study would serve no particular benefit at this stage of the Master Plan, some study of potential areas of impact does contribute to the understanding of ecological value and associated mitigation opportunities in the context of the options currently being considered and also next steps of planning and design. The locations of study which have been discussed with Town staff include the following:

1. Fourteen Mile Creek upstream of North Service Road to the point of the potential diversion to Bronte Creek (would cover both the proposed on-line storage location and water intake to Bronte Creek diversion)
2. Receiving reach in Bronte Creek where flows may potentially be diverted to
3. Diversion alignment from McCraney Creek to Fourteen Mile Creek (north side of railway)

The assessment of ecological resources in these locations has required consideration of both terrestrial (Dougan & Associates; now Dougan Ecology (Dougan)) and aquatic (C. Portt and Associates (C. Portt)) systems. Dougan (NHS) and C. Portt and Associates (Aquatics / Fisheries) have been engaged (ref. reports provided in **Appendix E**). The following provides a summary of the salient findings related to the Aquatic and Terrestrial assessment.

Flow Diversion from Fourteen Mile Creek

Assumptions

1. The footprint of the potential flood diversion intake structure on Fourteen Mile Creek would be located outside of the stream channel, but within the floodplain and the regulated habitat of Redside Dace (meander belt width plus 30 m setbacks).
2. A restriction in the floodplain may be necessary to provide sufficient water depth to divert a portion of flows in excess of the approximately 25 - 50-year storm event.
3. All work will follow the Best Management Practices provided in MNRF (2016).

Assessment

The Endangered Redside Dace and its habitat is protected under the Ontario ESA, and this location is likely considered a Redside Dace stronghold. While the required structural components of the intake will not directly impact the stream channel, regulatory review and approvals will be required for work within the regulated Redside Dace habitat that is riparian to good quality stream habitat. Best efforts should be made to minimize the footprint of the structure and the extent of construction-related disturbances. While rare high flow events will be attenuated, high flows that are important for the maintenance of instream habitats (e.g. sediment flushing, removal of debris jams and beaver dams, etc.) will still occur downstream. **With thoughtful planning and careful implementation and mitigation, this project can be undertaken with minimal impacts to Fourteen Mile Creek and Redside Dace habitat.**

Flow Diversion to Bronte Creek

Assumptions

1. The footprint of the potential flood diversion outlet structure on Bronte Creek would be located outside of the stream channel, but within the floodplain.
2. The diversion of the 25 - 50-year flood peaks from Fourteen Mile Creek (a relatively small system) will amount to a small proportion of the flow in Bronte Creek (a relatively large system).
3. All work will follow appropriate Best Management Practices to minimize impacts to Bronte Creek habitats and species at risk.

Assessment

The Threatened Silver Shiner and the Endangered American Eel, and their habitats, are protected under the Ontario ESA, and both are known to occur in Bronte Creek. While regulatory review and approvals will be required, it is expected that the diversion of 25 - 50-year flood peaks from Fourteen Mile Creek will have minimal impacts upon Bronte Creek.

Fourteen Mile Creek On-line Flood Control Structure

Assumptions

1. The footprint of the potential on-line flood control structure on Fourteen Mile Creek, just upstream from the QEW, will be located outside of the stream channel, but within the floodplain and the regulated habitat of Redside Dace (meander belt width plus 30 m setbacks).
2. Flood control will only target flows in excess of the 25 - 50-year storm events.
3. All work will follow the Best Management Practices provided in MNRF (2016).

Assessment

The Endangered Redside Dace and its habitat is protected under the Ontario ESA, though the instream Redside Dace habitat at this location is considered poor. While the required structural components of the control structure will not directly impact the stream channel, regulatory review and approvals will be required for work within the regulated Redside Dace habitat that is riparian to the instream habitats. Best efforts should be made to minimize the footprint of the structure and the extent of construction-related disturbances. While rare high flow events will be attenuated by this flood control facility, high flows that are important for the maintenance of instream habitats (e.g. sediment flushing, removal of debris jams and beaver dams, etc.) will still occur downstream. **With thoughtful planning and careful implementation and mitigation, this project can be undertaken with minimal impacts to Fourteen Mile Creek and Redside Dace habitat.**

Flow Diversion from McCraney Creek

Assumptions

1. The diversion of the 25 - 50 years flood flows and greater from McCraney Creek would be facilitated by the modification of an existing on-line flood control facility just upstream of Fourth Line.
2. All work will follow appropriate Best Management Practices to minimize impacts to aquatic habitats.

Assessment

The diversion of occasional flood flows from McCraney Creek will likely have little impact upon the already poor habitat and the simple community of resilient fishes that occurs in McCraney Creek.

Flow Diversion Path from McCraney to Fourteen Mile Creek

Assumptions

1. The diversion of the 25 - 50-year flood flows and greater from McCraney Creek to Fourteen Mile Creek will be facilitated by the construction and modification of a connecting ditch from an existing on-line flood control facility on McCraney Creek, to an existing drainage ditch that flows west to Fourteen Mile Creek along the north side of the CNR tracks.
2. The existing ditch along the north side of the CNR tracks will be rehabilitated / reconstructed to provide better flow conveyance and improved aquatic habitat.
3. One Redside Dace was captured in the potential diversion channel in 2005, and therefore it is likely that a field investigation will be required to determine the current status of the fish community and Redside Dace, to guide the treatment of this channel.
4. All work will follow appropriate Best Management Practices to minimize impacts to aquatic habitats and species at risk.

Assessment

The diversion of occasional flood flows from McCraney Creek will likely have a positive effect upon habitat in the existing ditch along the north side of the CNR tracks, because a certain level of channel rehabilitation / reconstruction will initially be required, and the occasional higher flood flows may flush the channel of debris, beaver dams, and accumulated sediments.

Flow Diversion to Fourteen Mile Creek

Assumptions

1. No instream work will be required, because the outlet to Fourteen Mile Creek already exists within the floodplain of Fourteen Mile Creek.
2. The diversion of the 25 - 50-year flood peaks and greater from McCraney Creek (a relatively small system) will amount to a very small proportion of the flow in Fourteen Mile Creek (a relatively large system).
3. All work will follow appropriate Best Management Practices to minimize impacts to Fourteen Mile Creek habitats and species at risk.

Assessment

While regulatory review and approvals will be required, it is expected that the diversion of 25 - 50-year flood peaks and greater from McCraney Creek will have minimal impacts upon Fourteen Mile Creek. It is believed that Redside Dace no longer occur in Fourteen Mile Creek downstream of the potential diversion outlet.

Natural Heritage System Assessment

Dougan & Associates (now Dougan Ecology (Dougan)) conducted field vegetation investigations of the three areas on October 17, 2016, as a high-level screening of each site, with specific focus on understanding ecological community groups, habitat potential and identification of potential SAR. A wildlife screening has been conducted through a background review (ref**. Appendix E**) and has been subsequently followed up with infield observations on October 17, 2016. Based on the background review and field investigations the following has been determined regarding the flood management measures being considered for Fourteen Mile Creek and McCraney Creek (Taplow Creek).

While the details of the proposed flood mitigation works are still forthcoming, it is understood that the potential impacts to natural heritage resources are associated with the footprint caused by construction activities and potential changes to the hydrological regime. Given the flexibility in locating the proposed flood mitigation works and the opportunity for biodiversity enhancements it is anticipated this public infrastructure project can be implemented with negligible net impacts to the terrestrial resources through good design and the utilization of mitigation and compensation measures.

The recommendations for mitigation and compensation are based on assumed sets of activities that could impact the terrestrial natural heritage system. As outlined in Section 4.1 of the Terrestrial Ecology Report by Dougan (ref. **Appendix E**), there are two main sets of activities.

- **Set 1** activities include activities with a tangible footprint on the ground.
- **Set 2** activities result from potential changes in the hydroperiod that may have an effect on plant community response or change habitat suitability characteristics for existing species.

Set 1 activities can be mitigated for during the design phase of the project. When determining design details activities such as clearing, grading or other disruptive processes should be concentrated in areas identified as having lower quality vegetation (i.e. stands of invasive exotics and minimal native vegetation).

It is difficult to mitigate for Set 2 activities in advance of construction. While it is unlikely that changes in the hydroperiod will have a significant negative impact on existing vegetation and wildlife communities, these activities can be mitigated for through developing an adaptive management strategy that incorporates a monitoring period following the completion of the project.

Given that the details of the proposed infrastructure project(s) are preliminary and conceptual in nature, the recommended mitigation and compensation methods cited in the Dougan & Associates (now Dougan Ecology (Dougan)) report are to be used as a guide when developing these details. In summary, the recommendations are to avoid impacts on native species of high quality, direct disruptive activities towards low-quality vegetation, and compensate for negative impacts on vegetation and wildlife communities through replanting, restoring, and monitoring.

Once the details of the proposed infrastructure project(s) become finalized through the next stages of planning and design, it is likely that more detailed field surveys will be required to implement a design with no net negative impacts on the natural heritage features. This natural heritage assessment has provided a characterization of the landscape through desktop and field investigations, with suggestions for mitigating potential impacts on existing natural features. If these recommendations are applied, it is anticipated that potential negative impacts can be avoided, mitigated or compensated for, and the proposed flood control works can proceed without long term risk to the natural heritage resources.

5.2.3 Supplemental Alternative Assessment Summary

Based on the hydrologic / hydraulic, terrestrial and aquatic assessments the following summary of findings has been prepared:

- The Fourteen Mile Creek diversion to Bronte Creek would adequately offset the peak flows diverted from Taplow Creek to Fourteen Mile Creek. The Fourteen Mile Creek diversion would reduce the peak flows for the 2-year to 100-year storm events downstream of the CNR tracks, while marginally reducing the Regional Storm peak flows.
- The Taplow Creek to Fourteen Mile Creek diversion would divert flows for storm events 10-year and lesser frequency up to and including the Regional Storm, resulting in only the Regional Storm peak flows in McCraney Creek being reduced. The McCraney Creek peak flows for the 2-year to 100-year storm events are controlled by Glen Oak Creek.
- Off-line flood storage tanks have been assessed for each creek system. Optimization of the capture potential to increase the available head for most of the

storage tanks, including the Langtry Park Tank, would require some minor grading within the creek's overbank areas to increase the amount of runoff volume captured. The optimized flood storage tanks would not provide significant flow reductions for the 2-year to 100-year storm events, apart from the possible tank at Langtry Park on Fourteen Mile Creek, which would be able to moderately reduce 2-year to 100-year peak flows on Fourteen Mile Creek downstream of the CNR tracks.

— Two of the optimized culvert / embankment crossings provide moderate flow reductions for the 2-year to 100-year storm events for the Fourteen Mile creek system downstream of the QEW and if appropriately stabilized could be considered to provide a moderate level of flood risk reduction.
— The combined alternatives of the two flow diversions, and Langtry Park storage tank, would further reduce flooding risk within both Fourteen Mile Creek for the 25-year to 100-year storm events by 10% to 18%, and maintain a balance in peak flow for the Regional Storm.
— The Taplow Creek flow diversion would reduce flooding risk within the McCraney Creek for the Regional Storm by 12%.
— The scoped fish habitat assessment determined that with careful planning and consideration, each of the alternatives assessed would have minimal impacts to the existing fish habitat, including the Redside Dace Habitat within Fourteen Mile Creek.
— The NHS assessment determined that there are two sets of proposed works (Set 1 – with tangible footprints and Set 2 with potential impacts to hydroperiod). Set 1 works can be mitigated through careful design, implementation and revegetation. Set 2 works would have to be assessed in detail as to how hydroperiods may be impacted and how the impacts can be mitigated through an adaptive management strategy.

5.3 Diversion Alternatives Additional Assessment

Further to meeting with Conservation Halton (CH) and Town of Oakville (Town) on October 30, 2018, the subsequent meeting between WSP (then Wood) and CH staff on November 16, 2018, and further discussion with CH staff on November 19, 2018, CH staff requested WSP (then Wood) to determine the potential impacts resulting from the recommended Fourteen Mile Creek and Taplow Creek Flow Diversion to downstream peak flows and hydrograph volumes within the respective creek systems. CH's primary concern is related to potential impacts to fisheries passage and habitat conditions during the more frequent storm events up to, and including, the 10-year storm. As discussed with CH (ref. October 30, 2018, meeting), the recommended flow diversions will not impact flow conditions for storm events less than a 10-year frequency.

As per CH’s request, WSP prepared a tabular summary of peak flows and estimated hydrograph volumes resulting from the proposed flow diversions from Taplow Creek to Fourteen Mile Creek, and from Fourteen Mile Creek to Bronte Creek. Peak flows and hydrograph volumes have been determined accordingly for both flow diversions and downstream at the CNR crossings of Fourteen Mile Creek and McCraney Creek (confluence of Taplow Creek and Glen Oak Creek).

5.3.1 Fourteen Mile Creek Diversion Assessment

The recommended Fourteen Mile Creek Flow Diversion conceptual plan is included in **Appendix H** (depicted in Figure 9: Fourteen Mile Creek Flow Diversion). A summary of peak flows based on the Fourteen Mile Creek Flow Diversion has been provided in **Table 5.25** herein. As discussed with CH, the flow diversion would not begin to divert flows from Fourteen Mile Creek to Bronte Creek until peak flows reach between the 10-year to 25-year storm frequencies. The diverted flows are estimated to be approximately 4.7% to 11.4 % of existing peak flows, with the diverted Regional Storm peak flow at 9.5% of existing peak flows. Of note, there is a slight reduction in the 2-year and 5-year peak flows immediately downstream of the diversion, which continues downstream to Lake Ontario. This reduction in peak flows is a result of flow attenuation from the overbank grading, or ‘speed bump’, which has been proposed to raise water surface levels locally at the diversion. As part of future detailed study, the conceptual overbank grading could be refined to meet the objective of increasing flood elevations at the diversion and to minimize flow attenuation of the 2-year and 5-year storm flow hydrographs should this be deemed appropriate. In this regard, it may be possible to eliminate flow attenuation during the 2-year event entirely depending on the configuration and footprint of the ‘speed bump’.

As noted in **Table 5.25**, the impacts (benefits) of the proposed diversion are most prevalent immediately downstream of the diversion. Given that this work is intended as an off-setting measure to compensate for the Taplow Creek diversion, the impacts (in terms of flow reduction) downstream of the Fourteen Mile Creek Tributary and main branch confluence are generally minimal (ref. **Table 5.25**).

Table 5.25: Peak Flows (m3/s) in Fourteen Mile Creek with Fourteen Mile Creek Diversion to Bronte Creek In-place (m^3/s)

Location	PCSWMM ID	2	5	10	25	50	100	Regional Storm
Bronte Creek								
Upstream of Bronte Diversion	CJ6988.738	17.95	32.87	44.45	61.72	74.40	87.84	182.00
Diverted Flow to Bronte	C7	0.00	0.00	0.00	2.92	6.29	10.01	17.20
Diverted Flow to Bronte (%)	-	0.0%	0.0%	0.0%	4.7%	8.5%	11.4%	9.5%
Downstream of Bronte Diversion	CJ6894.028	17.91	32.87	44.46	58.74	68.17	77.67	165.60
Downstream of Bronte Diversion (%)	-	99.8%	100.0%	100.0%	95.2%	91.6%	88.4%	91.0%
CNR								
Existing Condition at CNR	J3066.327	22.53	42.66	57.44	78.18	93.07	107.20	256.10
CNR with Diversions	J3066.327	21.22	40.65	54.76	74.27	86.75	99.80	251.80
CNR with Diversions (%)	-	94.2%	95.3%	95.3%	95.0%	93.2%	93.1%	98.3%
Lake Ontario								
Existing Condition at Lake	OF100	24.67	42.70	57.29	77.62	91.94	106.80	267.70
Lake with Diversions	OF100	23.27	40.85	54.79	74.12	86.25	99.56	263.90
Lake with Diversions (%)	-	94.3%	95.7%	95.6%	95.5%	93.8%	93.2%	98.6%

Similar to the peak flows assessment in **Table 5.25**, flow hydrograph volumes have been determined and summarized in **Table 5.26**. The diverted flow hydrograph volumes range from 0.0 (up to 10-year event) to 7.4% for the Regional Storm at the diversion point. Downstream of this point (at CNR and Lake Ontario) the volume difference is less than 1%. The Fourteen Mile Creek 2-year to 100-year and Regional Storm hydrographs have been provided in **Appendix H**. Refer to the PCSWMM IDs within **Table 5.26** for location of hydrographs in **Appendix H.**

Table 5.26: Fourteen Mile Creek Diversion to Bronte Creek Peak Hydrograph Volumes (m^3)

Location	PCSWMM ID	2	5	10	25	50	100	Regional Storm
At Diversion								
Upstream of Bronte Diversion	CJ6988.738	293200	483900	618200	795500	910900	1037000	3534000
Diverted Flow to Bronte	C7	0	0	0	7193	19760	36350	262400
Diverted Flow to Bronte (%)	-	0.0%	0.0%	0.0%	0.9%	2.2%	3.5%	7.4%
Downstream of Bronte Diversion	CJ6894.028	292800	483500	617800	787900	890400	999800	3272000
Downstream of Bronte Diversion (%)	-	99.9%	99.9%	99.9%	99.0%	97.7%	96.4%	92.6%
CNR								
Existing Condition at CNR	J3066.327	511600	819900	1038000	1326000	1512000	1716000	5870000
CNR with Diversions	J3066.327	511800	820000	1038000	1329000	1510000	1707000	5826000
CNR with Diversions (%)	-	100.0%	100.0%	100.0%	100.2%	99.9%	99.5%	99.3%
Lake Ontario								
Existing Condition at Lake	OF100	593300	936100	1179000	1498000	1705000	1932000	6565000
Lake with Diversions	OF100	593400	936100	1179000	1501000	1703000	1923000	6521000
Lake with Diversions (%)	-	100.0%	100.0%	100.0%	100.2%	99.9%	99.5%	99.3%

5.3.2 Taplow Creek Diversion Assessment

The recommended Taplow Creek Flow Diversion is depicted in **Appendix H** (refer to Figure 7 and Figure 8 (Flow Diversion Channel (Taplow Creek to Fourteen Mile Creek)). A summary of peak flows with the Taplow Creek Flow Diversion in-place has been provided in **Table 5.27**. As discussed with CH, the flow diversion would not divert flows from Taplow Creek to Fourteen Mile Creek until approximately the 10-year storm frequency. The diverted peak flows reduce downstream of the Taplow Creek diversion point (to Fourteen Mile Creek), at approximately the 10- to 25-year event frequency, ranging between 0 to 39.2%. Further downstream, on the McCraney Creek, due to timing effects, the peak flows for the 2- to 100-year events remain the same, while the Regional Storm peak reduces by 17% at CNR and 12.4% at Lake Ontario.

Table 5.27: Peak Flows (m^3/s) Taplow / McCraney Creek with Taplow Creek Diversion to Fourteen Mile Creek In-Place

Location	PCSWMM ID	2	5	10	25	50	100	Regional Storm
Taplow Creek at Diversion	CJ183	2.04	3.68	5.20	9.40	11.47	13.39	39.73
Diverted Flow	WMC_DIV	0.00	0.00	0.01	2.42	3.43	4.35	15.59
Diverted Flow (%)	-	0.0%	0.0%	0.2%	25.7%	29.9%	32.5%	39.2%
Taplow Creek Downstream of Diversion	CJ155.7196	1.63	3.57	5.01	6.98	8.04	9.07	24.14
Taplow Creek Downstream of Diversion (%)	-	80.1%	96.9%	96.4%	74.2%	70.1%	67.7%	60.8%
Existing McCraney Creek at CNR	J2295.416	13.50	20.31	24.62	30.99	35.63	40.52	82.44
McCraney Creek at CNR with Diversion	J2295.416	13.50	20.31	24.62	30.99	35.63	40.52	68.43
McCraney Creek at CNR with Diversion (%)	-	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	83.0%
Existing McCraney Creek at Lake	OF400	17.99	28.65	35.42	43.80	50.12	55.97	110.20
McCraney Creek at Lake with Diversion	OF400	17.99	28.65	35.42	43.80	50.12	55.97	96.55
McCraney Creek at Lake with Diversion (%)	-	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	87.6%

Similar to the peak flow assessment in **Table 5.27**, flow hydrograph volumes have been determined and summarized in **Table 5.28**. The diverted flow hydrograph volumes range from 0% at the 10-year to 29.4% at the Regional Storm immediately at the diversion point. Further downstream (on McCraney Creek at the CNR) the volumetric change is 0% at the 10-year up to 13.8% at the Regional Storm, and at Lake Ontario the amount reduces to 10.3% for the Regional Storm event. The Taplow Creek and McCraney Creek 2-year to 100-year and Regional Storm hydrographs have been provided in **Appendix H**. Refer to the PCSWMM IDs within **Table 5.28** for location of hydrographs in **Appendix H**.

Table 5.28: McCraney Creek Diversion to Fourteen Mile Creek Hydrograph Volumes (m^3)

Location	PCSWMM ID	2	5	10	25	50	100	Regional Storm
Taplow Creek at Diversion	CJ183	63970	98470	123300	158400	181600	207200	746000
Diverted Flow	WMC_DIV	0	0	5.94	10040	18160	27820	219200
Diverted Flow (%)	-	0.0%	0.0%	0.0%	6.3%	10.0%	13.4%	29.4%
Taplow Creek Downstream of Diversion	CJ155.7196	63970	98420	123300	148400	163400	179400	526600
Taplow Creek Downstream of Diversion (%)	-	100.0%	99.9%	100.0%	93.7%	90.0%	86.6%	70.6%
Existing McCraney Creek at CNR	J2295.416	162900	242600	298900	372600	419400	471700	1582000
McCraney Creek at CNR with Diversion	J2295.416	162900	242600	298900	363400	400800	444800	1363000
McCraney Creek at CNR with Diversion (%)	-	100.0%	100.0%	100.0%	97.5%	95.6%	94.3%	86.2%
Existing McCraney Creek at Lake	OF400	219200	327700	404300	504600	568700	640300	2145000
McCraney Creek at Lake with Diversion	OF400	219200	327700	404300	494500	550600	612500	1925000
McCraney Creek at Lake with Diversion (%)	-	100.0%	100.0%	100.0%	98.0%	96.8%	95.7%	89.7%

5.3.3 Summary of Diversion Assessments

Fourteen Mile Creek Diversion

The recommended Fourteen Mile Creek Diversion to the Bronte Creek would not divert flows until between the 10-year and 25-year storm events. A slight (local) reduction in peak flows for the 2-year to 5-year storm events, have been shown to occur as a result of the flow attenuation from the overbank grading or ‘speed bump’ proposed to locally increase water surface elevations at the flow diversion. It is expected that subsequent studies could develop refined grading in the creek overbank areas for the ‘speed bump’, resulting in no reduction in the 2-year peak flow and a minimized reduction in the 5-year peak flow.

Downstream of the confluence of the main Fourteen Mile Creek and the Fourteen Mile Creek branch along the CNR tracks, with the Taplow Creek Diversion contributing flow, the flow hydrographs volumes range from 99.5% to 100% of existing levels. The results for the Fourteen Mile Creek Diversion indicate that the flow hydrographs and associated peak flows on Fourteen Mile Creek would remain unaffected for storm events up to the 10-year event. For storm events with a frequency of 25-years or less, the Taplow Creek Diversion would limit the reduction to peak flows to less than 7% from the CNR to Lake Ontario.

Taplow Creek Diversion

The recommended Taplow Creek Diversion to Fourteen Mile Creek would be in effect for flows above the 10-year storm event. The flow diversion would not reduce the McCraney Creek 2-year to 100-year peak flows due to timing effects, the Regional Storm peak flow at the CNR tracks would be reduced by 17% from existing conditions. The McCraney Creek hydrographs volume would range from 94.3% to 97.5% for the 25-year to 100-year storm events, with the Regional Storm at 86.2% depending on downstream location.

5.3.3.1 Overall Summary

As documented in previous sections, the Fourteen Mile Creek Diversion and Taplow Creek Diversion would not impact peak flows up to, and including, the 10-year storm event generally considered a threshold for environmental and stream forming conditions. There are limited reductions in peak flows for storm events between the 25-year to 100-year event, with the Regional Storm incurring the greatest reduction in peak flows on McCraney Creek.

WSP has determined the impact to peak flows and flow hydrographs as per CH’s request, demonstrating that there would be little to no impact of peak flows for the 2- to 10-year storm events on both Fourteen Mile Creek and McCraney Creek and that fisheries passage and habitat, including stream morphology, should not be adversely impacted by the recommended flow diversions.

5.3.4 Additional Fourteen Mile Creek Diversion Assessment

Through further discussion with CH, conceptual level analysis was requested to determine potential impact in downstream flows and corresponding floodplain risk and Regulation within the Bronte Creek system as well as potential increase to the Regulated floodplain immediately upstream of the diversion inlet.

In order to carryout this analysis hydrograph information on Bronte Creek is required. , it was noted that CH staff were unable to provide the Bronte Creek Regional Storm hydrograph at the QEW and the Bronte Creek hydrologic model, however CH staff provided excerpts from a report titled “Bronte Creek Floodplain Mapping Study” prepared by Proctor & Redfern Limited (date unknown). Included in the excerpt are the Bronte Creek watershed drainage area plan and Regional Storm peak flows just upstream of the QEW (refer to **Appendix H**).

Based on the foregoing, and to accommodate CH’s request, WSP suggested using a surrogate Regional Storm hydrograph to represent the Bronte Creek hydrograph near the QEW. Specifically, WSP recommended the Sixteen Mile Creek watershed as a surrogate due to the similar drainage areas of the respective watersheds and available data. The following outlines the details of the surrogate hydrograph assessment.

5.3.4.1 Hydrologic Assessment

Bronte Creek

Excerpts from the Proctor & Redfern report are provided in **Appendix H** for reference. Contained within the excerpts are a Subcatchment plan (Figure 3 of the Proctor & Redfern report) of the Bronte Creek watershed and associated Subcatchment data (i.e. drainage area, peak flows, etc.). As indicated on Figure 3 (Proctor & Redfern), the downstream end of Subcatchment 11 (Node 41) is within the vicinity of the QEW, and given the information available in the excerpts, is also nearest to the location where the proposed Fourteen Mile Creek division would enter the Bronte Creek system. The drainage area to Node 41 reported in Table 1B is 29,759 ha (114.9 mi^2) and the Regional Storm peak flow reported in Table 2 at this location is 886.3 m^3/s (31,300 ft^3/s).

Sixteen Mile Creek

The Subwatershed Study (SWS) for the South Milton Urban Expansion Area is currently on-going supporting the secondary planning stages of development in the south Milton area. As part of the SWS, an HSP-F hydrologic model has been developed, which represents the entire Sixteen Mile Creek watershed. The Sixteen Mile Creek watershed generally extends from the middle of Halton Hills to Lake Ontario, with a total drainage area of approximately 45,700 ha. Upstream of Highway 407, the watershed is generally split into a West Branch (17,666 ha) and an East Branch (23,919 ha). Downstream of Highway 407, the West and East Branches combine into the Main Branch until its termination at Lake Ontario (ref. Figure 4.1.8 “South Milton Uban Expansion Area – Subcatchment Plan”, attached in **Appendix H**). The South Milton Urban Expansion

Area Subcatchment plan and model schematic are provided in **Appendix H** for reference.

It should be noted that the Sixteen Mile Creek system upstream of Highway 407 consists of multiple branches / tributaries that generally drain in a parallel pattern. It is well understood that creek systems with parallel drainage conditions tend to produce peak flows that are more coincident at confluences, thus exhibiting shorter time to peak durations than creek systems that lack parallel tributaries and are more linear with less tributaries.

Fourteen Mile Creek Diversion

The recommended Fourteen Mile Creek diversion (refer to Figure 9 (“Fourteen Mile Creek Flow Diversion”, attached in **Appendix H**) is outlined within the Technical Memorandum, titled “Fourteen Mile Creek / McCraney Creek, Supplemental Alternative Assessment, Town of Oakville” prepared by Wood, dated June 28, 2018 (the content of which has been integrated into the current summary report). The Fourteen Mile Creek diversion is proposed along with a diversion from Taplow Creek to Fourteen Mile Creek.

The Fourteen Mile Creek diversion is intended to offset Regional Storm flows diverted by the Taplow Creek to Fourteen Mile Creek diversion. The Regional Storm hydrograph of the Fourteen Mile Creek diversion is provided in **Appendix H**. The diverted peak flow, as per the results presented on the hydrograph, is approximately 16.5 m^3/s.

5.3.4.2 Hydrograph Comparison

Given the comparable drainage areas between Bronte Creek at Node 41, south of Upper Middle Road (29,759 ha) and the East Branch of Sixteen Mile Creek (23,919 ha), it has been advanced that the East Branch would be an appropriate surrogate of the Bronte Creek hydrologic function upstream of the QEW for the Regional Storm (i.e. comparable timing and peak flow). As such, the East Branch hydrograph has been selected for the surrogate assessment.

The Regional Storm hydrograph for the Sixteen Mile East Branch is provided in **Appendix H**. The Regional Storm peak flow on the East Branch is 512 m^3/s. The Regional Storm peak flow at Bronte Creek (Node 41) reported in Table 2 of the Proctor & Redfern report is approximately 886.3 m^3/s (31,300 ft^3/s). In order to determine the impact to the Regional Storm peak flow within the Bronte Creek system resulting from the Fourteen Mile Creek diversion, the Sixteen Mile Creek East Branch hydrograph has been adjusted by a factor of 1.73 (886.3 m^3/s divided by 512 m^3/s), such that the peak flow of the adjusted surrogate hydrograph equals 886.3 m^3/s. The adjusted East Branch Regional Storm hydrograph (i.e. surrogate hydrograph) has been overlaid with the Fourteen Mile Creek diversion hydrograph to compare the timing and peak flows from the respective creek systems and to determine the potential effects of the diverted flow on the receiving Bronte Creek System (ref. **Appendix H**).

As depicted in **Appendix H**, the timing of the peak flow from the Fourteen Mile Creek diversion and the surrogate Sixteen Mile Creek East Branch hydrograph are slightly coincident such that the effect of the Fourteen Mile Creek diversion results in a slight increase in the Regional Storm peak flow for the surrogate East Branch hydrograph. The increase in the Regional Storm peak flow is from 886.3 m^3/s to 900 m^3/s, approximately 13.7 m^3/s (1.5%).

The increase in the Regional Storm peak flow of 1.5% is considered to be minor (i.e. 13.7 m^3/s out of 886.3 m^3/s). It should also be noted that the surrogate hydrograph assessment is limited in its applicability, due to the hydrologic function of the Bronte Creek system in comparison to the East Branch of the Sixteen Mile Creek system. As previously outlined, the Sixteen Mile Creek consists of multiple branches / tributaries that generally drain in a parallel pattern, while the Bronte Creek system has a more linear drainage pattern. As such, the actual Regional Storm hydrograph for Bronte Creek is expected to have a larger delay in peak flow timing than what is represented by the surrogate East Branch hydrograph. The delay in peak flow timing would be expected to be sufficiently significant to further offset the impact from the Fourteen Mile Creek diversion hence would have little to no influence on the Regional Storm peak flow within the Bronte Creek system, upstream of the QEW.

5.3.4.3 Summary

Based on the foregoing assessment, the following summary has been prepared:

1. The Sixteen Mile Creek East Branch Regional Storm hydrograph is considered to be an approximate surrogate of the Bronte Creek hydrograph.
2. The impact from the Fourteen Mile Creek diversion on the surrogate East Branch hydrograph is considered to be minimal (<1.5%).
3. The actual Bronte Creek hydrograph is expected to have a larger delay in peak flow timing than what is represented by the surrogate Sixteen Mile Creek East Branch hydrograph.
4. The impact from the Fourteen Mile Creek diversion is expected to have little to no influence on the Regional Storm peak flow within the Bronte Creek system.

5.4 System Versus Local Alternatives Assessment

5.4.1 Overview

Subsequent to the foregoing, a cost benefit assessment is provided for the recommended preliminary flood mitigation alternatives which include:

1. Fourteen Mile Creek Flow Piped Diversion to Bronte Creek
2. Taplow Creek Flow Diversion to Fourteen Mile Creek, including the Spur Line Culvert Upgrade
3. Langtry Park Off-Line Storage Tank, north of QEW
4. McCraney Creek at Lakeshore Road Culvert Upgrades
5. McCraney Creek at CNR Culvert Upgrades
6. Flood Protection Berms

An initial cost-benefit analysis was provided in the draft Fourteen Mile Creek and McCraney Creek Flood Mitigation Scenario Cost Benefit Assessment memo on July 11, 2019, and last revised on February 21, 2020. This analysis considered the implementation of all flood mitigation alternatives combined. After further discussion with the Town, it was necessary to modify the cost-benefit approach to compare and contrast the preliminary preferred alternatives more discreetly based on Local vs. System Wide approach.

Therefore, the Cost-Benefit (C/B) assessments conducted herein has been used in the decision-making process for the recommended alternatives and supersede all previous cost-benefit analyses. The Local C/B assessment would reflect the physical condition representing the scenario with all bridges / culverts and flood protection berms in-place, with no flow modifications due to diversions or flood storage, while the System-wide C/B assessment would reflect the physical condition representing the scenario with the flood storage and diversions in-place, but none of the other local improvements.

The recommended preliminary flood mitigation alternatives (refer to drawings included in **Appendix H**) have been separated into two scenarios are as follows:

Local Flood Mitigation Approach (Scenario 1)

1 McCraney Creek at Lakeshore Road Culvert Upgrades
2 McCraney Creek at CNR Culvert Upgrades
3 Flood Protection Berming

System wide Flood Mitigation Approach (Scenario 2)

1 Fourteen Mile Creek Flow Piped Diversion to Bronte Creek
2 Taplow Creek Flow Diversion to Fourteen Mile Creek
3 Langtry Park Off-line Storage Tank, north of QEW

5.4.2 Scenarios

Scenarios have been assessed relative to existing conditions to ascertain the potential flood risk reduction benefits. Accordingly, WSP has completed a review of the proposed 10-year, 100-year, and Regional Storm floodlines for Fourteen Mile Creek and McCraney Creek, south of the QEW highway (south of the 14 Mile Creek flow diversion) with the subject works in-place. Through comparison of the existing and proposed (with the combined flood mitigation alternatives) 10-year, 100-year, and Regional Storm floodlines, WSP has determined the number of properties and buildings that would be expected to be at a "reduced" flood risk or "removed" from the floodplain, based upon each specified storm event.

5.4.3 Flood Risk Reduction

Properties and buildings that would be at a "reduced" flood risk represent those where the depth of flooding resulting from the respective storm event, would be reduced under proposed conditions, however the respective property or building would remain flooded. Properties and buildings that are "removed" from the floodplains are those that are no longer flooded by the respective storm event with the flood mitigation alternatives implemented. It should be noted that if a building is within the floodplain for a given storm event, that building would be considered flooded, however, the property parcel of that building would not be considered flooded since counting the property parcel as flooded would result in double counting of the same land area and would over-estimate the flood risk. **Tables 5.29** to **5.34** provide an approximate estimate of the number properties and buildings at flood risk for the 10-year, 100-year and Regional Storm events. It should be noted that at-risk locations in spill zones have not been directly quantified, and as such, have been disregarded from the location tally in **Tables 5.29** to **5.34**. With that said, if for a spill location under a given scenario, the simulated water surface elevation is found to be lower than the existing conditions, those locations have been indicated on the drawings provided in **Appendix H**. Based on the proposed simulated water surface elevations and the difference to the existing conditions simulated water surface elevations, these locations could potentially have reduced spill or a contained spill resulting in reduced flood risk. However, a detailed 2D hydraulic modelling would be required in order to assess the spills and quantify the level of flood risk more accurately.

Tables 5.29 to 5.34 also provide a summary of the properties and buildings that are expected to be at either a "reduced" flood risk or are "removed" from the 10-year, 100-year and Regional Storm floodplain under proposed flooding conditions for each flood protection scenario. In cases where a building floods under the existing conditions but the risk of flooding is lowered to the property parcel and the building is removed from flooding under a specific flood mitigation alternative scenario, those cases are denoted in parentheses. A more detailed benefit breakdown (ref**. Appendix H**) and proposed floodlines (ref. **Appendix H**) for both scenarios for the 10-year, 100-year and Regional Storm events has been provided.

Table 5.29: Approximate Number of Properties at Flood Risk (10-year Storm Event)

Creek System	Existing	Reduced		Removed		Total Flood Risk Reduction for Creek System	
		Local	System	Local	System	Local	System
Fourteen Mile Creek	92	23	73	4	3	27	76
McCraney Creek	97	5	0	7	0	12	0
Total Flood Risk Reduction for Alternatives						39	76

Table 5.30: Approximate Number of Buildings at Flood Risk (10-year Storm Event)

Creek System	Existing	Reduced		Removed		Total Flood Risk Reduction for Creek System	
		Local	System	Local	System	Local	System
Fourteen Mile Creek	12	0	8	0	0(1)	0	9
McCraney Creek	48	0	0	0	0	0	0
Total Flood Risk Reduction for Alternatives						0	9

Table 5.31: Approximate Number of Properties at Flood %Risk (100-year Storm Event)

Creek System	Existing	Reduced		Removed		Total Flood Risk Reduction for Creek System	
		Local	System	Local	System	Local	System
Fourteen Mile Creek	130	30	80	15	19	45	99
McCraney Creek	96	2	4	12	0	14	4
Total Flood Risk Reduction for Alternatives						59	103

Table 5.32: Approximate Number of Buildings at Flood Risk (100-year Storm Event)

Creek System	Existing	Reduced		Removed		Total Flood Risk Reduction for Creek System	
		Local	System	Local	System	Local	System
Fourteen Mile Creek	46	1	17	1(1)	1(15)	3	35
McCraney Creek	86	14	16	3	0	17	16
Total Flood Risk Reduction for Alternatives						20	51

Table 5.33: Approximate Number of Properties at Flood Risk (Regional Storm Event)

Creek System	Existing	Reduced		Removed		Total Flood Risk Reduction for Creek System	
		Local	System	Local	System	Local	System
Fourteen Mile Creek	132	27	70	21	0	48	70
McCraney Creek	131	5	46	14	20	19	66
Total Flood Risk Reduction for Alternatives						67	136

Table 5.34: Approximate Number of Buildings at Flood Risk (Regional Storm Event)

Creek System	Existing	Reduced		Removed		Total Flood Risk Reduction for Creek System	
		Local	System	Local	System	Local	System
Fourteen Mile Creek	140	0	57	13(15)	0(1)	28	58
McCraney Creek	149	9	70	3(3)	0(8)	15	78
Total Flood Risk Reduction for Alternatives						43	136

"Based on the information in **Tables 5.29 to 5.34**, Scenario 1 (Local Flood Mitigation Alternatives) offers the most elimination of flood risk by removing 35 properties and 34 buildings from the Regional Storm event floodplain. This is achieved predominately through the introduction of flood protection berms designed to accommodate Regional Storm flood elevations at proposed locations. Culvert upgrades provide localized flood reduction immediately upstream of the improved crossing. However, based on the simulated floodlines the culvert upgrade along McCraney Creek at the CNR track only shows a small reduction in flooding depth upstream of the crossing and does not remove any upstream buildings or properties from the floodplain, as opposed to the proposed culvert upgrade along McCraney Creek at Lakeshore Road, which shows greater benefit with removal of flood risk for four (4) buildings.

Under Scenario 2 (System Wide Flood Mitigation Alternatives), flood risk for properties and buildings is reduced, though the difference in existing versus proposed simulated floodlines is negligible. This scenario removes 20 properties and 9 buildings from the Regional Storm event floodplain, resulting in less overall flood risk removal compared to Scenario 1.

5.4.4 Flood Mitigation Alternatives Costing

Cost estimates have been prepared for the recommended preliminary flood mitigation alternatives (ref. **Appendix H**). A brief overview of the items accounted for in each recommended alternative is as follows:

Fourteen Mile Creek Flow Diversion to Bronte Creek

— Based on Micro-tunnelling operations

— Storm sewer pipes, maintenance chambers and inlet and outlet headwalls

Taplow Creek Flow Diversion to Fourteen Mile Creek / Spur Line Culvert Upgrade

— Excavation / grading
— Channel restoration with topsoil and seeding
— Spur line culvert upgrade

Langtry Park off-line Storage Tank

— Inlet / outlet pipes and headwalls
— Tank excavation, cast-in-place construction, appurtenances

The preliminary cost estimates apply to construction costs only, and account for compensation of labour, equipment and material to complete the construction works associated with each recommended alternative. Costs for dewatering, mobilization, and erosion and sedimentation controls have also been included for each alternative. A summary of the cost estimate is provided in **Table 5.35**, and a detailed breakdown of each recommended alternative is attached to in **Appendix I**.

A 15% contingency has also been considered in the cost estimate excluding engineering and design costs, ongoing maintenance, quality control inspections, site access and additional infrastructure costs, site preparation costs, and land and legal costs. The contingency funds include contingency for change orders, utility relocation costs, costs related to public relations and outreach and insurance costs. In case of berms, the contingency amount has been raised to 25% since it would require more effort towards public relations and outreach.

The general size of the berm is between approximately 60 to 150 cm high (depending on the simulated water surface elevations at a given location) with 3:1 side slope. The detailed layout (including width of a top bench and grades) could be prepared during detailed design. In addition, berming has not been considered for implementation for properties surrounded by flooding, since both the rear and front lot would require berms. Areas incurring flood depths more than 1.5 m at the property boundary were typically not considered due to poor constructability, feasibility and the resulting natural heritage impacts. The maximum allowable berm height considered was 1.5 m, with berms of greater height being considered infeasible from a construction point of view.

The flood protection berms have been configured to maximize local flood protection to properties and buildings for a specific storm event (Regional Storm event). Impacts on trees and riparian storage have been considered while maximizing the local flood protection benefits. Providing berms only for flooded homes would reduce the loss of riparian storage, which would have to be mitigated through grading. Similarly, potential vegetation and habitat loss would have to be mitigated through re-vegetation and habitat restoration. Flood protection berms that only prevent flooding of property have been identified and discussed more in detail in **Section 5.4.4**.

It should be noted that typically for flood protection berms, costs associated with the land acquisition and transfer contribute to the majority of total budget. Hence, the proposed locations of the berms have been prioritized on town owned lands except for a few locations where adhering to such criteria meant it would negatively impact the feasibility and constructability of the berms.

Recommended preliminary culvert upgrades along Fourteen Mile Creek and McCraney Creek consist of the following:

— McCraney Creek CNR crossing sized at 15m by 9.0 span by 2.4 m rise

— McCraney Creek Lakeshore Road crossing 24 m by 14.64 m by 3.96 m

The construction cost estimates for the culvert upgrades are considered to be preliminary and conservative and will require further assessment at the preliminary design stage.

Costs for localized flood protection berming have also been considered. Construction costs have currently only included berm fill and landscaping costs. Additional costs for the creek works that may be required to offset the loss of riparian flood storage, have not been included, as additional assessment of creek works would be required. Construction cost estimates do not include construction access, sediment and erosion controls, property fencing and other property alterations. Costing for the localized flood protection berming and other flood mitigation alternatives has been provided in **Table 5.35**.

Table 5.35: Recommended Alternative Preliminary Cost Summary

Recommended Alternative	Total Cost ($M)	With Contingency ($M)
Scenario 1 – Local flood mitigation alternatives assessment		
Culvert Upgrade at Lakeshore Road along McCraney Creek	5.34	6.15
Culvert Upgrade at CNR Track, McCraney Creek	$17.4M	$20M
Berming and Landscaping at Glen Oaks and Main Branch[1]	1.48M	1.85M
Scenario 1 Total	**$24.22**	**28**
Scenario 2 – System Wide flood mitigation alternatives assessment		
Fourteen Mile Creek Flow Diversion to Bronte Creek	$19.97 M	$22.97 M
Taplow Creek Flow Diversion to Fourteen Mile Creek / Spur Line Culvert Upgrade	$4.34 M	$4.99 M
Langtry Park Off-line Storage Tank	$26.85 M	$30.88 M
Scenario 2 Total	**$51.16 M**	**$58.84 M**

[1]: To compensate for the under estimation of the berming costs, a 25% contingency has been applied to account for the other costs.

5.4.5 Cost Benefit Summary

The flood risk reduction benefits associated with each Scenario, as well as associated costing have been summarized in **Table 5.36**. The flood risk reduction benefit is inclusive of the total number of properties and buildings with either "reduced" risk or are "removed" from risk within the Fourteen Mile Creek and McCraney Creek systems.

Table 5.36: Estimated Total Cost (with Contingency) and Flood Risk Benefits (Reduced and Removed Risk – Scenarios 1 and 2)

Scenario	Cost	Storm Event	Properties	Buildings
Scenario 1 Local Approach	**28M**	10-Year	39	0
		100-Year	59	20
		Regional	67	43
Scenario 2 System wide Approach	**59M**	10-Year	76	9
		100-Year	103	51
		Regional	136	136

'Reduced' flood risk refers to a decrease in water surface elevations (WSE), but the extent of this reduction has not been quantified. This reduction does not necessarily indicate a significant change in flood risk. For example, although the System Wide Approach shows a greater reduction in flood risk for both properties and buildings compared to the Local Approach, the implemented system-wide improvements are negligible when floodlines are mapped against existing conditions.

Furthermore, to accurately quantify the reduced flood risk for properties and buildings, it would be necessary to determine the flood depth at each affected property, assess the building type and location of openings and other condition according to Provincial building codes, and apply the Provincial Damage curves. In the absence of this detailed analysis, a more simplified approach using Provincial damage curves has been utilized. Under this more simplified approach, the Town and WSP has assumed the building flood risk removal tallies (for the Regional Storm) to be the most relevant, hence have divided the total scenario costs by the number of relieved buildings for a basic comparison (ref. **Table 5.37**).

Note that Scenario 1 in **Table 5.36** has been revised to exclude the culvert upgrade at the CNR Track. Since the culvert is owned by Metrolinx, any upgrades, improvements, or replacements fall outside the town's jurisdiction. Additionally, due to the high cost and minimal reduction in flooding, the culvert upgrade is not recommended for further consideration.

Table 5.37: Unitary Costs per Building by Scenario

Scenario	Cost ($M)	Total Number of Buildings Removed From Flooding (Regional Storm)	Cost per Building ($k)
Scenario 1: Local Approach	**8M[1]**	34	235
Scenario 2: System wide Approach	**$59 M**	9	6,560

[1]: Removes the CNR Culvert Upgrade from Total Costs

The unitary costs per building are considerably lower for Scenario 1 with local improvements and would provide more value for the mitigated flood risk for the given cost of implementation. It should also be noted that while the cost estimates provided in

Table 5.37 are fairly high-level, the observation that Scenario 1 provides better value is independent of the accuracy of the cost estimates provided.

Within Scenario 1, it has been demonstrated that berming offers a good return on investment. However, since the works impact private property, 100% participation of landowners at each proposed berming location is necessary for the works to be implementable and effective. Additionally, several other challenges have been identified for implementing localized flood protection berms effectively. The following list provides an overview of considerations that must be addressed through detailed design, through consultation with Conservation Halton:

- Berm locations are prioritized on town-owned lands, except in a few cases where excluding work on private lands would affect the feasibility and constructability of the berms.
- Obtain appropriate permissions from private landowners before proceeding with berm construction, both for berms entirely on private property and for those adjacent to private property, where grading may extend into private land.
- Berms help mitigate flood risk but may not reduce the Regulatory floodplain limit based on the applicable Provincial Technical Guidance (MNR, 2002, as enforced by Conservation Halton). Further discussion with Conservation Halton is recommended to determine if there are any circumstances under which they could be credited. In some jurisdictions flood protection landforms (larger berms with potential additional design considerations and support analyses) have been credited for Regulatory Floodplain benefit.
- Berming locations and configurations are to be optimized based on maximum flood protection for the Regional Storm event and reduced impact on trees.
- With input from Conservation Halton, compensatory work within the floodplain may be required to limit the impact on flood storage and water surface elevations.
- Berms will require ongoing maintenance from both the town and landowners, including inspections, repairs, and vegetation management.

A detailed list of properties which are expected to be affected by the berm construction is provided in **Appendix H**) A total of 21 properties would be affected along Glen Oaks Creek, and a further 78 properties would be affected along Fourteen Mile Creek.

5.5 Preferred Alternatives

The Cost Benefit Assessment resulted in the Localized Flood Mitigation Scenario (Scenario 1) being preferred along with the associated alternatives for Fourteen Mile Creek and McCraney Creek.

5.5.1 Both Systems

Low Impact Development (LID)

This study considered green infrastructure (GI) in the form of Low Impact Development (LID) as an option to reduce flood risk. However, LID is not intended to handle severe floods like a 100-year storm as a standalone solution. Instead, integrating GI practices (such as LIDs) during detailed design offers environmental benefits.

Berming

Berming along McCraney Creek and 14 Mile Creek will require full participation from landowners. It may impact property use and require significant tree removal. Notably, some of the identified berming areas coincide with future creek erosion mitigation projects (as identified in the Town's 2021 Creek Inventory and Assessment). Therefore, it is recommended to assess berming feasibility during the erosion mitigation works, considering that the area will need to be disturbed at that time.

The proposed berming works have a total estimated cost of $1.85M with 25% contingency included.

McCraney Creek at Lakeshore Road Crossing Upgrade

As per the hydraulic modelling analyses completed, the preferred alternative includes upgrading (increasing) the hydraulic capacity of the structure along McCraney Creek at Lakeshore Road. The current crossing size is a 5.4 m wide by 2.9 m high concrete box; the proposed upgrade would be a 14.64 m wide by 3.96 m high bridge structure. The proposed culvert upgrade has a total estimated cost of $6.15M including a 15% contingency.

6 NEXT STEPS AND IMPLEMENTATION

6.1 Prioritization

The preferred alternatives for mitigating the flood risk at various identified sites on Fourteen Mile and McCraney Creeks, as presented herein, can be advanced to the next stages of planning and design. Prioritization of the alternatives would be established by the Town as part of overall flood risk mitigation works and stormwater network works being considered through the lens of the Rainwater Management Financial Plan (RMFP). The Rainwater Management Financial Plan (RMFP) takes a comprehensive approach to integrate the state of good repair and increase resiliency of the town's stormwater network based on various studies and assessments completed to date. The multi-phase RMFP will deliver a financing plan that provides an all-inclusive approach to planning and implementing stormwater-related infrastructure renewal and improvement projects into the future.

6.2 Implementation

Implementation of each of the alternatives has been considered based on the Municipal Class EA process and associated project schedules (ref. **Table ES.6**) and whether each alternative will or will not require a more detailed Class Environmental Assessment. For the recommended culvert upgrade and the proposed flood protection berming, this Class EA has fulfilled the Municipal Class EA process and associated assessment requirements.

The Town will implement LIDs within the Fourteen Mile Creek and McCraney Creek Subwatershed areas, as town projects occur with the appropriate conditions (e.g. groundwater depths, soil conditions, availability of space, etc.) and in accordance with the Town of Oakville's Stormwater Management Master Plan and Town of Oakville Climate Action Plan

7 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions have been prepared based on the findings of this study:

1 The Town of Oakville initiated a comprehensive flood risk assessment for Fourteen Mile and McCraney Creeks, identifying flood-prone areas and developing a prioritized flood mitigation plan. The study followed the Municipal Class Environmental Assessment Process of which, the first two phases have been completed.

2 The study has utilized hydrologic and hydraulic modelling techniques, specifically employing the PCSWMM and HEC-RAS models, to accurately assess flood risks and develop detailed floodplain maps for various modelling scenarios.

3 The PCSWMM hydrologic model has been developed and calibrated using observed rainfall and flow data, to determine peak flows for the 2-year to 100-year and Regional Storm (Hurricane Hazel) events for both creek systems.

4 The HEC-RAS hydraulic model has been prepared for both Fourteen Mile and McCraney Creeks, using topographic mapping and field reconnaissance to validate the model against observed flows and high-water levels. This detailed modelling has been used for determining flood elevations and assessing various flood mitigation alternatives.

5 A detailed evaluation of flood mitigation alternatives has been conducted, leading to the selection of local improvements such as Low Impact Development (LIDs), a hydraulic crossing (culvert) upgrade, and berming as the preferred approach due to cost-effectiveness and targeted risk reduction.

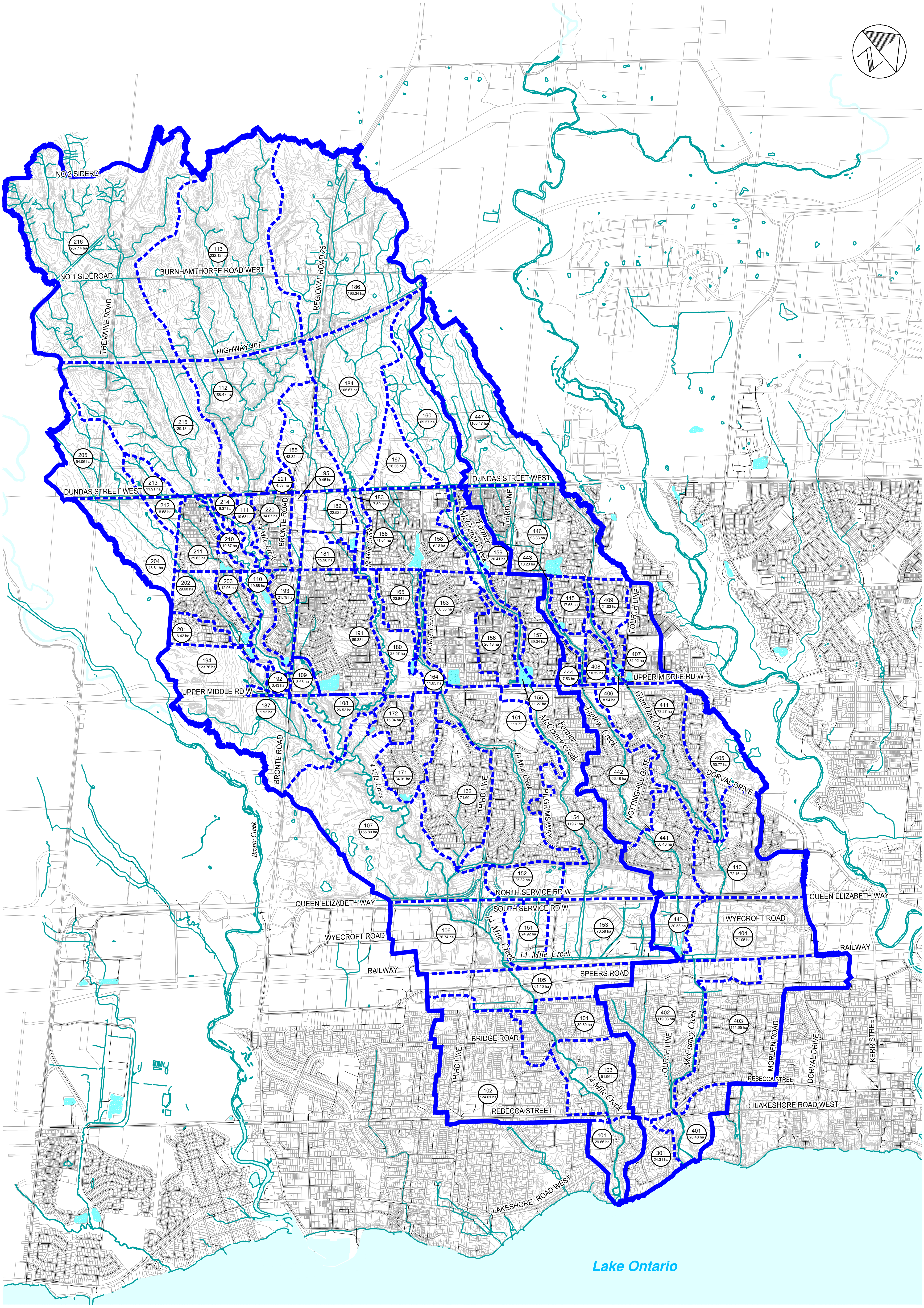
6 Non-structural alternatives including regulation, creek maintenance, emergency preparedness, and flood forecasting, were considered and are recognized as current being implemented. Land acquisition was excluded due to significant social and economic implications.

7 The preferred alternatives offer flood risk reduction benefits per dollar spent for properties and buildings, particularly during Regional Storm events, with a total cost of approximately $8m million, including contingency.

8 Subject to approval, the preferred alternatives will advance to planning and design stages, integrated into the Town's Rainwater Management Financial Plan to ensure sustainable stormwater infrastructure improvements.

9 Collaboration with property owners is essential for implementing flood protection measures on private lands, ensuring community support and participation in flood risk reduction efforts.

Drawings



SCALE VALID ONLY FOR 24"x36" VERSION

FOURTEEN MILE CREEK McCRANEY CREEK SYSTEM FLOOD MITIGATION OPPORTUNITIES STUDY TOWN OF OAKVILLE	SUBCATCHMENT BOUNDARY PLAN	wsp	Scale 1:17500 (0 200 400 800) Consultant File No. TP111031 Drawing No. 1

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