Mud Creek Cumulative Impact Study

Study Report

May 5, 2020

Prepared for:

City of Ottawa

Prepared by:

Stantec Consulting Ltd.

and

JTB Environmental Systems

Revision	Description	Author		Quality Check		Independent Review	
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1	Draft	J. Sidhu	2020/03/25	S. D’Aoust	2020/03/25		
2	Report	J. Sidhu	2020/03/25	S.D’Aoust	2020/04/27	J.Beebe	2020/04/27
3	Report	J. Sidhu	2020/03/25	S.D’Aoust	2020/05/05	J.Beebe	2020/04/27

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Executive Summary

Mud Creek is a tributary of Green’s Creek which collects drainage from about 1750 hectares of agricultural and suburban land in the Blackburn Hamlet/Orléans area of the City of Ottawa. Historical land use alterations and land development within the Mud Creek watershed has led to erosion of stream bed and bank materials as evidenced by stream bank instabilities. While stormwater management facilities have been incorporated within the residential developments, these have been designed to mitigate against peak flow increases and do not address increases in runoff volumes or runoff flows which are sustained over longer periods and are at the root of the erosion problems.

The purpose of this study is to complete a cumulative impacts assessment for upper Mud Creek whereby the potential impacts of foreseeable public and private developments are considered. The goal is to recommend stormwater management design criteria for future development that will mitigate to the extent possible the resulting impacts on Mud Creek. Where stormwater management alone may not be sufficient, recommendations for in-stream works will be made.

The study is following Schedule ‘B’ of the Municipal Class Environmental Assessment Process and includes public and review agency consultation, an evaluation of alternatives, an assessment of potential environmental effects of the proposed improvements, and identification of reasonable measures to mitigate any potential adverse impacts.

The study involved establishing baseline conditions within Mud Creek for relevant hydrologic and hydraulic parameters. This was undertaken with the help of a calibrated hydrodynamic model which was later updated to reflect planned development. The model was used to simulate and compare projected changes in stream flow conditions. A geomorphic assessment established the erosion thresholds for the stream bed and bank material encountered along the upper portion of Mud Creek. This, together with the projected flow regime, allowed the City to establish expected changes in erosion associated with the future development.

Results indicate a potential for significant increases in both peak discharges and runoff volumes during infrequent events in the future. Simulations of a continuous 25-year period indicate the potential for up to a 22-fold increase in erosion threshold exceedance hours in the future for the Mud Creek section above the escarpment (downstream of Navan Road). Such increases are in the order of 40% further downstream, near Renaud Rd. The net increase in exceedance hours between existing and future conditions below the escarpment is lower since the channel substrate is finer than the upstream creek section and the erosion threshold is easily exceeded even under existing conditions.

Mitigation measures investigated as part of this study included:

1. Stormwater management (SWM) measures to reduce the intensity and duration of peak stream flows:
    a. The opportunity to upgrade existing end of pipe stormwater management facilities (ponds) in an effort to further attenuate peak runoff from flows.

    b. The possibility of implementing low impact development (LID) stormwater management measures at the source.

2. In-stream works along the upper sections of Mud Creek to improve the resilience of the creek bed and banks. Two approaches were considered including:
    a. Restoration concepts previously identified by the NCC (Groupe Rousseau Lefebvre and JTBES, 2014) and predicated on the use of natural channel design strategies to expand the floodplain and create natural resilience to the system. The approach requires expansion of the creek footprint in strategic locations and is used to absorb some excess energy.
    b. Channel reinforcement by proving a layer of less erodible materials to protect the underlying finer creek substrate.

A review of SWM facility upgrades revealed that an opportunity for expansion may only be present for the southernmost (EUC 'Pond 3') SWM facility. However, modeling of an expansion of the facility did not show any significant benefit in reducing erosion potential within Mud Creek.

In Ottawa, the potential LID options available for implementation are often constrained by subsurface conditions. These include low permeability soils, sensitive clays, high groundwater conditions and shallow bedrock. Nonetheless, an evaluation of LID effectiveness was completed, which indicated that moderate LID application (retain 5 mm of rainfall) over approximately 250 ha of future development has the potential to reduce the duration of exceedance of the erosion threshold discharges in the order of 20% when compared to future uncontrolled conditions for the creek section above the escarpment. The expected reductions are much smaller (~2.5%) below the escarpment owing to the finer bed and bank material.

Therefore, while the opportunistic implementation of LID stormwater management measures is recommended, these are expected to provide limited benefit with respect to mitigating in-stream erosion especially below the escarpment. Therefore, the development of the alternative solutions required consideration of in-stream measures.

Excluding the do-nothing or baseline alternative, three (3) alternative solutions were developed:

- Channel Reconfiguration: Opportunistic implementation of low impact development stormwater management measures in combination with five (5) channel reconfiguration projects.
- Channel Reinforcement: Opportunistic implementation of low impact development stormwater management measures in combination with reinforcement of approximately 2,850 m of channel.
- Hybrid Solution: Opportunistic implementation of low impact development stormwater management measures along with four (4) channel reconfiguration projects combined with reinforcement of approximately 1,800 m of channel.

The Class D opinion of probable costs for the various in-stream works was prepared and are summarized in **Table E-1**. This opinion considers capital costs along with City prescribed allowances and project contingency.

Table E-1: Summary of Opinion of Probable Costs

Description	Channel Reconfiguration	Channel Reinforcement	Hybrid
Capital Cost	$2.87M	$1.73M	$3.08M
Allowances (incl. Engineering)	$1.20M	$0.73M	$1.30M
Contingency	$1.63M	$0.98M	$1.75M
Total Cost	**$5.70M**	**$3.43M**	**$6.13M**

The evaluation of the alternative solutions considered technical, socio-cultural, natural environment and economic criteria and the resulting evaluation is summarized in **Table E-2** .

Table E-2: Evaluation Summary

Alternative Solution	Preferred	Overall		By Individual Categories							
				Technical		Socio-Cultural		Natural Environment		Economy	
		Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score
Do Nothing	No	4	1.75	4	0.47	4	0.28	1	0.50	1	0.50
Channel Reconfiguration	No	3	1.91	3	0.53	1	0.69	1	0.50	3	0.19
Channel Reinforcement	No	2	1.92	1	0.67	3	0.56	4	0.38	2	0.32
Hybrid	Yes	1	2.00	2	0.64	1	0.69	1	0.50	4	0.17

The hybrid alternative is recommended as the preferred alternative. As illustrated in **Figure E-1**, the hybrid solution includes a combination of restoration measures in four locations in the study area with channel reinforcement for about 1800m of the creek in the lower and upper channel reaches in the study area. Where land to create a more active floodplain is available, channel reconfiguration is recommended whereas in areas where land is not available, channel reinforcement is recommended. Implementation of these in-stream works will undoubtedly impact some adjacent riparian vegetation and will necessitate some restoration including tree planting. If necessary, studies/work will be prioritized for the creek sections with the most susceptible (finer) bed and bank materials.

Implementation of the preferred alternative, specifically the in-stream measures, is expected to result in short-term environmental impacts that will require mitigation. The anticipated impacts include disruption of fish and wildlife in Mud Creek and its riparian area and the loss of riparian vegetation. Detailed mitigation measures will be developed during future design stages of the project, intended to fulfill all regulatory permitting requirements.

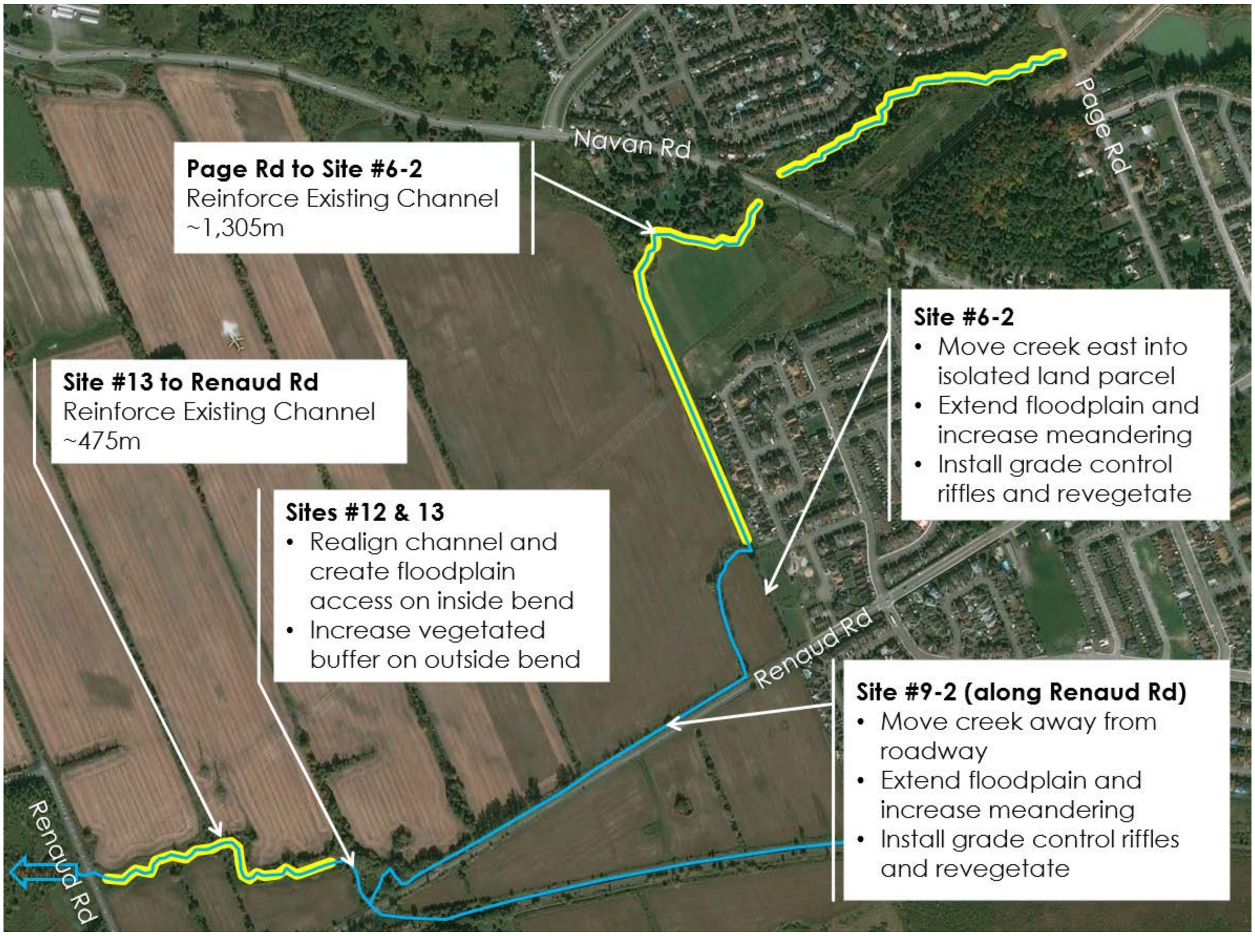

Figure E-1: Recommended In-Stream Works

Abbreviations

CDP	Community Design Plan
CIS	Cumulative Impact Study
Dstor	Detention Storage
D10, D50 & D90	10th percentile, median and 90th percentile substrate diameter by weight
EUC	East Urban Community
EMC	Event Mean Concentration
HGL	Hydraulic Grade Line
LID	Low Impact Development
MCEA	Municipal Class Environmental Assessment
MDP	Master Drainage Plan
MECP	Ministry of the Environment, Conservation and Parks
MOECC	Ministry of the Environment and Climate Change (name of Ministry prior to MECP)
MUC	Mixed Use Centre
NCC	National Capital Commission
OPC	Opinion of Probable Cost
ROW	Right-of-Way
RVCA	Rideau Valley Conservation Authority
RVCT	Runoff Volume Control Target
SWM	Stormwater Management
TP	Total Phosphorus
TSS	Total Suspended Solids

1 INTRODUCTION

Mud Creek is a tributary to Green's Creek and has been the topic of extensive study and analysis by a variety of agencies in recent years. Specifically, these studies have focused on establishing and understanding the current and future state of bank stability and rates of erosion due to the increase in storm runoff resulting from historical land use alterations and land development within the watershed (JTB Environmental Systems Inc., 2011) (RVCA, 2012) (Douglas Associates and JTBES, 2013) (JTB Environmental Systems Inc., 2013). While a portion of the developed lands within the watershed have employed stormwater management (SWM), this has typically been limited to peak flow control (post-to-pre), the intent of which is based on the concept that it is the capacity of the downstream watercourse which is the limiting design criteria. As highlighted by many background studies, the erosion caused by increased runoff from developed (impervious) lands has been detrimental to the stability of the watercourse, and it is therefore the erosion caused by increased runoff volumes which has become the limiting design criteria.

2 STUDY OBJECTIVES

The purpose of this study is to complete a cumulative impacts assessment for the upper portion of the Mud Creek subwatershed based upon the current Official Plan land use, including the implementation of all identified City projects for the foreseeable future. Based upon this assessment, design criteria for all future development (in particular stormwater management criteria for the East Urban Community Mixed Use Centre (EUC MUC)) and City projects are to be developed that will mitigate to the extent possible the resulting impacts on Mud Creek. Where SWM alone may be insufficient, recommended off-site/in-stream works are to be identified.

The study will be limited to the reaches of Mud Creek upstream of Renaud Road, and north of the abandoned rail line and includes areas that will be diverted from McKinnon's Creek to Mud Creek. Refer to **Figure 2-1** .

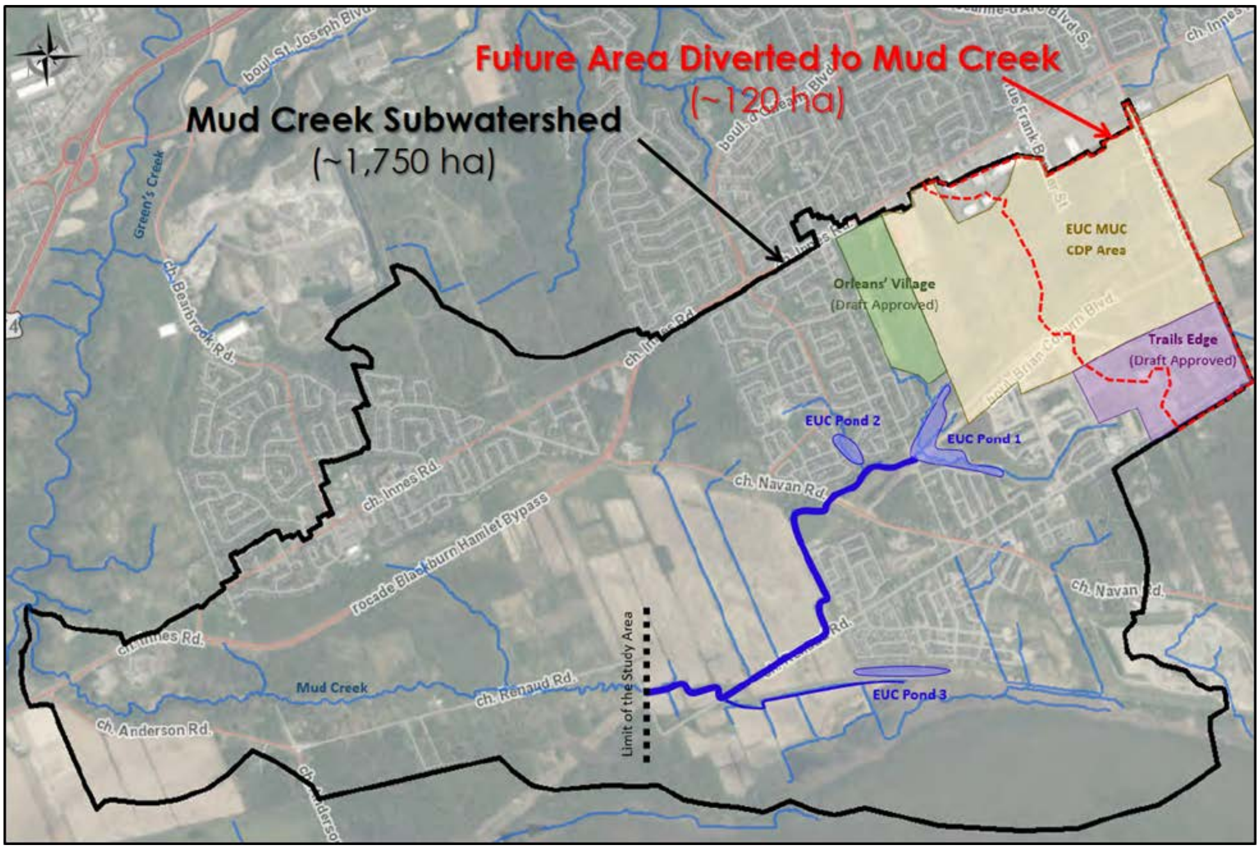

Figure 2-1: Mud Creek Subwatershed Study Area

3 STUDY APPROACH

The following approach was adopted to complete this cumulative impact study:

- Establishing water quantity and quality baseline conditions within the subwatershed. This included developing a hydrologic/hydraulic model of the subwatershed using information from other existing calibrated models and studies. The baseline conditions model included water quality features to account for pollutant build-up, wash-off, and typical pollutant concentrations for urban stormwater runoff.
- Identifying existing erosion thresholds through a geomorphic assessment to establish baseline conditions to which proposed development scenarios were compared.
- Updating the existing conditions model to create a future conditions model to represent ultimate build-out conditions using drainage area and land use assumptions and information available from previous modelling and/or City development and land use plans. This model was used as the base and adjusted as necessary to suit and assess each impact mitigation scenario (see below) from both a water quantity and quality perspective and compared against existing conditions to examine their respective benefits.
- Developing a hydraulic model to prepare preliminary mapping of the 2-yr and 100-yr flooding extents using available base mapping information, including LiDAR.
- Developing impact mitigation alternatives which may be composed of stormwater management measures within the existing or future development areas and/or structural changes to the creek to accommodate the expected hydrological changes within the catchment.
- Selecting SWM criteria and identifying and evaluating the opportunity to implement runoff volume controls / low impact development measures to reduce or mitigate the impact of existing and future urbanization on erosion conditions in Mud Creek.
- Completing a geomorphological assessment of each scenario. This included assessing the impacts of each scenario on Mud Creek compared to existing erosion thresholds, and to provide recommendations for in-stream works, if required.
- Evaluating each scenario on the benefit provided toward mitigating development impacts on Mud Creek, considering criteria such as volume and flow reduction benefits, associated costs, feasibility and opportunity for phasing.
- Selecting a preferred solution upon which recommendations on SWM design criteria for future developments and City projects were made and preparing preliminary flooding extents to confirm the preferred solution does not result in changes to flood levels impacting private property.
- An associated opinion of probable cost and implementation plan was then developed for the preferred scenario

This approach is documented in further detail in the subsequent sections of this report.

To be consistent with past studies mandated by the NCC and the City, the reaches described in this report will be as illustrated in **Figure 3-1**. The reaches were delimited based on creek substrate type and restoration opportunities / constraints.

Figure 3-1: Mud Creek Reaches through Study Area

3.1 MCEA PROCESS

As described herein, this study follows Schedule 'B' of the "Municipal Class Environmental Assessment" and involves the evaluation of a combination of stormwater management and in-stream measures to address cumulative impacts on Mud Creek specifically bed and bank erosion. The Class EA process includes public and review agency consultation, an evaluation of alternatives, an assessment of potential environmental effects of the proposed improvements, and identification of reasonable measures to mitigate any potential adverse impacts.

A Notice of Study Commencement and Online Information Session was published in the Ottawa Citizen on November 1, 2019. An on-line information session was hosted on the City of Ottawa website from

November 1, 2019 to December 2, 2019. A copy of the Notice of Commencement, the website and the on-line posters can be found in **Appendix A**.

Following Planning Committee and City Council approvals, the next steps in the MCEA process is to post this Class EA Report for a 30-day public review period. This is expected to take place in Summer 2020. Project implementation, starting with preliminary design, is expected to be initiated in 2021 and construction commencing 2022/2023.

4 BASELINE CONDITIONS

4.1 EXISTING STUDIES / MODEL CONVERSION

The Mud Creek subwatershed has been the subject of previous hydrologic modelling and geomorphic assessment due to significant erosion occurring within the watercourse. Increased development and rainfall intensities are contributing to increased volume and flow rate within the creek. This study was initiated to examine opportunities for implementation of stormwater volume reduction measures combined with creek restoration or stabilization work to mitigate existing and future erosion.

Previous hydrologic modelling for the Mud Creek subwatershed was completed using SWMHYMO modelling software (JFSA, 2014). For this study, it was decided to rebuild the previous SWMHYMO model in a PCSWMM model as it would provide a better platform for the evaluation of volume reduction measures. The original SWMHYMO modelling was completed to reflect 2011 conditions. To reflect changes to "existing conditions" since 2011, the model was updated to reflect 2014 development conditions to allow for calibration to 2014 flow monitoring data.

HECRAS modelling completed for Mud Creek was imported into the PCSWMM model to provide creek geometry, including junctions, channels and outfalls. This geometry was modified with a series of transformations and scale factors, as well as modifications to the overall layout, while maintaining the existing segment lengths. For the completion of the preliminary flooding extents, the channel geometry was supplemented with cross-section information derived from Light Detection and Ranging (LIDAR) mapping. The model conversion and build/calibration is documented in further detail in the *Mud Creek Initial Conversion of JFSA SWMHYMO Modelling* (refer to **Appendix B**) and *Mud Creek PCSWMM Existing Conditions Model Build and Calibration* (refer to **Appendix C**) and Flooding Extents Analysis (refer to **Appendix D**) technical memos prepared by Stantec.

4.2 WATER QUANTITY / EROSION

JTB Environmental Systems Inc. was tasked to determine erosion thresholds for the upper sections of Mud Creek upstream of Renaud Road (JTB Environmental Systems Inc., 2019). In-situ erosion thresholds were determined using a device that shoots a jet of water at a bank or bed location and measures, over time, the displacement of sediment. Through resolving the relationship between displacement and applied force over time, it is possible to determine the strength (in this case shearing strength) of the material. The benefit of this approach is it accounts for cohesive strength of a mass of sediment, whereas other standard measures which require removal of sediment and mechanical separation of grain size patterns result in a loss of cohesive strength and by doing so, give a completely different result.

The calibrated hydrologic model was used as the basis for establishing existing flows within Mud Creek and the basis for developing a future conditions model (refer to **Section 5**). The streamflow series from a 25-year continuous simulation period (1975 - 2000) were used in combination with the in-situ erosion thresholds to determine and compare the total hours where the erosion threshold discharges are exceeded (A.K.A. exceedance hours) for three different particle sizes (D10, D50 and D90 respectively for the 10th percentile, median and 90th percentile substrate diameter) at 3 representative locations along the creek.

Refer to **Table 4-1** for a summary of critical flows and estimated exceedance hours at representative locations. These values establish a relative baseline against which future conditions and potential alternative mitigation measures will be compared (refer to **Section 5**).

Table 4-1: Exceedance Hours under Existing (2014) Conditions

Location	Parameters	Particle Sizes		
		D10	D50	D90
J7855 (D/S Page)	Qcrit (m^3/sec)	0.005	0.186	0.993
	Existing Conditions (hrs)	96,900	710	13
J7267 (D/S Navan)	Qcrit (m^3/sec)	0.005	0.186	0.993
	Existing Conditions (hrs)	101,200	4,130	150
J5463 (at Confluence w/ South Tributary)	Qcrit (m^3/sec)	0.005	0.017	0.023
	Existing Conditions (hrs)	116,200	103,900	101,400

4.3 WATER QUALITY

The approach for modelling water quality in the Mud Creek subwatershed model was derived from the Pinecrest Creek CIS (JFSA, 2016) and supplemented by information in the Eastern Subwatersheds study report (Morrison Hershfield, 2018). A total of five (5) pollutants, including total suspended solids (TSS), total phosphorus (TP), copper (Cu), zinc (Zn), and E. Coli, were included in the model using an event mean concentration (EMC) approach. The attributes and wash-off parameters, as summarized in **Table 4-2**, were defined in the model for each pollutant by land use type. Further details on how water quality was defined and applied in the model is documented in **Appendix E**.

There are three existing stormwater management facilities (‘SWM Ponds’) located in the study area that provide varying degrees of quantity control and extended detention for quality and erosion control: SWM Pond 1 – located east (upstream) of Pagé Road; SWM Pond 2 – located on the north side of Mud Creek, about 250m upstream of Navan Road; and SWM Pond 3 – located south of Renaud Road near the abandoned railway corridor, that outlets to a tributary of Mud Creek, about 800m upstream of Renaud Road.

Pollutant removal was also applied at the three SWM Ponds to simulate quality control provided by each pond. The removal parameters for SWM Pond 1) and SWM Pond 3 were derived from the *International Stormwater Best Management Practices (BMP) Database* (Wright Water Engineers Inc. and Geosyntec Consultants, 2016). SWM Pond 2 provides approximately 75% of the treatment volume necessary to meet Ministry of the Environment, Conservation and Parks (MECP) basic protection level. Pollutant removal values for this pond have therefore been assumed to be equivalent to 75% of the international BMP values. Final pond treatment values are summarized in **Table 4-3**.

Table 4-2: Land Use Pollutant Wash-off Parameters

Land Use	Pollutant				
	Total Suspended Solids (mg/L)	Total Phosphorus (mg/L)	Copper (mg/L)	Zinc (mg/L)	E. Coli (#/100mL)
Agriculture	400	0.35	0.002	0.018	30,000
Commercial	150	0.20	0.020	0.030	30,000
Forest	50	0.12	0.001	0.011	100
Industrial	100	0.35	0.025	0.200	2,000
Institutional	50	0.18	0.015	0.113	8,500
Open Space	70	0.10	0.010	0.020	5,000
Residential	150	0.20	0.025	0.080	40,000
Street	150	0.20	0.020	0.030	40,000

Table 4-3: SWM Facility Pollutant Removal Parameters

SWM Facility	Pollutant Removal (%)				
	Total Suspended Solids	Total Phosphorus	Copper	Zinc	E. Coli
Pond 1	80	52	57	64	70
Pond 2	50	13	33	41	48
Pond 3	80	52	57	64	70

The model was run using rainfall data from the Avalon rain gauge for the period of May 2011 to November 2011. This aligned with the period of water quality monitoring data presented in the Eastern Subwatersheds report to which the modelled Mud Creek results were compared. Pollutant concentrations at seven (7) locations are summarized in **Table 4-4**. The modelled existing conditions pollutant concentrations along Mud Creek generally are comparable to those observed in the surrounding creeks during wet weather flow periods. The E. Coli concentrations presented in the Pinecrest Creek CIS report are approximately one order of magnitude higher than those presented in the Eastern Subwatersheds report which may be indicative of more conservative water quality parameters used in the Pinecrest study and this study. Therefore, modelled E. Coli concentrations in Mud Creek may be overestimated. However, the EMC approach and modelling parameters used in the model are overall considered to provide acceptable estimates of wet weather pollutant concentrations in Mud Creek.

Table 4-4: Pollutant Concentration Comparison (Existing Conditions vs. Monitored Data)

Location	Total Suspended Solids (mg/L)	Total Phosphorus (mg/L)	Copper (mg/L)	Zinc (mg/L)	E. Coli (#/100mL)
Green's Creek*	317	0.198	0.015	0.037	804
Bilberry Creek*	742	0.332	0.023	0.066	4,741
Taylor Creek**	104	0.087	0.014	0.036	6,237
Voyageur Creek*	239	0.268	0.023	0.066	3,446
Mud Creek – U/S of Navan Rd Culvert (Node J7300)***	79	0.164	0.015	0.046	18,640
Mud Creek – Confluence with South Branch near Renaud Rd (Node J5463)***	198	0.219	0.019	0.046	20,710
Mud Creek – D/S of Innes Rd Culvert (Node J600)***	260	0.529	0.049	0.118	20,640

*Observed pollutant concentrations from on 2010 monitoring data.

**Observed pollutant concentrations from on 2011 monitoring data.

***Modelled pollutant concentrations extracted from 2014 Existing Conditions model for Mud Creek.

4.4 Preliminary Flooding Analysis

The current version of the future conditions PCSWMM model was used as a base for this analysis. Additional cross-sections derived from Light Detection and Ranging (LiDAR) were added to the model at an interval of approximately one every 100 m. Existing sections were also extended where necessary to enable a preliminary estimate of the 100-year water levels for Mud Creek from the Renaud Road, upstream to Pagé Road. Channel and overland roughness parameters were derived from a desktop review using available reports, and/or Google Earth / Street View.

The updated model was run for the following design events to estimate a range of flooding extents along this section of Mud Creek:

1) 2-yr 24-hr SCS;
2) 100-yr 12-hr SCS;
3) 100-yr 24-hr SCS with Pond P1 outflow = 11.2 m^3/s (i.e. Stantec's PCSWMM model) – considered to be a conservative estimate of discharges; and
4) 100-yr 24-hr SCS with Pond P1 outflow = 6.7 m^3/s (i.e. DSEL design, added as a uniform inflow).

The maximum hydraulic grade line (HGL) results for all four design event scenarios were extracted at each model node along the subject section of Mud Creek (refer to attached Table 1). Of the 100-yr events, the 24-hr SCS scenario with a Pond P1 outflow of 11.2 m^3/s yielded the highest maximum water levels, while the 24-hr SCS scenario with a Pond P1 outflow of 6.7 m^3/s yielded the lowest maximum water levels. The estimated flooding extents for these two scenarios were mapped using the LiDAR data. These extents are shown in **Figure 4-1**, **Figure 4-2** and **Figure 4-3**.

In general, preliminary analysis of the extent of flooding under 100-year flow conditions shows that flooding is contained within publicly owned land – with the exception of the short section of channel that crosses private property, just downstream of Navan Road. In this section of channel, the preliminary analysis shows the 100-year flow is contained within the top-of-bank. For additional details of the preliminary flooding analysis please see **Appendix D**.

Stantec

Legend

- Model Node

Model Conduit

- Mud Creek
- Storm Sewer

Flooding Extents for 100-yr 24-hr Design Event

- P1 Outflow = 6.7 cms
- P1 Outflow = 11.2 cms
- Property Parcel

N

0 100 200 metres

(At original document size of 11x17)
1:6,000

Notes
1. Coordinate System: City of Ottawa

Ottawa, ON

Client/Project
City of Ottawa
Mud Creek Cumulative Impact Study
Scope Change #4 - Floodplain Analysis

Figure No.
4-1

Title
Flooding Extents - Navan to Renaud Roads)

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Stantec

Legend

- Model Node

Model Conduit

- Mud Creek
- Storm Sewer

Flooding Extents for 100-yr 24-hr Design Event

- P1 Outflow = 6.7 cms
- P1 Outflow = 11.2 cms
- Property Parcel

N

0 30 60 metres

(At original document size of 11x17)
1:2,000

Notes
1. Coordinate System: City of Ottawa

Ottawa, ON

Client/Project
City of Ottawa
Mud Creek Cumulative Impact Study
Scope Change #4 - Floodplain Analysis

Figure No.
4-2

Title
Flooding Extents near Whispering Winds Way

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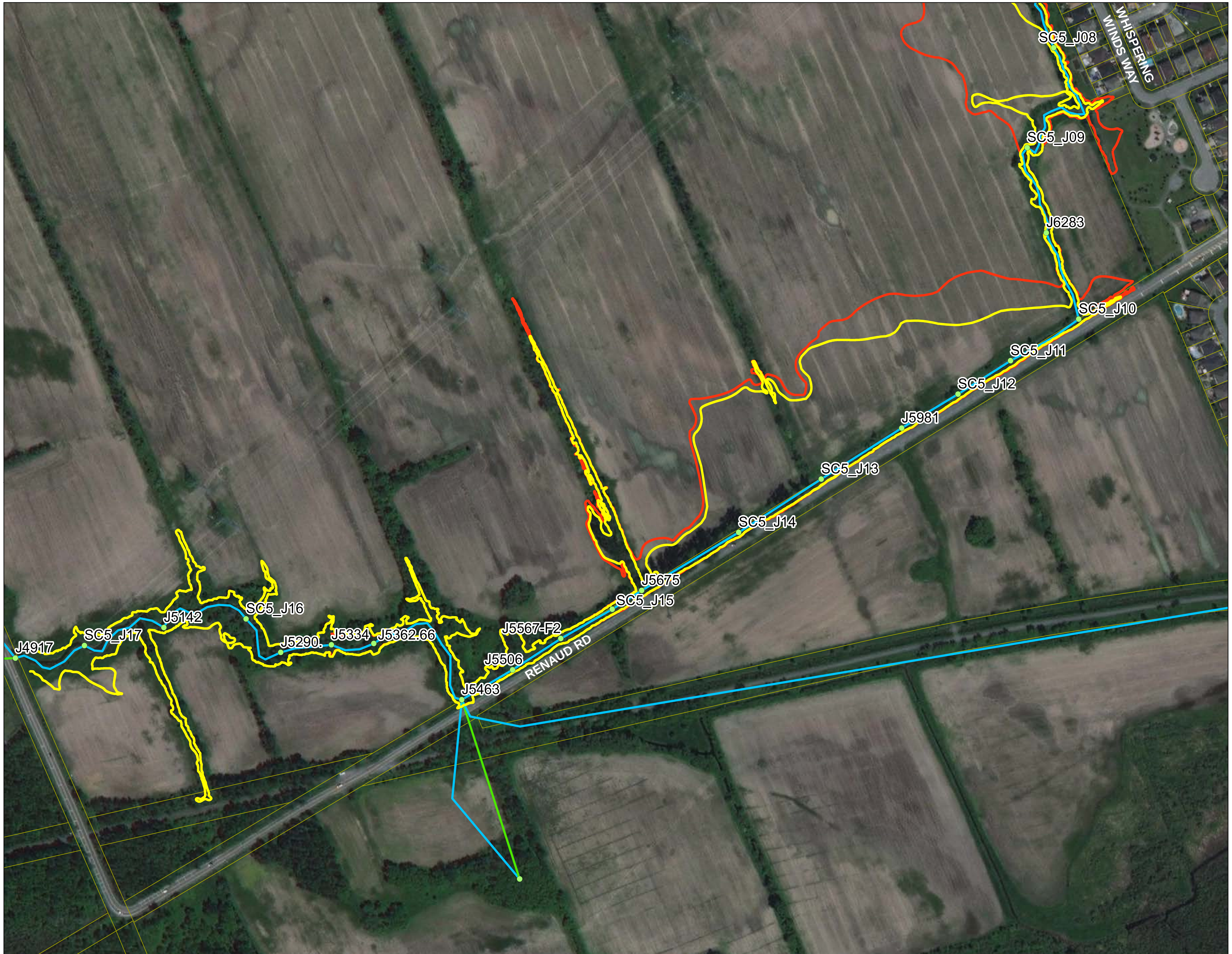

Stantec

Legend

- Model Node

Model Conduit

- Mud Creek
- Storm Sewer

Flooding Extents for 100-yr 24-hr Design Event

- P1 Outflow = 6.7 cms
- P1 Outflow = 11.2 cms
- Property Parcel

N

0 70 140 metres
(At original document size of 11x17)
1:4,000

Notes
1. Coordinate System: City of Ottawa

Ottawa, ON

Client/Project
City of Ottawa
Mud Creek Cumulative Impact Study
Scope Change #4 - Floodplain Analysis

Figure No.
4-3

Title
Flooding Extents along Renaud Road

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5 FUTURE CONDITIONS

5.1 FUTURE CONDITIONS MODEL

The 2014 existing conditions model was updated to represent future build-out conditions. This included revising the creek's tributary area to reflect the October 2017 East Urban Community (EUC) Mixed Use Centre (MUC) Community Design Plan (CDP) and proposed development of the Ashcroft Eastboro subdivision. The CDP development area, which extends past the existing Mud Creek subwatershed boundary to Mer Bleue Road as shown in **Figure 5-1**, will drain to Mud Creek via SWM Pond 1. Trunk sewers (i.e. 750 mm diameter or larger) in the CDP area, as well as existing developed areas, were added to the model to better represent the routing and hydraulics that will be present once the land is developed. Where this information indicated a change in discharge location from existing conditions, major system components were added as necessary to represent anticipated overland drainage.

Several roadway and transitway development projects are also anticipated within the Mud Creek study area. These are shown in **Figure 5-2** and include the proposed Chapel Hill Park and Ride. The proposed SWM design for the park and ride as developed and modelled by Stantec (Stantec, 2018), including all minor and major system components, was incorporated into the Mud Creek future conditions model.

David Schaeffer Engineering Limited (DSEL) is recommending the expansion of SWM Pond 1 to control discharge from the EUC MUC CDP area. Modifications to the stage-storage and stage-discharge design characteristics of SWM Pond 1 have been subject to a number of design iterations. The design characteristics used in the Mud Creek CIS future conditions analysis was derived from March 27, 2018, as provided by DSEL. A number of design iterations have occurred since, however, the modifications were deemed to be minor in nature. The future Functional Design and Detailed Design of the Mud Creek improvements will be coordinated with the Detailed Design of the SWM Pond 1 design characteristics . The stage-storage curve for Pond 2 was also modified to improve representation of the SWM facility in the model. No modifications were made to Pond 3.

The CDP includes a snow disposal facility whose discharge is pumped from the facility to Pond 1. To simulate the facility's forcemain discharge, a baseflow was added to the Pond.

Further details on the future conditions model build is documented in **Appendix F**.

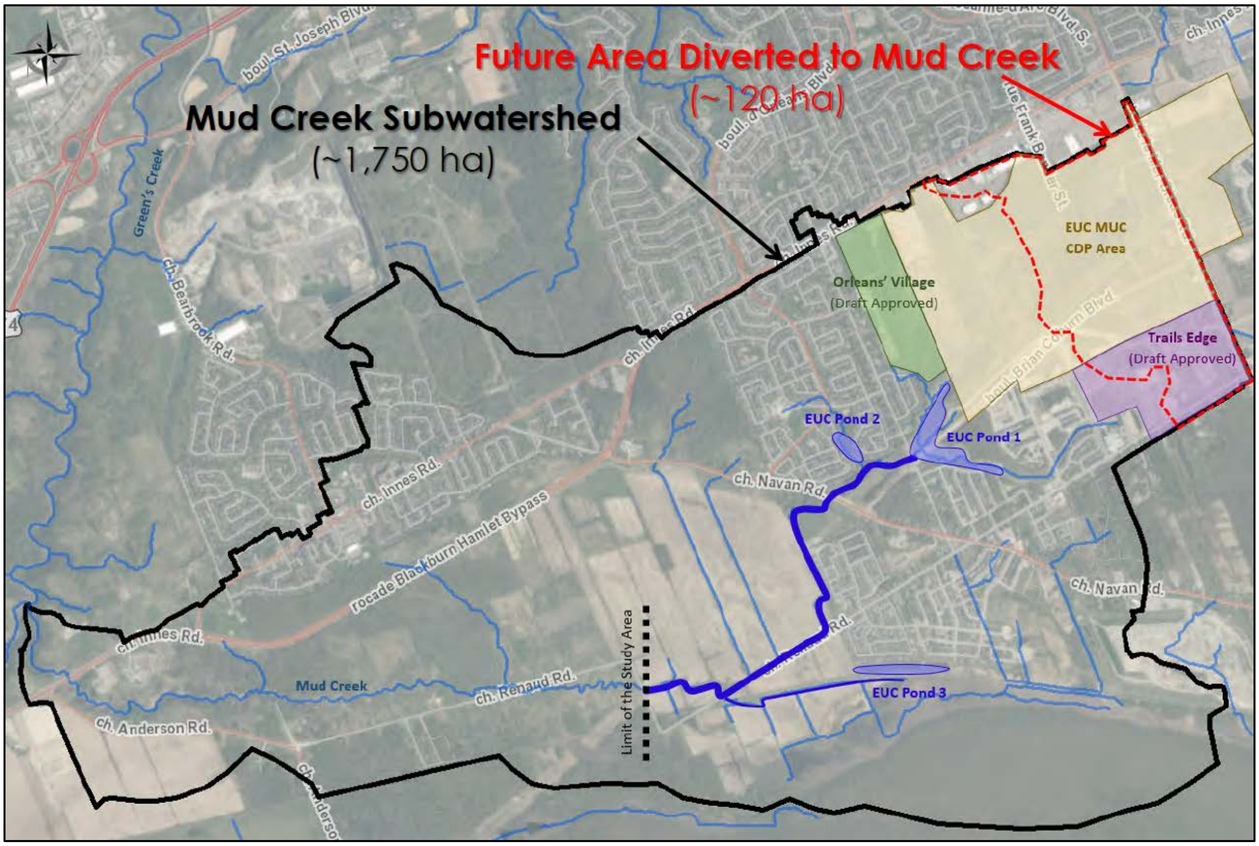
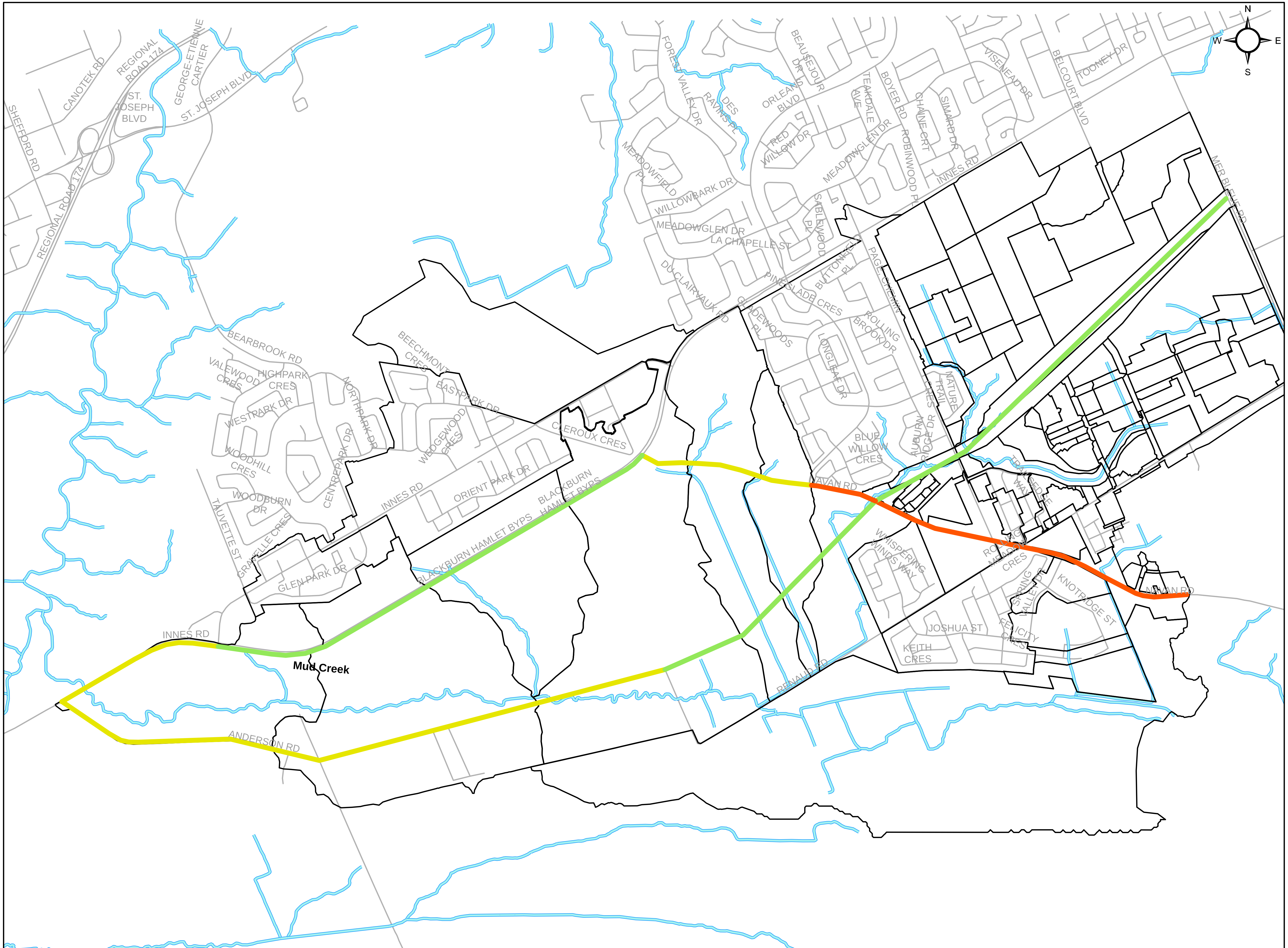


Figure 5-1: Future Subwatershed Extents



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Legend

- Watercourses
- Future Conditions Model Catchments

Future Roadway Projects

- 2 Additional Lanes
- 2 Additional Lanes & Sidewalk
- 4 Additional Lanes

Client / Project:

CITY OF OTTAWA

MUD CREEK CUMULATIVE IMPACTS STUDY

OTTAWA, ON

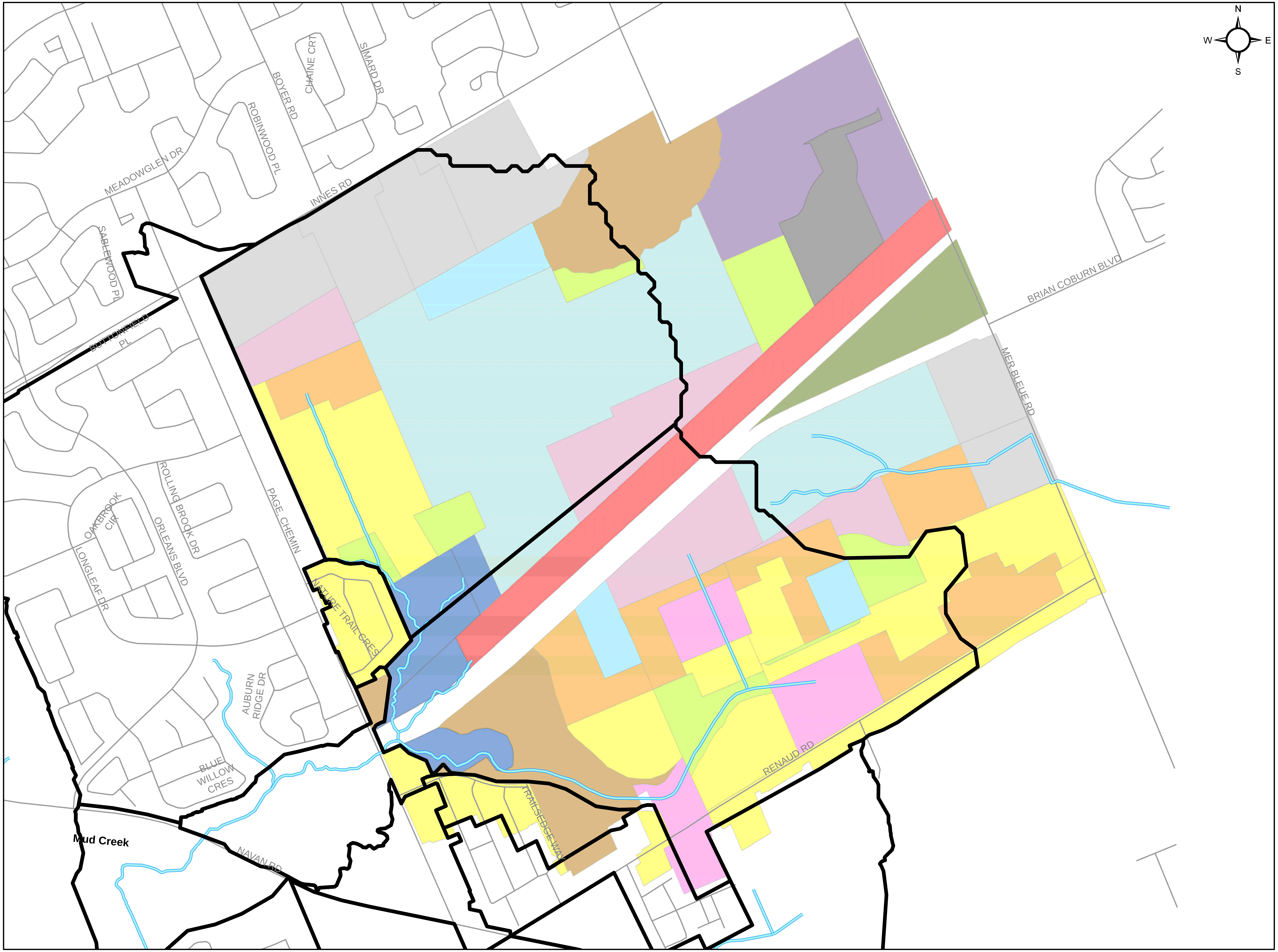
Title:

Proposed Roadway and Transitway Project Boundaries

Project No.:	Figure No.:
163401321	**5-2**

Scale:

0 0.25 0.5 Kilometers



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Legend

- Watercourses
- 2014 Existing Catchment Boundaries

CDP Land Use

- Back to Back Residential
- Commercial
- Employment
- Hydro Corridor
- Institutional
- Low Density Residential
- Mid-High Density Residential
- Mixed Use
- Park
- Pond
- Single-Detached Residential
- Snow Dump
- Townhouses Residential
- Woodlot

Client / Project:

CITY OF OTTAWA

MUD CREEK CUMULATIVE IMPACTS STUDY

OTTAWA, ON

Title:

CDP Land Use and Development Boundaries

Project No.:	Figure No.:
163401321	**5-3**

Scale:

0 0.15 0.3 Kilometers

5.2 WATER QUANTITY/EROSION

A comparison between the existing and future conditions model indicates that significant increases in both estimated peak discharges and runoff volumes are expected during infrequent events (refer to **Table 5-1**). Increases in the order of 100% to 300% are predicted for peak discharges for the 1:5-yr event with the greatest increases expected at the upstream end near Pagé Rd. The predicted increases in peak discharges for the 1:100-yr event are in the order of 110 % to 760%. The expected increases in runoff volumes range from 10% to 55% for the 1:5-yr event and 20 % to 45% for the 1:100-yr event.

A comparison of the peak flows computed in this study to flows computed in previous studies and/or analyses, reveals the future conditions peak flows for this study are generally more conservative. For example, downstream of Pond 1, the future conditions peak flow generated by this study's model is 11.2 m^3/s for the 100-yr 24-hr SCS design event, which is approximately 70% higher than the future conditions peak flow of 6.7 m^3/s for the same design event from the DSEL/JFSA design report (DSEL & JFSA, Revised March 2014), and 40% higher than the pre-development EUC Master Drainage Plan (MDP) peak flow of 7.8 m^3/s for the 100-yr 6-hr Chicago design event (Gore & Storrie Ltd., 1993). The discrepancy may be due to the use of a different infiltration method used for this study (Horton versus SCS used in previous studies), somewhat conservative C values originally provided by DSEL and applied in this model, or that major system storage within the subdivisions was not accounted for in this CIS study. We confirmed that the same drainage area and Pond 1 rating curve were used for this study. Given this apparent conservatism, we must use the absolute values generated from the hydrologic model with caution. It is believed that the modeling results may be used to establish relative comparisons between scenarios for the purposes of this study.

Table 5-1: Peak Flow and Volume Comparison

Condition	D/S of Pond 1	U/S of Navan Road Culvert	Confluence with South Branch	D/S of Innes Road Culvert
5-yr 24-hr SCS Storm				
2014 Conditions Peak Flow (m^3/s)	0.7	1.7	4.5	11.1
Future Conditions Peak Flow (m^3/s)	2.8	4.0	9.0	15.7
2014 Conditions Volume (m^3)	90,000	130,000	250,000	460,000
Future Conditions Volume (m^3)	140,000	180,000	300,000	510,000
100-yr 24-hr SCS Storm				
2014 Conditions Peak Flow (m^3/s)	1.3	3.1	11.1	26.7
Future Conditions Peak Flow (m^3/s)	11.2	13.5	23.2	38.7
2014 Conditions Volume (m^3)	110,000	190,000	410,000	820,000
Future Conditions Volume (m^3)	260,000	340,000	570,000	970,000

As with the existing conditions model, the streamflow series from a 25-year continuous simulation period (1975-2000) were used to determine and compare the total hours where the erosion threshold discharges are exceeded (A.K.A. exceedance hours) for three different particle sizes (D10, D50 and D90 respectively for the 10th percentile, median and 90th percentile substrate diameter). **Table 5-2** and **Figure 5-4** summarize the estimated exceedance hours for both existing and future conditions at three location within Mud Creek including:

- Immediately downstream of Pagé Rd (model node J7855)
- Base of the escarpment downstream of Navan Rd (model node J7267)
- The lower reach of Mud Creek - upstream of Renaud Rd and downstream of the confluence with the south tributary (model node J5463)

As illustrated by the results, a 4 to 22-fold increase in the D50 exceedance hours is predicted Page and Navan Roads whereas the increases are in the order of 40% further downstream near Renaud Rd. The net increase in exceedance hours between existing and future conditions for the creek below the escarpment is lower since the channel substrate is finer than within the creek above the escarpment and the erosion threshold is easily exceeded even under existing conditions.

Table 5-2: Exceedance Hours for Existing and Future Uncontrolled Conditions

Location	Parameters	Particle Sizes		
		D10	D50	D90
J7855 (D/S Page)	Qcrit (m^3/sec)	0.005	0.186	0.993
	Existing Conditions (hrs)	96,900	710	13
	Future Uncontrolled (hrs)	144,900	15,300	200
J7267 (D/S Navan)	Qcrit (m^3/sec)	0.005	0.186	0.993
	Existing Conditions (hrs)	101,200	4,130	150
	Future Uncontrolled (hrs)	145,200	18,300	590
J5463 (D/S of Confluence w/ South Tributary)	Qcrit (m^3/sec)	0.005	0.017	0.023
	Existing Conditions (hrs)	116,200	103,900	101,400
	Future Uncontrolled (hrs)	156,800	146,500	124,800

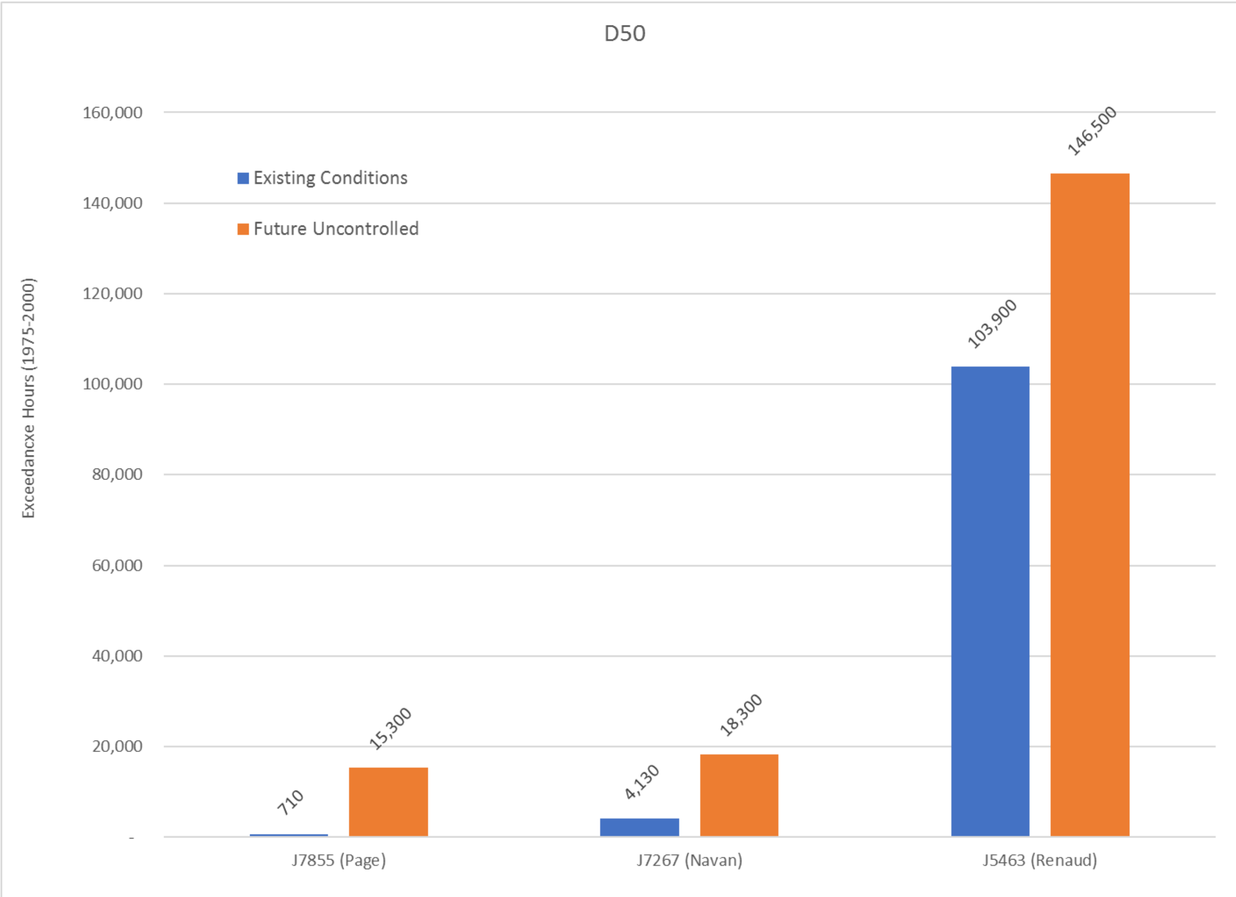

Figure 5-4: Exceedance Hours for Existing and Future Uncontrolled Conditions (D50)

5.3 WATER QUALITY

The future build-out conditions model was modified to include water quality modeling including the potential benefits from future LID. The pollutants represented and their attributes are consistent with the existing conditions model (refer to **Section 4.3**). Areas included in the CDP where the community drainage plan was on-going, or the subdivision plan was draft approved were assumed to be the only locations where Low Impact Development (LID) measures could be applied. This analysis considered the application of Silva Cells, Infiltration Trenches and Biofiltration Systems.

Details of the assumed LID application per land use, assumed treatment/bypass rates and anticipated LID pollutant removal rates can be found in Future Conditions Water Quality Modelling Technical Memo in **Appendix G.**

Table 5-3 summarizes the average and maximum pollutant removals applied in the future conditions model to represent LID including the Chapel Hill Park & Ride biofiltration facility currently under construction.

Table 5-3: Estimated LID Catchment Pollutant Removal Rates

Pollutant	Park and Ride Catchments Removal (%)	All Other Catchments	
		Average Removal (%)	Maximum Removal (%)
Total Suspended Solids	51.1	11.1	18.9
Total Phosphorus	0	3.2	6.6
Copper	4.6	7.1	11.0
Zinc	16.1	10.0	16.6
E. Coli	0	6.5	11.9

The future conditions water quality model was run using rainfall data from the Avalon rain gauge for the period of May 2014 to September 2014. The existing conditions water quality model was run with the same rain gauge data to compare the change in overall pollutant loading. The maximum observed pollutant concentrations in both scenarios for the entire run period at the following three locations in Mud Creek are presented in **Table 5-4**, where:

- Location 1: Upstream of the Navan Road Culvert (Node: J7300)
- Location 2: Downstream of Renaud Road Culvert, at the confluence of Mud Creek and the channel coming from the Mer Bleue Wetland and EUC Pond 3 (Node: J5463)
- Location 3: Downstream of Innes Road Culvert (Node: J600)

Table 5-4: Pollutant Concentration Comparison (May to September 2014)

	Total Suspended Solids (mg/L)	Total Phosphorus (mg/L)	Copper (mg/L)	Zinc (mg/L)	E. Coli (#/L)
Location 1: Navan Road					
Existing Conditions	79	0.165	0.015	0.042	183,200
Future Conditions	76	0.164	0.015	0.035	185,800
Location 2: Renaud Road (Confluence of Mainstem and South Tributary)					
Existing Conditions	167	0.195	0.014	0.037	193,400
Future Conditions	236	0.221	0.013	0.030	236,000
Location 3: Innes Road					
Existing Conditions	145	0.174	0.014	0.039	191,000
Future Conditions	122	0.158	0.013	0.032	173,000

The pollutant loading was also compared to provide a total quantity of each pollutant that would be discharged into the Creek during the run period. **Table 5-5** provides the total pollutant loadings.

Table 5-5: Mud Creek Total Pollutant Loading (May to September 2014)

	Total Suspended Solids (kg)	Total Phosphorus (kg)	Copper (kg)	Zinc (kg)	E. Coli (Count)
Location 1: Navan Road					
Existing Conditions	19,800	43.8	4.0	9.6	4.58×10^{13}
Future Conditions	30,500	75.7	6.9	15.2	8.05×10^{13}
Location 2: Renaud Road (Confluence of Mainstem and South Tributary)					
Existing Conditions	56,600	91.4	7.0	18.7	9.18×10^{13}
Future Conditions	73,600	140.0	11.1	26.2	1.43×10^{14}
Location 3: Innes Road					
Existing Conditions	136,100	188.0	14.2	39.6	1.96×10^{14}
Future Conditions	161,000	246.2	18.8	48.5	2.52×10^{14}

Our analysis shows that pollutant concentrations in Mud Creek are predicted to be slightly higher under existing conditions than predicted under future conditions for most pollutants at most locations. The pollutant concentrations discharging from Pond 1 are effectively unchanged between existing and future conditions. The area tributary to Pond 1 consists mostly of open space in existing conditions and is developed into residential and Industrial/Commercial/Institutional under future conditions. Under existing conditions, open space generates minimal runoff in smaller events, so the pond inflow originates largely from developed catchments with higher pollutant runoff concentrations. The increase in impervious area in future conditions results in higher runoff from all catchments such that most catchments are contributing to the inflow in all events. While the stormwater treatment facility is oversized under current conditions, the assumed treatment rates were unchanged between existing and future conditions.

In the future conditions model, runoff from all area that discharges to the tributary branch of Mud Creek that flows along the rail corridor is directed through Pond 3. Therefore, in the future conditions model, all flow through this tributary branch is treated through Pond 3. In the existing conditions model, catchments which are undeveloped or were developed with rural drainage systems discharge directly to the tributary branch such that the runoff bypasses treatment from Pond 3. Discharge through the tributary branch therefore has higher pollutant concentrations under existing conditions than under future conditions in large events.

The ponds provide quantity and quality control such that the flow and pollutant concentrations in Mud Creek can be heavily influenced by runoff from catchments which discharge directly into Mud Creek or a tributary of Mud Creek. These catchments generate runoff with no quantity or quality control. In the future conditions model, most flow in Mud Creek is treated discharge from the ponds during large events. The highest pollutant concentration is therefore seen in smaller events when a larger proportion of flow in Mud Creek is runoff from catchments which discharge directly into Mud Creek or a tributary of Mud Creek. In the existing conditions model, a larger proportion of flow in Mud Creek originates from catchments that discharge directly into Mud Creek or a tributary of Mud Creek during large events. The highest pollutant concentration is therefore generated in these larger events. This is also why a larger reduction in pollutant concentration is seen in the future conditions model between locations 2 and 3 than in existing conditions. The smaller events which govern the pollutant concentrations at location 2 in the future conditions model are not the events which govern the pollutant loading at location 3.

The annual pollutant loading is higher for all pollutants at all locations in the future conditions model. This is expected given that the runoff volume in the future conditions model is 1.5 to 2.0 times greater than the existing conditions model as a result of an overall increase in impervious area. However, the loadings are within the same magnitude in both conditions. The percent difference between existing and future conditions annual loading decreases as you move downstream, as more area that is unchanged between existing and future conditions is contributing to the total flow.

6 DEVELOPMENT OF IMPACT MITIGATION ALTERNATIVES

The development of impact mitigation alternatives was undertaken in a progressive manner involving the following approaches:

- Opportunities to improve the effectiveness of existing stormwater management (SWM) facilities in the study area; and/or
- Opportunities to control stormwater runoff at its source through implementation of Low Impact Development measures (LIDs); and, if necessary, in combination with
- Targeted in-stream improvements to Mud Creek.

Details of the hydrologic assessment of the mitigation alternatives are included in **Appendix H**.

6.1 MAXIMIZE EFFECTIVENESS OF EXISTING SWM PONDS

One method to counter in-stream impacts of urbanization is to maximize the benefits of the existing SWM ponds. There are three (3) SWM facilities within the study area:

- the Pagé Rd Pond located east of Pagé Road (Pond 1)
- the Chapel Hill South pond located within the ravine between Blue Willow Crescent and Auburn Ridge Drive (Pond 2)
- The SWM pond located south of Keith and Felicity Crescents (Pond 3)

As part of our review, each of these facilities was considered for a potential retrofit to increase the storage volume to increase runoff attenuation and reduce in-stream erosive forces.

Modifications to the design of the Pagé Rd pond have been recommended in the East Urban Community Mixed Use Centre Master Servicing Study (MSS) to provide additional quantity and quality controls necessary to accommodate future development. It was found through the MSS that insufficient lands were available around the pond to provide anything but a marginal increase in extended detention capacity necessary for enhancing downstream erosion control protection. Based on the foregoing, this Pond was not considered further as part of this evaluation.

The Chapel Hill South pond is a dry pond located within a relatively narrow ravine to the north of Mud Creek. It does not have any adjacent City-owned land that would allow for an expansion of the pond footprint. There is limited vertical clearance between the pond's current high-water levels and nearby homes, therefore increases in water levels cannot be considered. Retrofit for this pond is therefore not considered feasible.

As illustrated in **Figure 6-2**, there is a large City-owned lot adjacent to Pond 3 which provides the opportunity for an increase in pond footprint by approximately 17,000 m^2. Expansion of Pond 3 was considered above the permanent pool level to provide additional quantity control. The potential increase in active storage volume was calculated to be approximately 25,000 m^3 (assuming 4:1 side slopes). To quantify the impact of this scenario, modelling of a modified Pond 3 was undertaken to account for the additional volume.

Additional modeling of Pond 3, including this potential increase in active storage, did not show any significant benefit to Mud Creek. This potential modification did not result in a decrease in exceedance hours (total hours where the erosion threshold discharges for the D10-D90 particle sizes are exceeded) when compared to the future uncontrolled conditions within the lower reach. In fact, we observed a slight increase. This can be explained by the Mud Creek bed and bank materials in this reach being very fine and the corresponding erosion threshold being very low (D90 is 0.023 m^3/sec). The potential Pond 3 expansion would reduce the occurrence of flows greater than 0.075 m^3/sec within the southern tributary downstream of the pond but conversely it increases the duration of flows less than 0.075 m^3/sec. The threshold flows in the lower reaches of Mud Creek are much lower than the range of flows benefiting from the potential additional flow attenuation with an expanded Pond 3.

Table 6-1: Exceedance Hours with Potential Pond 3 Expansion

Location	Parameter	Particle Sizes		
		D10	D50	D90
J5463 (D/S of Confluence w/ South Tributary)	Qcrit (m^3/sec)	0.005	0.017	0.023
	Existing Conditions (hrs)	116,200	103,900	101,400
	Future Uncontrolled (hrs)	156,800	146,500	124,800
	Future Pond 3 Expansion (hrs)	157,900	147,500	126,200

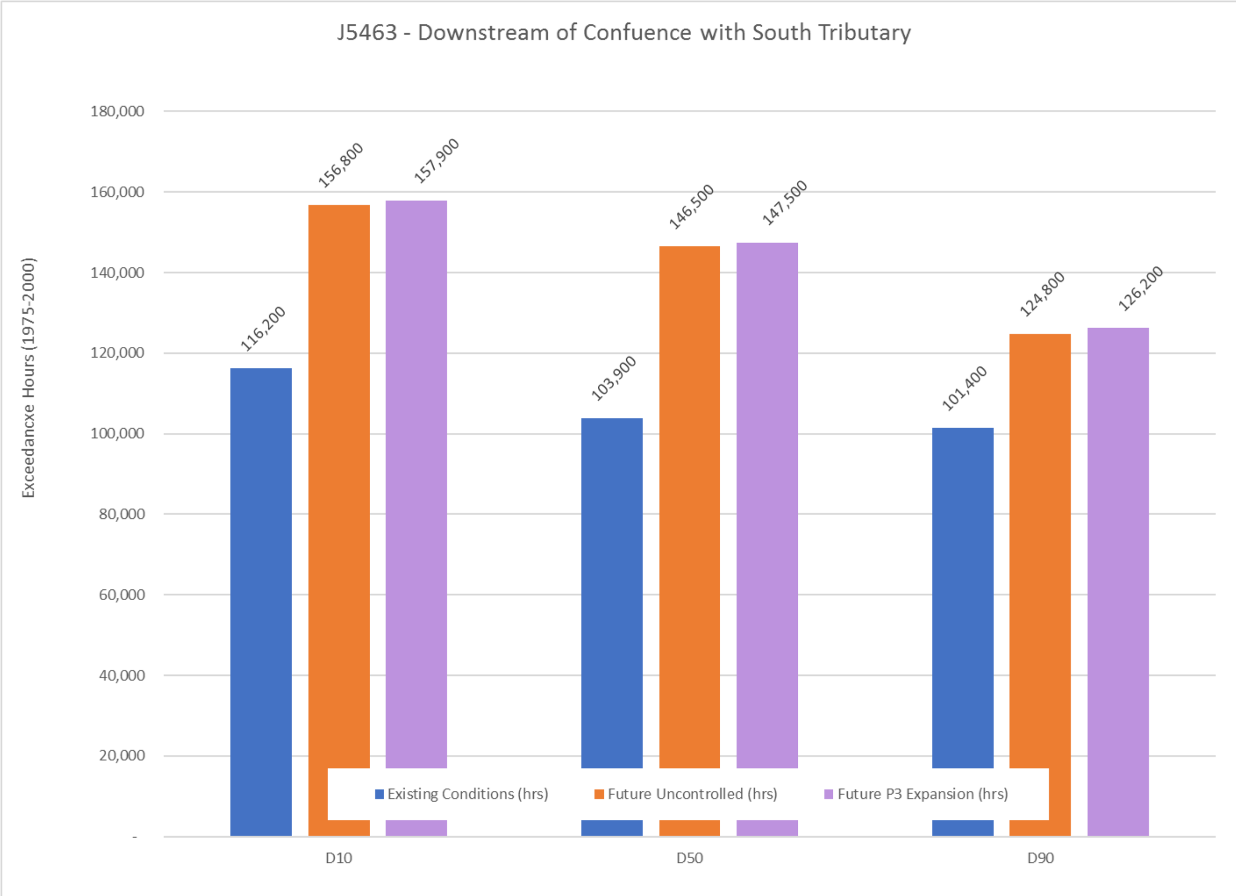

Figure 6-1: Exceedance Hours with Potential Pond 3 Expansion

6.2 LOW IMPACT DEVELOPMENT MEASURES

Low impact development (LID) measures are design elements that can provide an improvement in water quality and an opportunity to decrease runoff volume or peak flow from a given watershed. They are generally applied in areas to be developed to reduce the water quality and quantity impacts applied from increased impervious area. Types of LID measures include, but are not limited to, amended soils, enhanced grass swales, bioretention, rainwater harvesting/re-use, permeable pavers, perforated pipe systems, prefabricated modules, and green roofs. LIDs can contribute to stormwater management by:

- Decreasing effective impervious cover;
- Minimizing direct connections to the storm sewer system, resulting in attenuating surface runoff rates;
- Decreasing surface runoff volume; and
- Increasing filtration, infiltration and evapotranspiration.

The type of LID measure(s) that can be implemented will be dependent on the soil and groundwater characteristics of the proposed site, as well as the proposed or existing land use. The use of LID measures is consistent with the MECP's draft hierarchy (MOECC, 2017) intended to achieve the 90th Percentile Runoff Volume Control Target (RVCT). The MECP's draft hierarchy is prioritized as follows:

- **Priority 1** (Retention) – infiltration, evapotranspiration and/or re-use to retain a portion of rainfall and meet local water balance needs;
- **Priority 2** (Volume Capture and Release) – use of LID filtration technologies to capture and slow release the runoff volume that could not be retained under Priority 1; and
- **Priority 3** (Other Volume Detention and Release) – use of other stormwater technologies which utilize filtration, hydrodynamic separation and or sedimentation (i.e. end-of-pipe facilities) to detain and treat runoff that could not be retained and detained under Priority 1 and Priority 2.

The modelling approach and identification of potential retrofit opportunities are discussed in the following sub-sections. Further details on LIDs and their related retrofit opportunities, specifically pertaining to those on City-owned property, are provided in **Appendix C**.

In general, there are more opportunities to incorporate LID measures into the design of new developments than retrofitting existing areas. The following section discusses the opportunities and challenges to incorporating LIDs into future development in the study area.

6.2.1 New Developments

As shown in **Figure 6-2**, approximately 250 ha of the study area is planned for future development. This includes lands in the EUC CDP study area, and other development (including Trails Edge East Phase 1 and Orleans Village) that has been Draft Approved and is at various stages of active development. The development of all other areas is considered to have progressed too far to implement a new set of SWM criteria which includes LID.

Generally, where site conditions permit, opportunities to include LID measures in new developments for runoff reduction and control should be taken. In Ottawa, the potential LID options available for implementation are often constrained by subsurface conditions. These include low permeability soils, sensitive clays, high groundwater conditions and shallow bedrock. Assessments in the upper Mud Creek sub basin have revealed much of the area north of the Hydro One corridor is not conducive to LIDs fed by conventional roadway CBs i.e. there is less than 1 m of clearance to the maximum observed groundwater level (72.5 ha) and/or shallow bedrock (31.5 ha) if the underside of LID is 2.4 m below grade (refer to **Figure 6-3**). Approximately half of the area north of the Hydro One corridor is not conducive to LIDs fed by surface sources i.e. can provide 1 m of clearance to the maximum observed groundwater level or shallow bedrock if the underside of LID is 1.2 m below grade (refer to **Figure 6-4**).

Under existing conditions, about half of all infiltration occurring on site is in the bedrock outcrop near Innes Woods. This area is home to a snake den and is considered a Significant Groundwater Recharge Areas (SGRAs) as identified within the CDP. The CDP has arranged land uses to protect the SGRAs to maintain pre-development infiltration 'hotspots' like the bedrock outcrop. Consistent with MECP guidelines, the stormwater management plan (designed by others) ensures that roadway drainage and drainage from other hard landscapes (associated with urban stormwater contaminants) will not be directed to SGRAs.

The CDP proposes traditional industrial uses such as manufacturing, warehousing, vehicle sales and service, and other uses requiring external storage in the employment lands. Per MECP guidelines, infiltration-based LIDs are not compatible with high-risk site activities like commercial trucking, commercial autobody shops, electronic manufacturing, garages, metal/plastic/paint/pharma/cosmetic fabrication.

Based on the foregoing, very limited opportunities for infiltration exist due to:

- Innes Park Woods: Sensitive “Significant Groundwater Recharge Area” (bedrock outcrop with snake den) which must be protected;
- High groundwater levels (with shallow perched water table) preventing effective use of LIDs (<1 m clearance from seasonal high-water table); and
- Industrial Areas – “Higher risk activities”.

Despite these significant challenges, future development within the EUC CDP must seek opportunities to apply LIDs where practical. Where constraints preclude the use of infiltration-based LIDs, the use of LIDs which utilize other mechanisms such as filtration, evapotranspiration (ET) and re-use as the primary processes should be considered (Dillon Consulting & Aquafor Beech, 2019). To help better mimic pre-development hydrology, the major landowners in the EUC CDP have committed to the following:

- A tree planting program in parkland;
- Using infiltration trenches in backyards of singles and townhomes where feasible; and
- Setting right-of-way widths for the majority of local roadways at 18 m (not 16.5 m) to ensure healthy street trees that will be effective in providing evapotranspiration in post-development conditions.

Figure 6-2: Areas where LID may be implemented

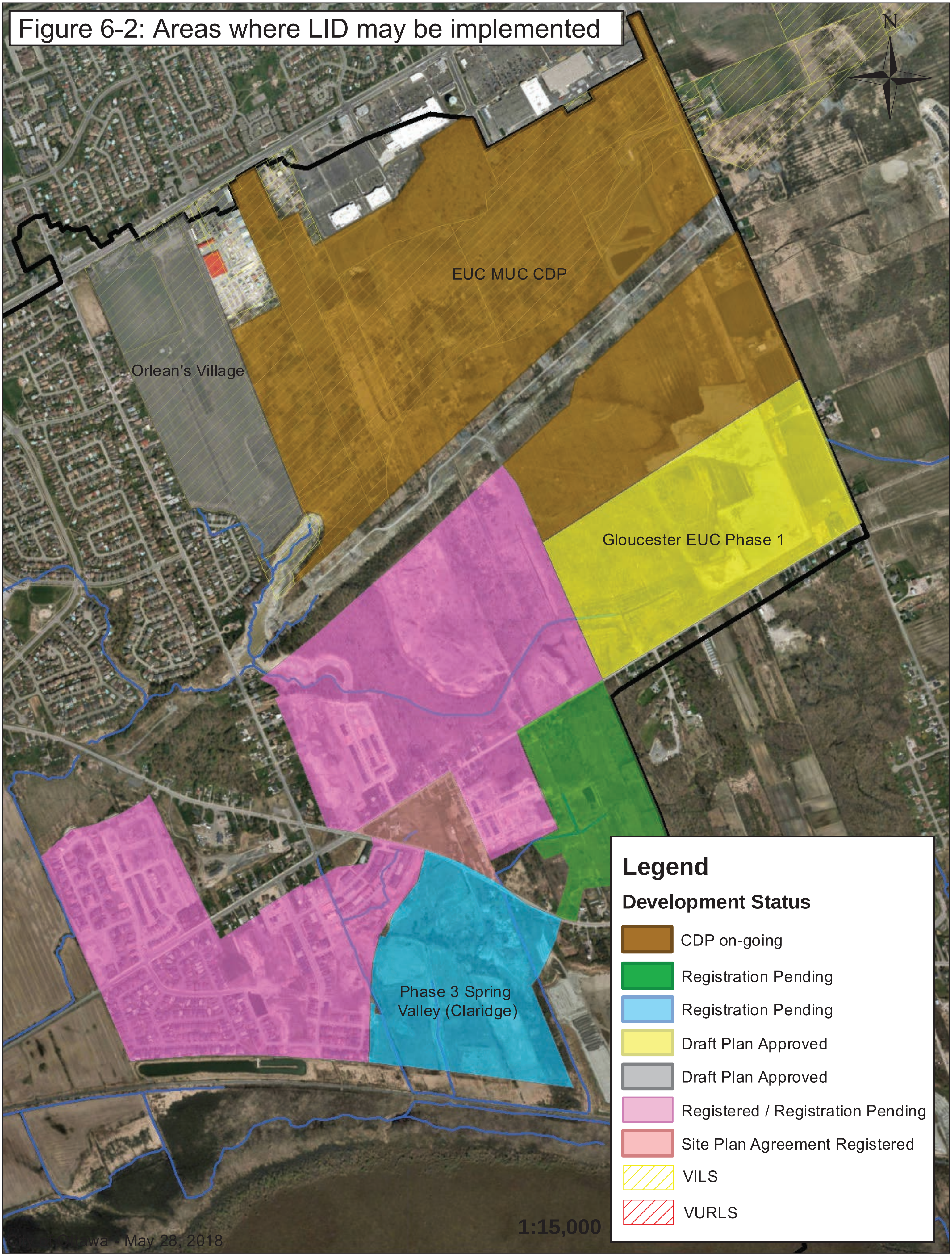

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Figure 6-3: Areas not conducive to LIDs fed by conventional Rroadway CBs (2.4m below road grade)

Based on East Urban Community Phase 3 Area Community Design Plan - Grading Plan | Prepared by DSEL April 18, 2019

PROJECT No. :	14-733
SCALE	1:4000
DATE:	OCTOBER 2018
DRAWING No.	2

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Figure 6-4: Areas not conducive to LID fed by surface (1.2m below road grade)

Based on East Urban Community Phase 3 Area Community Design Plan - Grading Plan
Prepared by DSEL April 18, 2019

PROJECT No. :	14-733
SCALE	1:4000
DATE:	OCTOBER 2018
DRAWING No.	2

6.2.2 Retrofits

The type of retrofit sites identified as potential City projects can be divided into two (2) categories: rights-of-way (e.g. roadways and surrounding boulevards) and City properties (e.g. parks, community centres, other miscellaneous property blocks owned by the City).

The greatest opportunity for the implementation of LID measures is along rights-of-way (ROWs) where reconstruction is proposed to occur since adjustments to ROW elements such as curb layouts are often required. There are no roadway reconstruction projects scheduled within the next 20 years in the study area, however many roads are scheduled to be resurfaced. With additional investment, LID measures may be adapted and implemented in these ROWs as part of resurfacing projects. Arterial and collector roads are considered to provide the most significant opportunity for retrofit because of their longer cross-sectional length which is preferable for implementation of LIDs such as grass swales and bioretention. **Figure 6-5** shows the location of all arterial and collector roads proposed to be resurfaced in the next 20 years and provide the opportunity for LID implementation. Site conditions would need to have suitable soils and bedding surrounding the LIDs for successful performance.

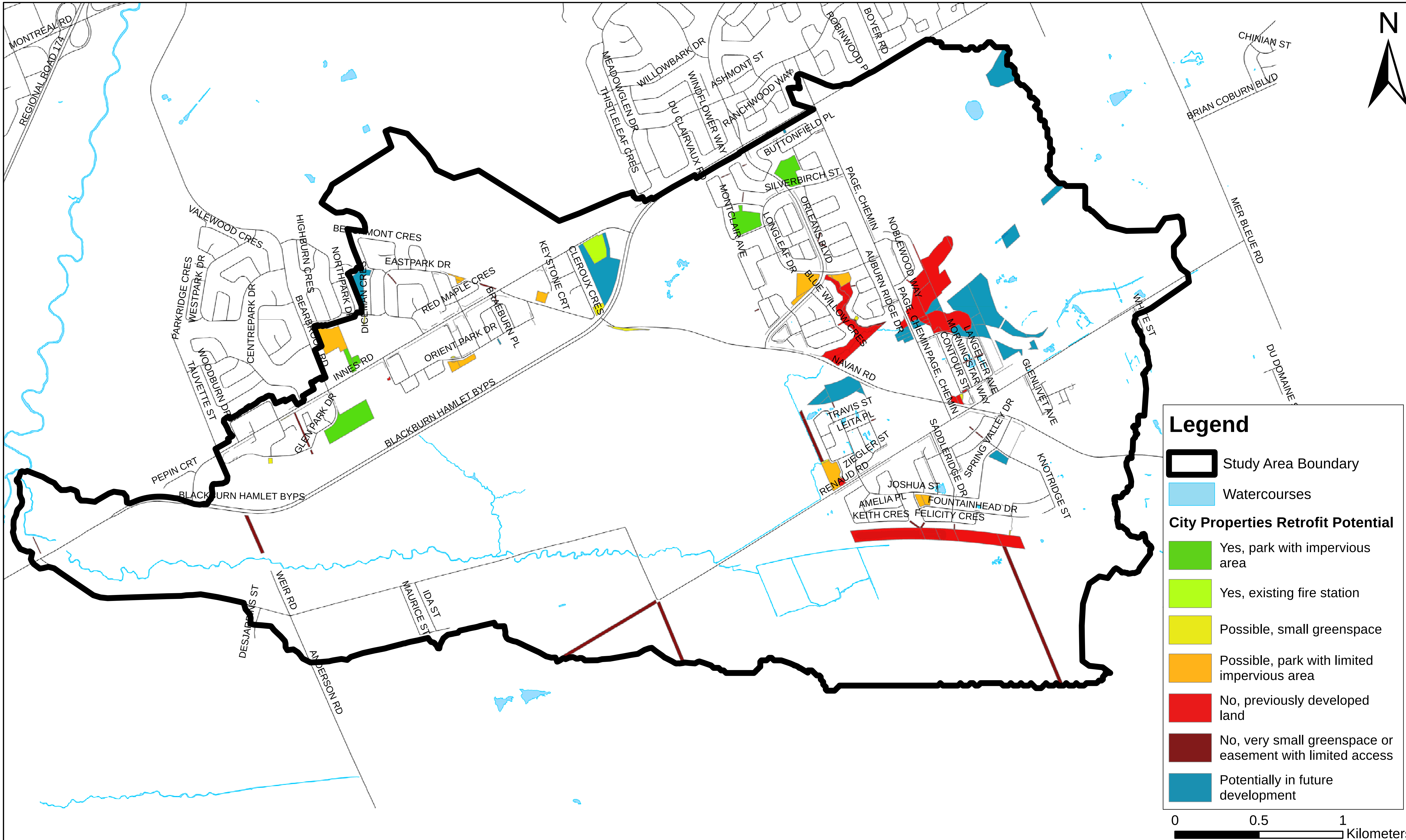
There is also potential for the implementation of LIDs on City properties such as parks, emergency stations and community centers. LID measures are more easily implemented on sites where complete reconstruction or new construction is to occur. Retrofit opportunities exist on City properties that are already developed including measures such as enhanced grass swales, bioretention, permeable pavers and prefabricated modules. However, these measures, with exception to permeable pavers, are highly dependent on existing drainage and grading of the site. **Figure 6-5** shows the location and boundaries of all City-owned properties divided into categories based on the site's LID retrofit potential. Further detail on these categories is provided in **Appendix I.**

The City had previously identified potential projects on City-owned properties within the Mud Creek subwatershed (City of Ottawa, 2015). These locations are shown in **Figure 6-8** and include: (1) Silverbirch Park, (2) Longleaf Park, (3) Bearbrook Park, (4) Orient Park, and (5) Fire Station 54. Each of these projects are considered to still be valid and provide the greatest LID retrofit potential opportunity for reductions in runoff as they are large areas with significant portions of impervious area. Potential retrofit may include replacing impervious surfaces with permeable paver systems, prefabricated storage infiltration modules that may be installed under parking areas, enhanced grassed swales or bioretention areas to treat runoff from impervious surfaces and/or additional tree planting. A detailed site assessment should be completed at each site to confirm feasibility of LID measures.

It is anticipated that the RVCT in Mud Creek cannot be achieved through the implementation of LID measures in the five aforementioned City-owned properties. Therefore, these properties are noted as potential areas to be retrofitted. To help achieve the RVCT, it may be recommended that the City implement LID measures along ROWs prior to scheduled reconstruction or include them as modifications to resurfacing projects.

Incentive programs that promote the use of LIDs on private property can be implemented by the City and may be effective in reducing runoff and increasing water quality in existing developments. For residential areas, the most common measure is the use of rainwater harvesting systems such as rain barrels for garden/lawn watering. The maintenance of LID measures implemented on private property is the responsibility of the property owner, therefore incentive programs are often better suited to multi-family residential, commercial, industrial or private sites where reinforcement of maintenance can be exercised, if necessary.

Figure 6.5: City Properties with LID Potential



6.2.3 Evaluation of LID Effectiveness

The effectiveness of LID measures at mitigating erosion impacts in Mud Creek was undertaken using a simplified modelling approach considering that this study is being undertaken at the sub-watershed level and that the design details for the future LID are unknown at this time. It was assumed that where there is opportunity to implement LID these will result in much needed retention. The effectiveness of LID measures was simulated by increasing the depression storage parameter (Dstor in the PCSWMM model) for both the impervious and pervious areas in the future catchments as outlined in **Section 6.2.1**. Two rainfall conditions were simulated: 5 mm (i.e. moderate LID application) and 10 mm (i.e. significant LID application) rainfall abstraction/retention.

The resulting streamflow series from 25-year continuous simulations (1975-2000) for the above scenarios were subsequently used to determine and compare the total hours where the erosion threshold discharges are exceeded (exceedance hours). The results of this evaluation are summarized in **Figure 6-6** and **Appendix J**. Our evaluation indicates that the use of LID that retain 5 mm of rainfall is expected to reduce the duration of exceedance of the erosion threshold discharges in the order of 20 to 25% when compared to future uncontrolled conditions for the section upstream of the escarpment while the expected reductions are much smaller (~2.5%) in the lower reach. The estimated reduction in exceedance hours for the 10 mm retention scenario is in the order of 30% to 40% for the D50 for the creek section above the escarpment while the expected reductions are small (~2% to 6% for the D10 to D90) in the lower reach. The benefit to in-stream erosion reduction of LID measures is reduced as you move downstream with increased flow contributions from uncontrolled areas and due to finer bed and bank materials which have lower erosion thresholds.

Based on the foregoing results, from a theoretical perspective moderate to high LID application may provide a significant benefit to the creek section above the escarpment (where the channel substrate is coarser). No noticeable benefit to in-stream erosion is expected from the application of LID for the creek sections below the escarpment.

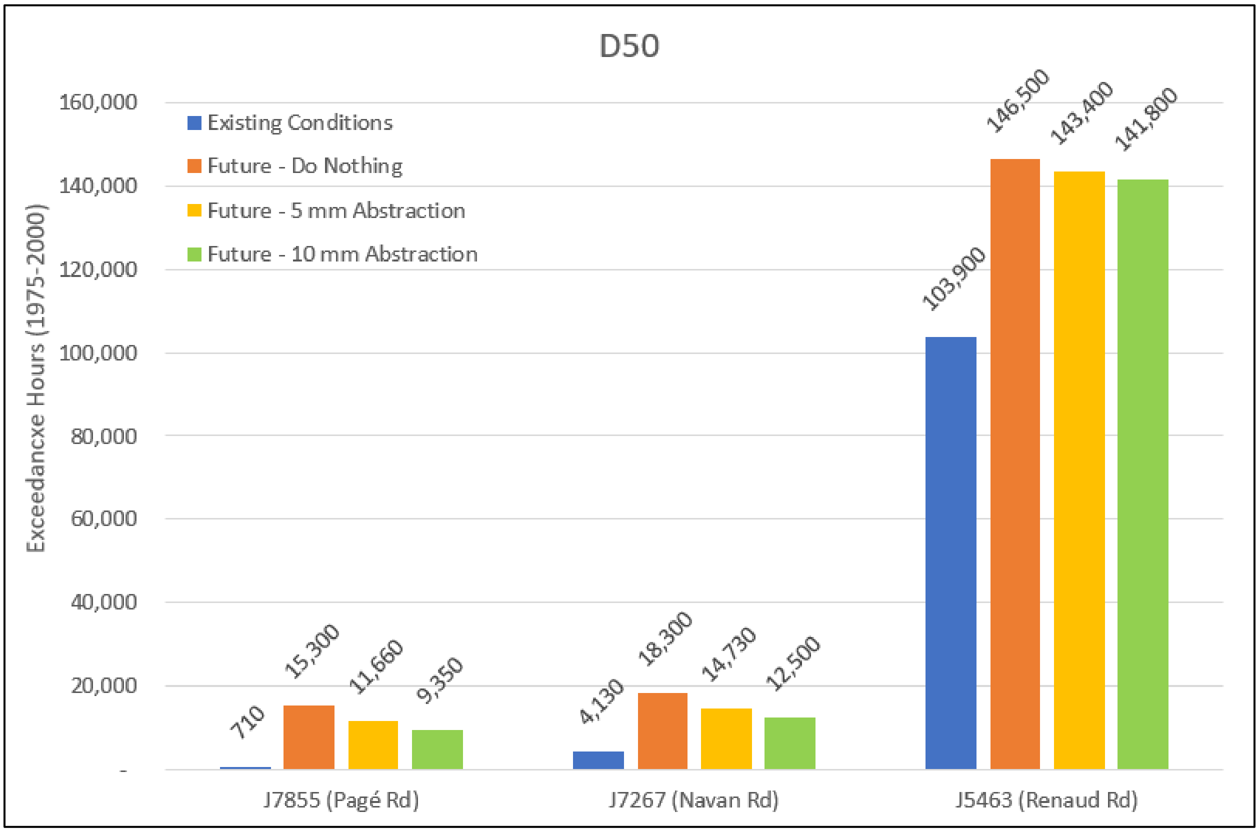


Figure 6-6: Exceedance Hours Comparison Including LIDs Median Substrate (D50)

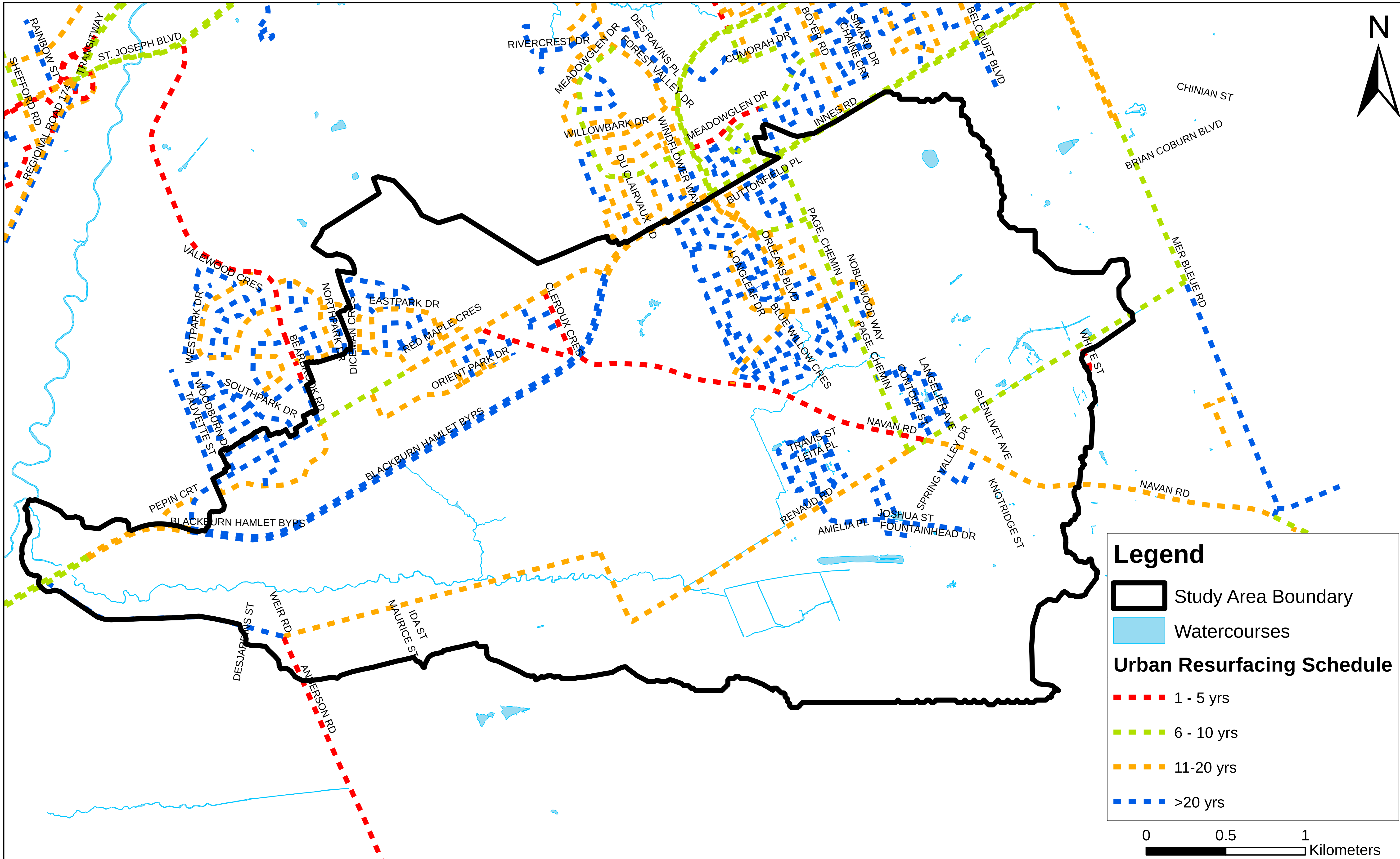
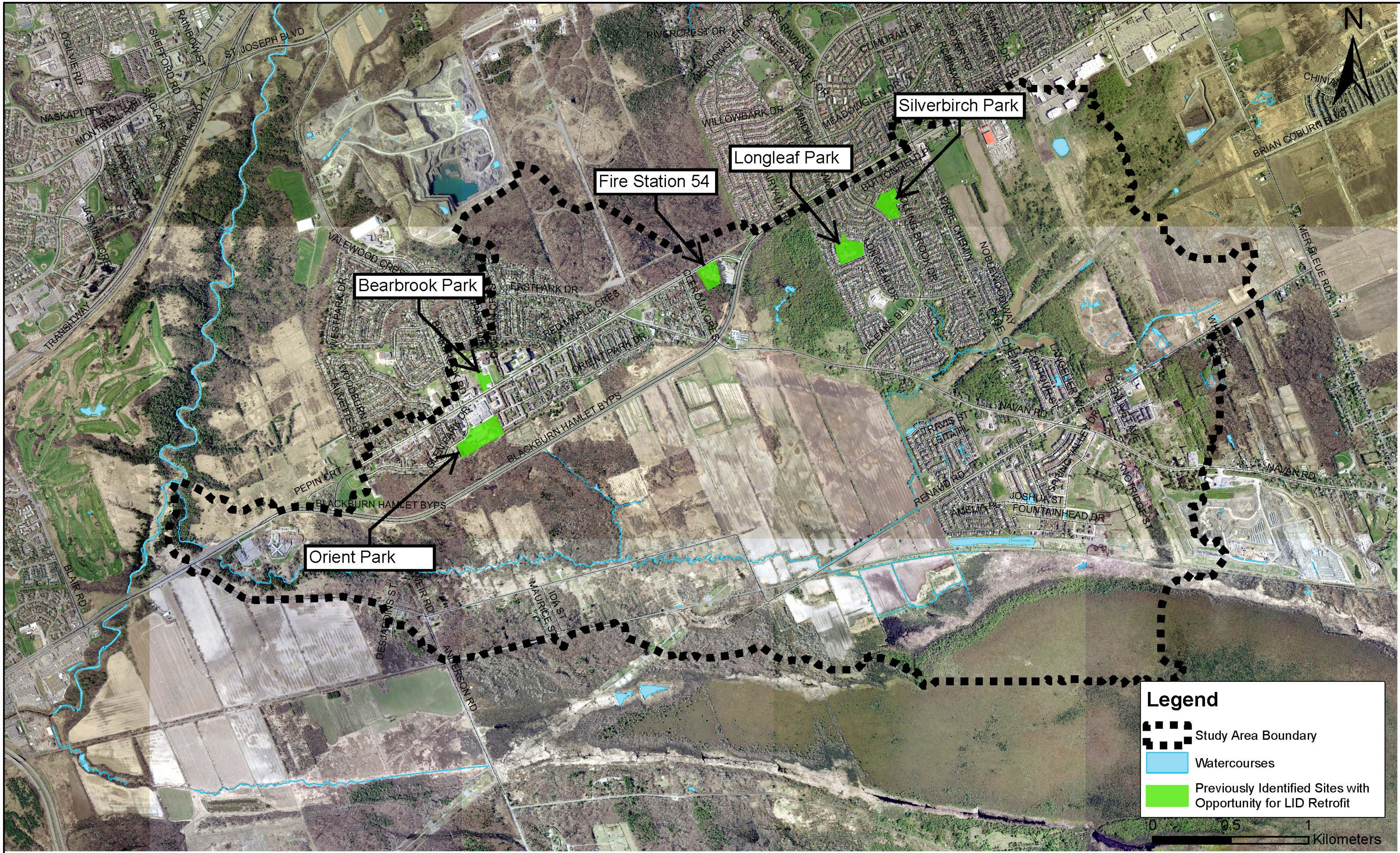


Figure 6-7: Right-of-Way Resurfacing Schedule

Figure 6-8: Previously Identified City Sites with LID Potential



6.3 IN-STREAM WORKS

Based on the results presented in earlier sections, the expansion of SWM ponds and/or the use of LID will not suffice on their own to mitigate the downstream erosion impacts on Mud Creek. Therefore, in-stream measures will be required to mitigate the impacts of future changes to the hydrologic cycle. These may include measures such as channel reconfiguration and/or reinforcing of the existing channel as discussed in the following sub-sections.

6.3.1 Channel Reconfiguration

A starting point for the development of potential solutions for Mud Creek is the work undertaken for the NCC as part of the Green's Creek watershed with a specific focus on the restoration concepts identified by JTB Environmental Systems Inc. (JTBS) as part of the *NCC Green's Creek Watershed Rehabilitation, Priority Rehabilitation Projects, Restoration Concepts* (Groupe Rousseau Lefebvre and JTBES, 2014). A portion of the report centers on the headwater area of Mud Creek where the identified opportunities focus on erosion control and are more easily implementable when compared to Lower Green's Creek. A total of six intervention areas (Sites 5, 6, 9, 12, 13 and 14) were identified in the Mud Creek CIS study area (**Figure 6-8**). The restoration concepts proposed in the Rousseau Lefebvre / JTBES report are reproduced in **Appendix K**.

The restoration concepts are predicated on the use of natural channel design strategies to expand the floodplain and create natural resilience to the system. The approach requires expansion of the creek footprint in strategic locations and is used to absorb some excess energy as opposed to translating it downstream. The following are advantages and disadvantages with channel reconfiguration:

Pros:

- Locally restore channel section and platform to provide natural flow processes which reduce peak velocities and bed/bank erosion;
- Potential for lower flood levels; and
- Protects Renaud Road from channel migration.

Cons:

- Need for additional property to widen stream section;
- On its own, they are unlikely to provide enough attenuation to revert the duration of excess erosive forces to existing conditions;
- Some creek segments which are not rehabilitated will remain at risk of increased excess erosive forces; and
- Creek will remain abnormally straight in some areas.

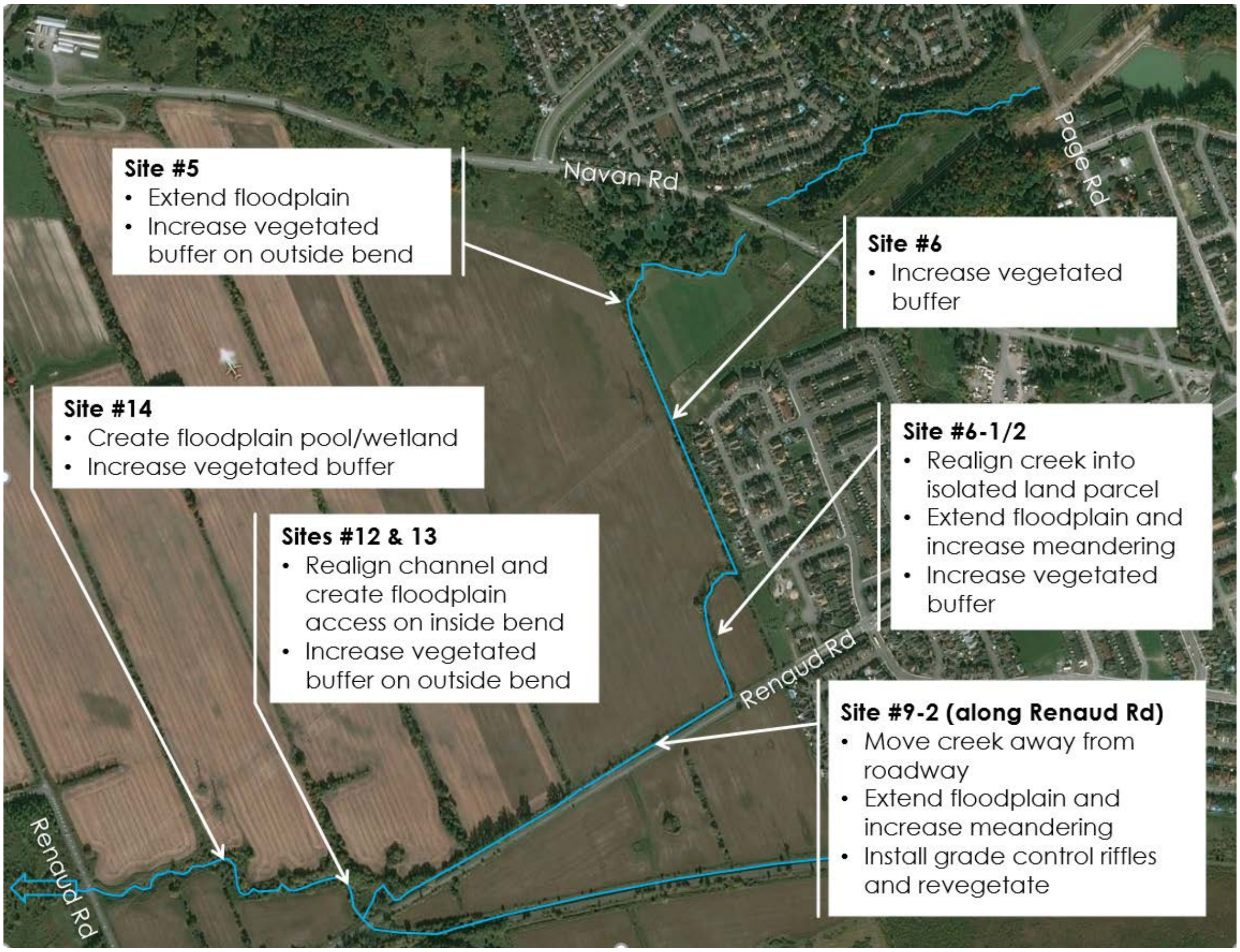


Figure 6-9: Proposed Locations for Channel Reconfiguration

Figure 6-10: Example of Channel Reconfiguration

6.3.2 Reinforce Existing Channel

Another variant on possible in-stream measures is to increase the resilience of the creek bed and banks by proving a layer of less erodible materials to protect the underlying finer creek substrate. In this case, granular material with a median size of up to 120 mm diameter would be placed and extend roughly up to the 1:2-yr flood level. For the most part this material will be placed over the existing creek bed/bank and the channel footprint would be maintained i.e. no widening. However, in some creek sections the channel reinforcement will have to replace the existing substrate to avoid increasing the creek bottom and to maintain infrequent flood levels. The following are advantages and disadvantages with reinforcing the existing channel:

Pros:

- Bed/bank substrate can be sized to counter expected velocities/erosive forces; and
- No need for additional property.

Cons:

- Potential for higher localized flood levels which may be mitigated by replacing existing channel material (lining thickness);
- No benefit beyond the creek reaches of interest (i.e. downstream of Renaud Road); and
- Creek will remain abnormally straight.

Figure 6-11: Example #1 of Reinforcing Existing Channel

Figure 6-12: Example #2 of Reinforcing Existing Channel

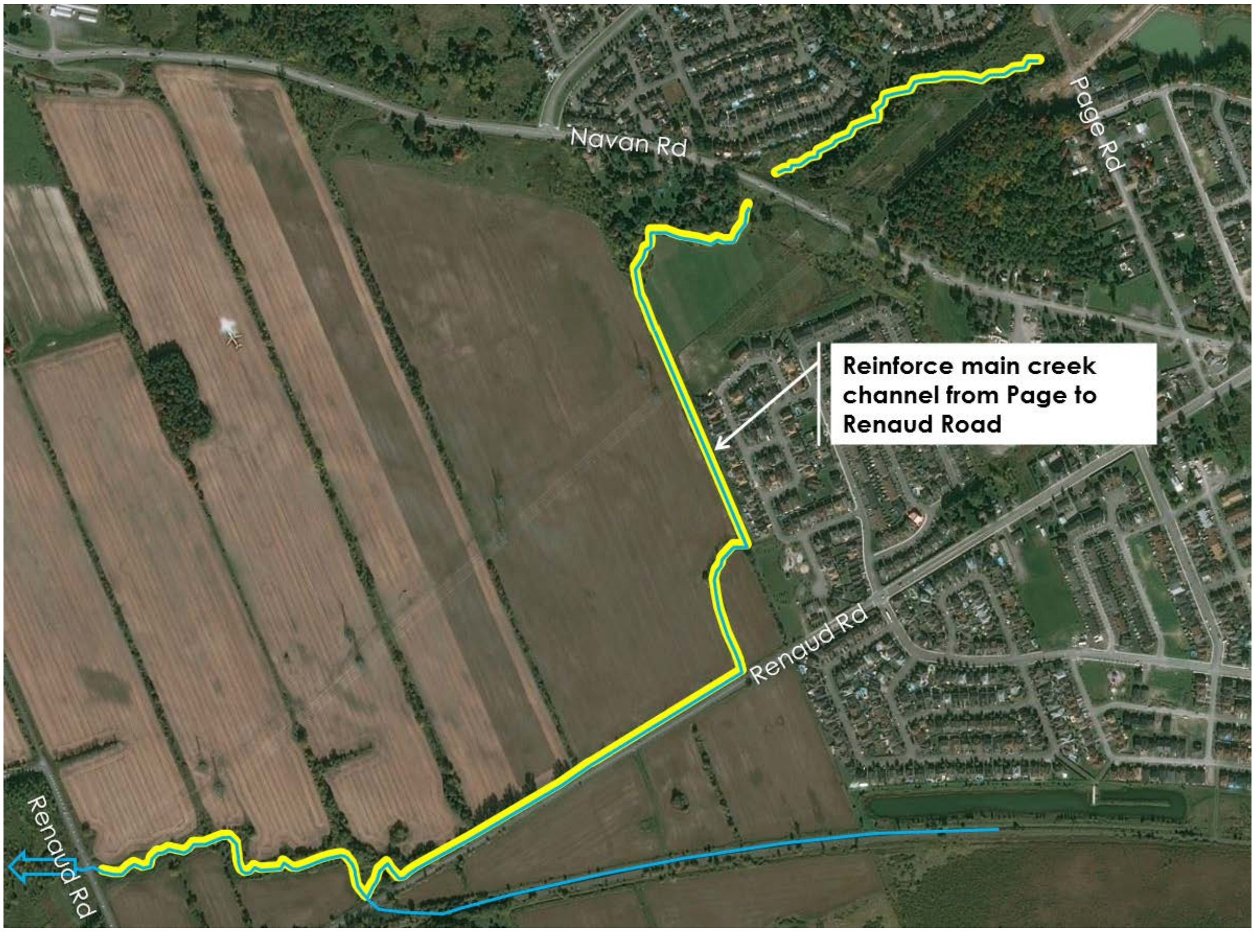


Figure 6-13: Reinforce Existing Channel Approach

6.4 PROPOSED IMPACT MITIGATION ALTERNATIVES

A total of four (4) alternative solutions have been developed. They include the do-nothing or baseline alternative along with three (3) alternatives which incorporate a combination of LID and in-stream works.

6.4.1 Alternative 1: Do Nothing (Baseline)

This alternative is offered for comparative purposes only and is considered the baseline condition if no additional effort is made to mitigate impacts to Mud Creek. In other words, the existing stormwater management facilities are the primary measures to mitigate impacts to Mud Creek and no pond expansions or LID are considered. Under this alternative it is anticipated that the peak flow observed in Mud Creek will increase by a maximum of 300% for the 5-yr 24-hr SCS design storm and up to 760% during the 100-yr 24-hr SCS design storm when compared to existing conditions (refer to **Table 6-1**). Similarly, the total volume is anticipated to increase up to 60% for the 5-yr 24-hr SCS design storm and up to 140% during the 100-yr 24-hr SCS design storm. The greatest relative increase is expected downstream of the Pagé Rd pond.

Over a 25-year continuous simulation period, exceedance hours for the Do-Nothing scenario increased significantly from existing conditions. As shown in **Figure 6-14**, the largest difference was observed in the creek section above the escarpment (2,000% at Pagé Road), whereas increases were less significant in below the escarpment (41% increase at the confluence with the south branch).

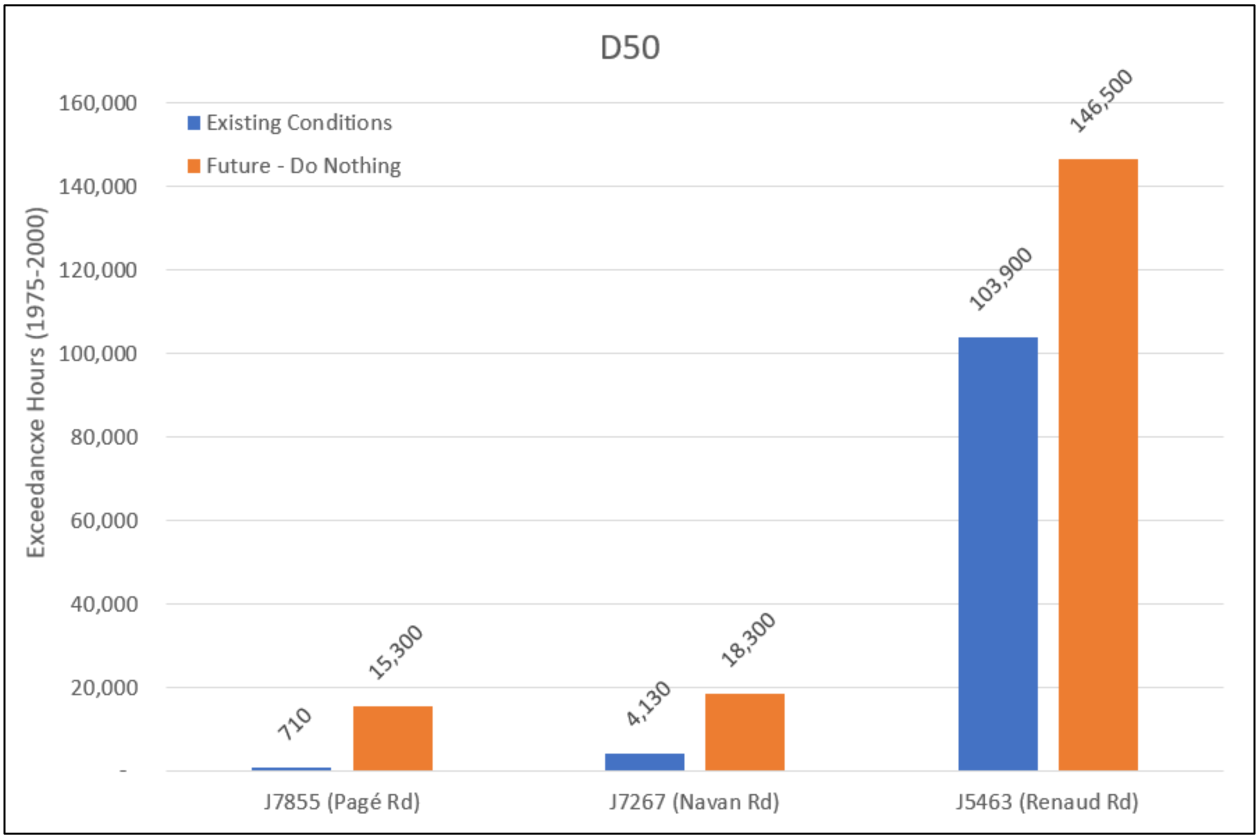


Figure 6-14: Comparison of D50 Exceedance Hours (Existing Conditions vs. Future Do Nothing)

6.4.2 Alternative 2: Channel Reconfiguration

As described below, this alternative relies on the implementation of the combination of SWM LID measures along with selected channel reconfiguration projects from the *NCC Green's Creek Watershed Rehabilitation, Priority Rehabilitation Projects, Restoration Concepts* (Groupe Rousseau Lefebvre and JTBES, 2014).

SWM LID Measures: Where opportunities exist, implementation of SWM LIDs for new developments including a tree planting program in parkland, using infiltration trenches in backyards of singles and townhomes where feasible and allowing 18m wide local roadway right of ways to ensure healthy street trees that will be effective in providing evapotranspiration in post-development conditions. Where constraints preclude the use of infiltration-based LIDs, LIDs which utilize filtration, evapotranspiration (ET) and re-use as the primary processes will be considered.

Channel Reconfiguration would include the implementation of the following in-stream elements (per site improvement locations referenced in Rousseau Lefebvre / JTBS report):

- Site 5: Realign the creek; increase floodplain width to provide flow access; regrade area and revegetate buffer.
- Site 6 incl. 6-2: Extend floodplain and increase meandering; install grade control riffles; revegetate. Increase existing channel length to increase sinuosity from 1.0 to 1.25. Move creek east into isolated land parcel.
- Site 9-2: Extend floodplain; increase meandering; move creek away from road right of way; install grade control riffles; revegetate. Increase existing channel length to increase sinuosity from 1.0 to 1.15.
- Sites 12 and 13: Realign channel and create floodplain access on inside bend; increase vegetated buffer on outside bend.
- Site 14: Create floodplain storage in a floodplain pool.

Implementation of this reconfiguration work will undoubtedly impact some adjacent riparian vegetation and will necessitate some restoration including tree planting.

6.4.3 Alternative 3: Channel Reinforcement

As described below, this alternative relies on the implementation of the combination of SWM LID measures along with channel reinforcement.

SWM LID Measures: Where opportunities exist, implementation of SWM LIDs for new developments including a tree planting program in parkland, using infiltration trenches in backyards of singles and townhomes where feasible and allowing 18m wide local roadway right of ways to ensure healthy street trees that will be effective in providing evapotranspiration in post-development conditions. Where constraints preclude the use of infiltration-based LIDs, LIDs which utilize filtration, evapotranspiration (ET) and re-use as the primary processes will be considered.

Channel Reinforcement: Place granular material, generally up to the 1:2-yr flood level, between Pagé Rd and Renaud Rd for an overall length of approximately 2,850 m. For the upper reach, this material may be placed over the existing creek bed/bank and the channel footprint would be maintained i.e. no widening. However, in the lower and middle reaches reinforcement will have to replace the existing substrate (equal depth) to avoid increasing flood levels and associated flood risks for adjacent properties (for example: residential properties on the west side of Whispering Winds Way). It is expected that this work will impacts some adjacent riparian vegetation and will necessitate some restoration. For costing purposes, we have assumed 1,500 trees will need to be planted as part of the reinforcement works.

6.4.4 Alternative 4: Hybrid (Channel Reconfiguration & Reinforcement)

Alternative 4 involves a combination of Alternatives 2 and 3, taking advantage of local opportunities where possible. Where floodplain extension is possible, channel reconfiguration is proposed, whereas in areas where floodplain extension is not possible, channel reinforcement treatments are proposed. This alternative would be composed of the following:

SWM LID Measures: Where opportunities exist, implementation of SWM LIDs for new developments including a tree planting program in parkland, using infiltration trenches in backyards of singles and townhomes where feasible and allowing 18m wide local roadway right of ways to ensure healthy street trees that will be effective in providing evapotranspiration in post-development conditions. Where constraints preclude the use of infiltration-based LIDs, LIDs which utilize filtration, evapotranspiration (ET) and re-use as the primary processes will be considered.

Channel Reconfiguration would include the implementation of the following in-stream elements:

- Site 6-2: Move creek east into isolated land parcel; extend floodplain and locally increase meandering; install grade control riffles and revegetate.
- Site 9-2: Extend floodplain; increase meandering; move creek away from road right of way; install grade control riffles; revegetate. Increase existing channel length to increase sinuosity from 1.0 to 1.15.
- Sites 12 and 13: Realign channel and create floodplain access on inside bend; increase vegetated buffer on outside bend.

Implementation of this reconfiguration work will undoubtedly impact some adjacent riparian vegetation and will necessitate some restoration including tree planting.

Channel Reinforcement: Place granular material, generally up to the 1:2-yr flood level. For the upper 1,400 m this material may be placed over the existing creek bed/bank and the channel footprint would be maintained i.e. no widening. However, in the lower 400 m portion of the creek, the channel reinforcement may have to replace the existing substrate (equal depth) to avoid increasing flood levels and associated flood risks for adjacent properties. It is expected that this work will impact some adjacent riparian vegetation and will necessitate some restoration. For costing purposes, we have assumed approximately 900 trees will need to be planted as part of the reinforcement works.

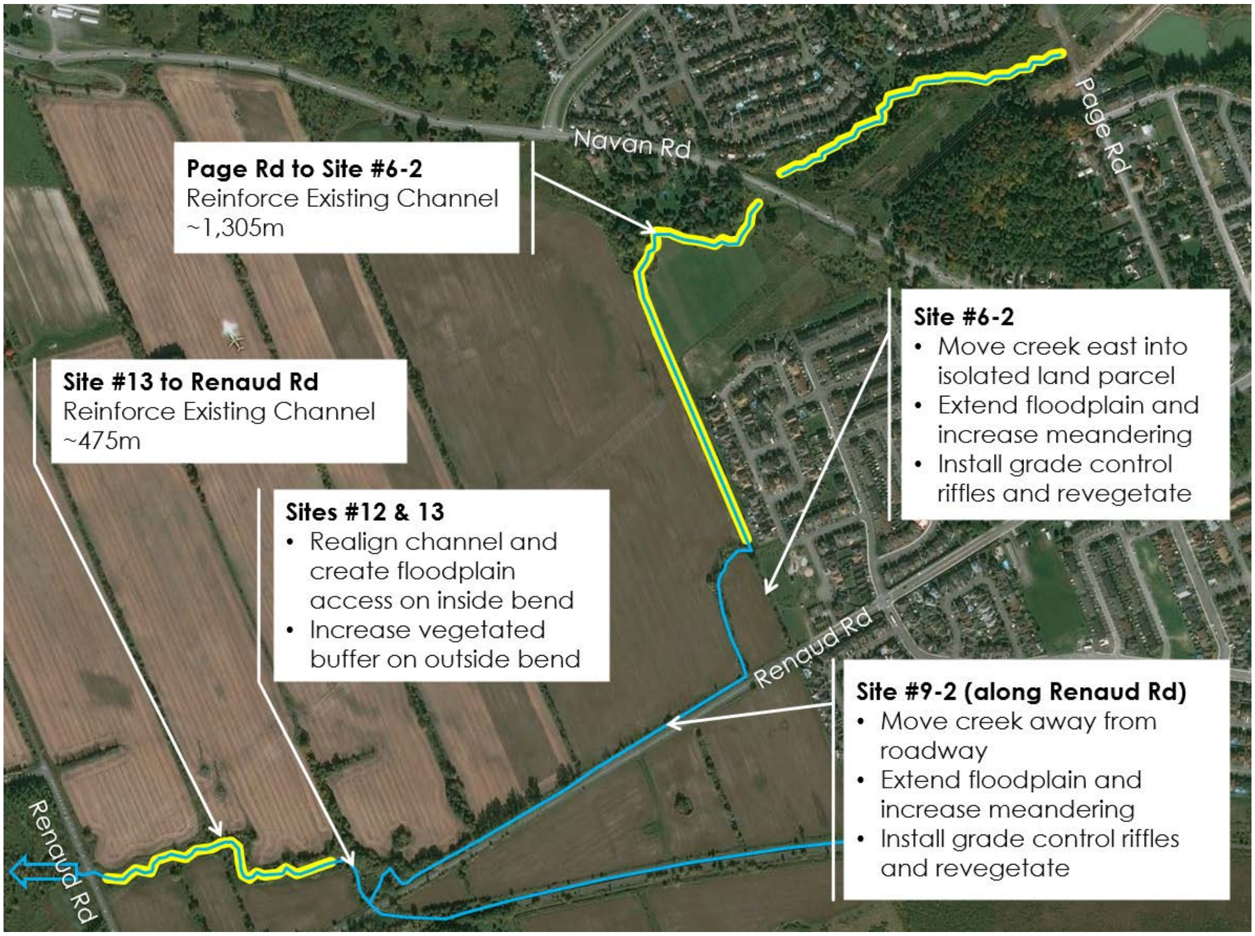


Figure 6-15: Proposed Locations for Channel Reconfiguration or Reinforcement

7 EVALUATION OF ALTERNATIVES

7.1 EVALUATION APPROACH

7.1.1 Evaluation Criteria

The evaluation criteria for the Mud Creek CIS were based on consideration of factors used in previous City projects including Pinecrest Creek / Westboro SWM Retrofit Study (JFSA, 2011). Stantec grouped the criteria within an overarching framework which has four categories: Technical, Socio-Cultural, Natural Environment and Economic. **Table 7-1** provides a summary of the proposed criteria to be carried forward and their rationale for inclusion.

Table 7-1: Summary of Proposed Criteria and Rationale

Category	ID	Criteria	Rationale for Inclusion / Indicator
Technical	T1	Erosion Impacts	Erosion caused by increased runoff (i.e. imperviousness) from developed lands is detrimental to the stability of the creek. Therefore, there is a need to limit the increase in exceedance hours with future development.
	T2	Water Quality	Benefit on pollutant concentration and/or loadings.
	T3	Flood Risk	Ensure flood risk to public health and safety and property is not increased with future development in the subwatershed.
	T4	Constructability	Potential limitations due to site conditions (e.g. proximity to existing infrastructure / private property, accessibility, property ownership, extent of proposed works, in-water construction timing restrictions).
Socio-Cultural	S1	Adverse Effects on Land Use	Potential to have adverse impacts on adjacent properties and land use.
	S2	Consistency with Planning Policies / Processes	Compatibility with current Zoning, NCC Plans and Policies.
Natural Environment	N1	Impact on Terrestrial Systems	Aim to improve or limit potential impacts on wildlife and terrestrial systems (e.g. riparian area).
	N2	Impact on Aquatic Systems	Aim to improve or limit potential impacts on aquatic life and aquatic systems (e.g. riparian area).
Economic	E1	Capital Costs	Total opinion of probable cost associated with capital works.

Table 7-2 summarizes the weightings derived for each of the criteria following application of a pair-wise comparison methodology. The scores for each criterion are summed to determine the overall category weighting. Further details on the pair wise comparison and weightings are provided in **Appendix L.**

Table 7-2: Summary of Evaluation Criteria Weightings

Evaluation Criteria	Weighting
Technical	**30.6%**
Erosion Impacts	11.6%
Water Quality	5.3%
Flood Risk	5.3%
Constructability	8.4%
Social	**27.8%**
Adverse Effects on Land Use	13.9%
Consistency with Planning Policies / Processes	13.9%
Natural Environment	**25.0%**
Impact on Terrestrial Systems	12.5%
Impact on Aquatic Systems	12.5%
Economic	**16.7%**
Capital Costs	16.7%

7.2 EVALUATION OF ALTERNATIVES

The alternative solutions were compared and ranked against each other using a “High”, “Medium”, or “Low” impact ranking system (assigned a score of 1, 2 and 3, respectively) with “High” being the least desirable, refer to **Table 7-3**. This type of evaluation represents the degree to which each alternative achieves project objectives and/or is preferred over other alternative solutions. A matrix was used to document and summarize the rating, provide a weighted score and associated ranking of each alternative. **Table 7-4** summarizes the evaluation of alternatives while the detailed evaluation matrix can be found in **Appendix L**.

Table 7-3: Summary of Impact Ratings

Impact Rating / Score	Description
LOW / 3	This score indicates that the alternative solution will have a low impact with respect to the evaluated criteria and is more desirable.
MEDIUM / 2	This score indicates that the alternative solution will have a medium impact with respect to the evaluated criteria and is neutral.
HIGH / 1	This score indicates that the alternative solution will have a high impact with respect to the evaluated criteria and is less desirable.

Based on the foregoing approach, the Hybrid - Channel Reconfiguration + Reinforcement) alternative was ranked as the preferred solution.

Table 7-4: Evaluation Summary

Alternatives		Preferred	Overall		Individual Criteria Categories							
					Technical		Social		Natural Env.		Economy	
			Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score
1	Do Nothing	No	4	1.75	4	0.47	4	0.28	1	0.50	1	0.50
2	Channel Reconfiguration	No	3	1.91	3	0.53	1	0.69	1	0.50	3	0.19
3	Channel Reinforcement	No	2	1.92	1	0.67	3	0.56	4	0.38	2	0.32
4	Hybrid	Yes	1	2.00	2	0.64	1	0.69	1	0.50	4	0.17

7.2.1 Opinion of Probable Costs

A Class D opinion of probable costs for the various in-stream works was prepared as per the City of Ottawa Cost Estimate Classification System. The opinion of probable costs considers capital costs along with City prescribed allowances and project contingency as outlined in **Table 7-5**.

Table 7-5: Summary of Applied Cost Allowances and Contingency

Allowance	Description	City Recommended Range (% of Capital Cost)	Value Applied
Engineering	Predesign/design, construction administration, studies, etc.	15% to 25%	25%
Property	Purchase, lease, easements, appraisals, legal support, etc. (Property cost implications unknown at this time. Assumed that NCC will allow access to property at no cost to the City.)	City Estimate	0%
Utilities	Relocation/protection of utilities, etc. (Few utilities expected.)	5% to 20%	5%
City Internal Costs	Project management, traffic management, water/sewer services, etc.	7% to 10%	7%
Miscellaneous	Permits, public art, communications, etc.	5%	5%
		Subtotal	42%
Contingency	Applied to capital cost estimate **plus above allowances.**	40% to 50%	40%
		Total Allowances + Contingencies as a % of Capital Cost Estimate	**98.8%**

A summary of the Class D opinion of probable costs for the for the in-stream component of the alternative solutions is provided in **Table 7-6**. Details of the estimates can be found in **Appendix M**.

Table 7-6: Summary of Opinion of Probable Costs

Description	Channel Reconfiguration	Channel Reinforcement	Hybrid
Capital Cost	$2.87M	$1.73M	$3.08M
Allowances	$1.20M	$0.73M	$1.30M
Contingency	$1.63M	$0.98M	$1.75M
Total Cost	**$5.70M**	**$3.43M**	**$6.13M**

8 PREFERRED ALTERNATIVE

The following section provides a summary of the preferred alternative to mitigate cumulative impacts to Mud Creek. The preferred alternative includes recommended stormwater management measures along with some in-stream measures. The evaluation process which identified the preferred alternative is described in **Section 7**.

8.1 STORMWATER MANAGEMENT MEASURES

Stormwater management measures are an integral part of the approach to mitigating impacts to Mud Creek. The existing end-of-pipe SWM facilities have the greatest influence on the magnitude and quality of the runoff from developed areas before it is discharged in Mud Creek. Pond 1 will be expanded to provide additional controls following recommendations of the Master Servicing completed in support of the EUC MUC Community Design Plan. It is expected that Pond 2 and Pond 3 will remain in place and be maintained moving forward. Proposed developments which do not drain to these facilities may need peak flow attenuation and will need to consider the downstream in-stream flow regime to establish control needs.

While subsurface conditions (i.e. low permeability soils, sensitive clays, high groundwater conditions and/or shallow bedrock) may limit the potential LID options available for implementation, it has been shown that LID measures have the potential to provide some benefits in mitigating cumulative impacts in Mud Creek. Therefore, where site conditions permit, opportunities to include LID measures for runoff reduction and control should be taken.

8.1.1 New Developments

In planning new developments, it is expected that opportunistic implementation of LID will take place. The major landowners in the EUC CDP have committed to incorporating the following measures in future developments:

- Tree planting programs in parkland;
- Infiltration trenches in backyards of singles and townhomes where feasible; and
- 18 m right-of-way widths for most local roadways to ensure healthy street trees.

8.1.2 City Projects

City projects also need to consider opportunistic implementation of LID measures for stormwater management. While infiltration may not be possible due to subsurface conditions, evaporation, evapotranspiration and filtration should be considered. One example is the use of biofiltration for the recently constructed Chapel Hill Park and Ride facility.

8.2 IN-STREAM WORKS

The recommended in-stream measures rely on a combination of approaches including the implementation of several restoration concepts previously identified by the NCC (Groupe Rousseau Lefebvre and JTBES, 2014) along with channel reinforcement for creek sections not mitigated by the restoration concepts. Where floodplain extension is possible, channel reconfiguration elements have been recommended whereas in areas where floodplain extension is not possible, channel reinforcement treatment has been recommended.

This recommended alternative would be composed of the following in-stream works (illustrated in **Figure 8-1**):

Channel Reconfiguration would include the implementation of the following in-stream projects:

- Site 6-2: Move creek east into isolated land parcel; extend floodplain and locally increase meandering; install grade control riffles and revegetate.
- Site 9-2: Extend floodplain; increase meandering; move creek away from road right of way; install grade control riffles; increase existing channel length to increase sinuosity from 1.0 to 1.15 and revegetate.
- Sites 12 and 13: Realign channel and create floodplain access on inside bend; increase vegetated buffer on outside bend.

Implementation of this reconfiguration work will undoubtedly impact some adjacent riparian vegetation and will necessitate some restoration including tree planting.

Channel Reinforcement: Place granular material, generally up to the 1:2-yr flood level. For the upper 1,400 m this material may be placed over the existing creek bed/bank and the channel footprint would be maintained i.e. no widening. However, the existing substrate may have to be replaced with an equal thickness of channel reinforcement material, for the lower 400 m portion of the creek, to avoid increasing flood levels and associated flood risks for adjacent properties. It is expected that this work will impacts some adjacent riparian vegetation and will necessitate some restoration. For costing purposes, we have assumed approximately 900 trees will need to be planted as part of the reinforcement works.

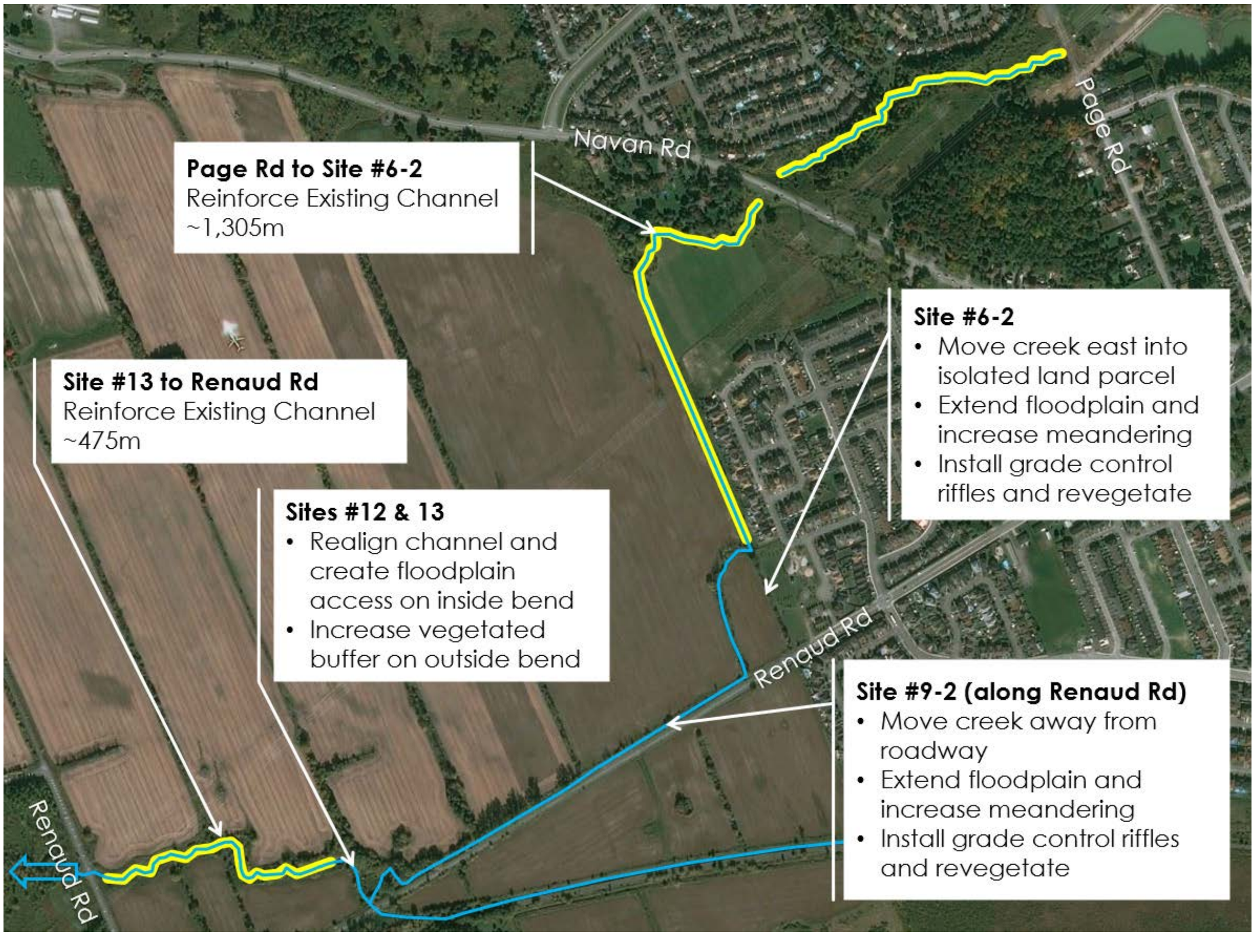


Figure 8-1: Recommended In-Stream Works

8.3 COMMENTS RECEIVED DURING PUBLIC CONSULTATION

The record of comments received during the public consultation period is included in Appendix N.

The National Capital Commission (NCC) provided the only comments specific to the design alternatives. The NCC suggested a fourth alternative that would have relocated the channel in Site 9-2 to the south side of Renaud Road, within a wetland area constructed between Renaud Road and the abandoned railway corridor. The City examined the alternative but found that the proposal would involve substantial additional costs, but provide little additional benefit to satisfying the objectives of the cumulative impact study.

Comments were also received from developers in the East Urban Community that related to land use assumptions and model parameters that are to form the basis of cost sharing for the design and construction of the preferred alternative. Resolution of the developers concerns with respect to cost sharing will be addressed as part of the process to amend the Area E-3 Stormwater Development Charge Bylaw.

8.4 IMPLEMENTATION PLAN

The following outlines key items of an overall implementation plan for the in-stream works.

1. Establish approach to funding/cost sharing for the natural inventories, design, construction and post-construction monitoring activities. The major funding partners will include the City, land developers and the National Capital Commission.
2. Establish the scope of and undertake preliminary and detailed design studies including natural inventories for the recommended in-stream works.
3. Continue public and agency consultation process. As the City proceeds with more detailed studies and design work, consultation with agencies will continue, including Ontario Ministry of the Environment, Conservation and Parks, Fisheries and Oceans Canada and the Ontario Ministry of Natural Resources and Forestry. More targeted public consultation is recommended during the detailed design process.
4. Based on findings during the preliminary and detailed design stages, identify any priority locations for stream improvements, such as locations in the middle and lower reaches where the most susceptible (finer) substrate materials are present.

8.4.1 Monitoring

Details of a post-construction monitoring program will be developed during the preliminary and detailed design stages, with a primary emphasis on monitoring of geomorphologic conditions of the in-stream works.

8.4.2 Residual impacts and mitigation measures

Implementation of the preferred alternative, specifically the in-stream measures including channel reconfiguration and reinforcement, is expected to result in short-term environmental impacts. These include disruption of fish and wildlife in Mud Creek and its riparian area and the loss of riparian vegetation. Mitigation measures may include the following:

- Identifying any potential fish and wildlife (with attention to species at risk) that may be present within the project areas and developing site specific management and monitoring plans. These will likely include undertaking fish and wildlife sweeps before implementing flow diversions.
- Undertaking tree inventories to enable the development of a tree management plan which will include tree protection and/or relocation where deemed practical and desirable.
- Developing and implementing site specific water management and sediment and erosion control plans.

A preliminary assessment of the hydraulic impact of the study recommendations under 2-year and 100-year flow conditions was completed (Refer to **Appendix D**). The analysis was completed assuming the channel reinforcement is placed on top of the existing channel bed without any excavation (i.e. channel invert raised by thickness of reinforcement). The modelling analysis shows that if the conservative 100-year peak flow is used, there is a potential for minor encroachment of floodwaters onto the rear yards of six adjacent properties along Whispering Winds Way. However, with the proposed peak flow controls for the Pagé Road SWM Pond and the proposed widening/floodplain extension of the downstream creek sections (Sites 6-2 and 9-2), no flooding of the adjacent lots would occur. More detailed hydraulic modelling will be prepared during the preliminary and detailed design to ensure that the implementation of the proposed measures does not negatively impact private property.

8.4.3 Permits and Approvals

It is anticipated that the following approval and/or permits may be necessary for the implementation of the preferred alternative:

- Permit under Conservation Authorities Act Section 174/06, Development, Interference with Wetlands and Alterations to Shorelines and Watercourses Regulation administered by the Rideau Valley Conservation Authority.
- Permit under the *Endangered Species Act administered by the* Ontario Ministry of the Environment, Conservation and Parks.
- Environmental Compliance Approval *administered by the* Ontario Ministry of the Environment, Conservation and Parks.
- Environmental Activity and Sector Registry or Permit to Take Water may be required if the construction involves taking, dewatering, storage or diversion of water in excess of 50 m^3/day - *administered by the* Ontario Ministry of the Environment, Conservation and Parks.
- Authorization under the Fisheries Act administered by Fisheries and Oceans Canada (DFO).
- License to collect fish for scientific purposes will be required from the Ontario Ministry of Natural Resources. It is responsible for in-water works timing windows in Ontario under agreement with DFO and are also responsible for fish in Ontario under the provincial *Fish and Wildlife Conservation Act*.
- Federal Land Use, Design and Transaction Approvals for works on federal lands administered by the National Capital Commission.
- Amendment to Gloucester Area E-3 Stormwater DC Bylaw.

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Appendix A CLASS EA NOTICE OF STUDY COMMENCEMENT AND ONLINE INFORMATION SESSION

Appendix B TM1: MUD CREEK INITIAL CONVERSION JFSA SWMHYMO MODELLING

Appendix C TM2: MUD CREEK PCSWMM EXISTING CONDITIONS MODEL BUILD AND CALIBRATION

Appendix D TM - PRELIMINARY FLOODING EXTENTS

Appendix E TM6: MUD CREEK EXISTING CONDITIONS WATER QUALITY MODELLING AND RESULTS

Appendix F TM4: MUD CREEK PCSWMM FUTURE CONDITIONS MODEL BUILD AND RESULTS

Appendix G TM8: MUD CREEK FUTURE CONDITIONS WATER QUALITY MODELLING AND RESULTS

Appendix H TM7: MUD CREEK CUMULATIVE IMPACT STUDY – HYDROLOGIC ASSESSMENT OF SCENARIOS

Appendix I TM3: MUD CREEK CUMULATIVE IMPACTS STUDY – LOW IMPACT DEVELOPMENT RETROFIT OPPORTUNITIES AND SCENARIOS

Appendix J EXCEEDANCE HOURS CHARTS

Appendix K IN-STREAM WORKS CONCEPTUAL DRAWINGS

Appendix L EVALUATION OF ALTERNATIVES

Appendix M OPINION OF PROBABLE COSTS

Appendix N COMMENTS RECEIVED DURING PUBLIC CONSULTATION