PINECREST CREEK/WESTBORO STORMWATER MANAGEMENT RETROFIT STUDY

OTTAWA, ON

FINAL REPORT

May 2011

Prepared for: Infrastructure Services & Community Sustainability, City of Ottawa

Prepared by: J.F. Sabourin & Associates Inc.

In association with:
JTB Environmental Systems Inc.
Kidd Consulting
Baird & Associates

J.F. Sabourin and associates Inc.
www.jfsa.com

JFSA Water Resources and Environmental Consultants

JFSA Water Resources and Environmental Consultants

J.F. Sabourin and Associates Inc.
52 Springbrook Drive, Ottawa, ON K2S 1B9
tel.: 613.836.3884, fax: 613.836.0332,
www.jfsa.com

PINECREST CREEK/WESTBORO STORMWATER MANAGEMENT RETROFIT STUDY

OTTAWA, ON

FINAL REPORT
May 2011

Prepared for:

City of Ottawa

Prepared by:

J.F.Sabourin and Associates Inc.

J.F. Sabourin, M.Eng., P.Eng.

H.C. Wilson, M.Sc., P. Geo.

JFSA Ref. No.: 741-09

PREFACE

This final report and supporting appendices document the work carried out for the Pinecrest Creek/Westboro Stormwater Management Retrofit Study from September 2009 to May 2011.

The City of Ottawa (the City) initiated the Pinecrest Creek/Westboro Stormwater Management Retrofit Project to improve stormwater management (SWM) in the Pinecrest Creek subwatershed and in the adjacent Westboro area. The SWM Retrofit is one of sixteen short-term projects included in the City's Ottawa River Action Plan. When implemented, the Retrofit Plan developed and selected by this study will help to:

- Improve water quality in Pinecrest Creek and the Ottawa River;
- Reduce flooding and erosion along the Creek;
- Improve the health of the Creek; and
- Reduce closures at Westboro Beach.

This study and the resulting Retrofit Plan also provides a template for how stormwater management retrofits can be carried out elsewhere in Ottawa, as the City moves forward to develop a comprehensive Stormwater Management Retrofit Master Plan.

Why is a SWM Retrofit Needed?

The Pinecrest Creek/Westboro area – like much of the core of the City – was developed before there was a requirement for municipalities to manage stormwater. For this reason, there are few facilities to treat stormwater in the study area. The various conditions cited above – existing erosion, water quality concerns, degraded health of the Creek – stem in whole or in part from uncontrolled stormwater runoff.

Previous Work

In response to the on-going erosion in the Pinecrest Creek corridor, the National Capital Commission, which owns most of the Creek corridor lands, commissioned a restoration plan in 2006 to identify a strategy to rehabilitate the Creek's degraded condition, and to improve its ability to accommodate the very "flashy" hydrology given current conditions with no SWM retrofit measures to better manage excess runoff volumes. The resultant Pinecrest Creek Restoration Plan (JTB Environmental Services et al, 2007) identified and prioritized a number of projects along the length of the Creek, some of which were implemented in 2008.

The City has also completed studies related to the impacts of wet weather flows on Westboro Beach and the Ottawa River (Baird & Associates, 2002; 2004; 2008). The untreated storm flows from both Pinecrest Creek, and from storm outfalls discharging directly to the Ottawa River upstream of the Beach, have been identified as contributing factors to frequent beach closures due to elevated bacterial counts in the Ottawa River.

Prior to the initiation of the Pinecrest Creek/Westboro SWM Retrofit Study, a SWM criteria and targets study was accelerated through a separate, preliminary assignment to determine subwatershed based SWM criteria for specific projects in the Pinecrest Creek subwatershed. This accelerated assessment was done to accommodate the imminent development schedule for those projects. The projects involved were: the Algonquin CCTBS building, the associated relocation of the Southwest Transitway and the City Archives building. The results of this preliminary assessment, referred to as the *Pinecrest/Centrepointe SWM Criteria Study* (J.F. Sabourin and Associates et al, 2010), have been integrated into the Pinecrest Creek/Westboro SWM Retrofit Plan.

How the Study was Carried Out?

This study examined ways in which stormwater management measures can be retrofitted into the community. A range of retrofit scenarios was defined and evaluated to identify a preferred SWM Retrofit Strategy for the study area.

The following key tasks were completed as part of this study:

1) a careful and knowledgeable synthesis of existing information related to the local environmental conditions, drainage areas, stream conditions and infrastructure (Step 1);
2) confirmation of SWM objectives and targets (Step 2);
3) identification of potential retrofit measures and opportunities including lot level, conveyance, and end-of-pipe opportunities and definition of alternative retrofit scenarios (Step 3);
4) evaluation of various SWM retrofit scenarios using suitable modelling and analytical tools to select a preferred SWM retrofit scenario (Step 4);
5) development of implementation and monitoring plans for the preferred SWM retrofit strategy (Step 5); and
6) documentation of the project's methodology and lessons learned.

SWM Guidelines for Infill and Redevelopment to complement this study are being prepared and will be provided under separate cover.

The work and results of Step 1are summarised in Part A of the report: Setting the Stage – Existing Conditions and SWM Retrofit Potential. The processes and results of Steps 2, 3 and 4 are described in Part B: Stormwater Retrofit – Selection of the Preferred Scenario. A summary and record of the public consultation that was done as part of this Municipal Class EA project are provided in Part C. The Implementation and Monitoring Plan is contained in Part D.

Municipal Class Environmental Assessment

The study was conducted as a Master Plan under the Municipal Class Environmental Assessment (MCEA) process, as follows: The existing conditions are described and the problems as well as opportunities and a range of solutions are identified; and the various solutions are evaluated and the predicted outcomes compared to arrive at a preferred solution – the preferred SWM Retrofit Plan.

Approach #1 of the MCEA process was followed (MEA, 2007). This approach involves the preparation of a Master Plan document at the conclusion of Phases 1 and 2 of the MCEA process. The Master Plan document is made available for public comment prior to being approved by the municipality.

As a Master Plan this study was done at a broad level of assessment. More detailed investigations will be conducted at the project-specific level in order to fulfil the Municipal Class EA documentation and consultation requirements for Schedule B and C projects identified within the SWM Retrofit Plan.

As required by the MCEA process, this SWM Retrofit Plan will be reviewed every 5 years.

The following team of consultants was formed to work on the study:

Pinecrest Creek/Westboro SWM Retrofit Project Team

- J.F. Sabourin & Associates Inc. - JFSA Team Members:

  Jean-François Sabourin – Senior Water Resources Engineer
  Heather Wilson – Senior Project Manager / Hydrogeologist
  Colin Brennan – Water Resources EIT
  Laura Pipkins – Water Resources EIT
  Kaila McTavish – Physical Geographer / Geomatics Specialist
  Josée Forget – Environmental Geographer / Water Resources
  Lieserl Woods – Environmental Scientist
  Melanie O'Brien – Administrative Support

- JTB Environmental Systems Inc.
- Kidd Consulting
- Baird & Associates

ACKNOWLEDGEMENTS

The Pinecrest Creek/Westboro SWM Retrofit Study has been accomplished with the assistance of numerous people and agencies. The Project Team would like to express its appreciation to all those individuals, who contributed their time, effort and information. In particular the Team would like to thank City of Ottawa staff, Senior Project Manager Darlene Conway, P. Eng., and the members of the Public Advisory Committee and Technical Advisory Committee for their efforts during the study.

The Team would also like to thank the local residents and others who attended the public meetings and who provided invaluable perspectives on the proposals brought before them.

PINECREST CREEK / WESTBORO
STORMWATER MANAGEMENT RETROFIT STUDY

FINAL REPORT

TABLE OF CONTENTS

PART A: SETTING THE STAGE

EXISTING CONDITIONS AND SWM RETROFIT POTENTIAL

PART A: SETTING THE STAGE:

EXISTING CONDITIONS AND SWM RETROFIT POTENTIAL

CONTENTS

TABLES

FIGURES

1. INTRODUCTION

This part of the report, Part A, provides a summary of the data collection, analysis and review undertaken in **Step 1: Background Information and Inventory** of the Pinecrest Creek/Westboro SWM Retrofit Study.

Step 1 was conducted in two parts. The first part was the collection, review and analysis of available study area information further to the data already collected for the Pinecrest/Centrepointe SWM Criteria Study. This information included data on the existing environmental and built environment conditions, an augmentation of drainage area information, and a summary of anticipated future development. The second part of Step 1 involved inventorying the following: stream corridor infrastructure; land use, road and development types; stream bank stability, erosion threats, flood risk and fluvial geomorphology in the stream corridors. In addition, a preliminary screening of the outfalls data from the infrastructure inventory was done to identify any potential end-of-pipe retrofit opportunities. In the same vein, data were collected to characterize the conveyance systems and residential lots across the study area as a preliminary screening for lot level and conveyance SWM measures opportunities.

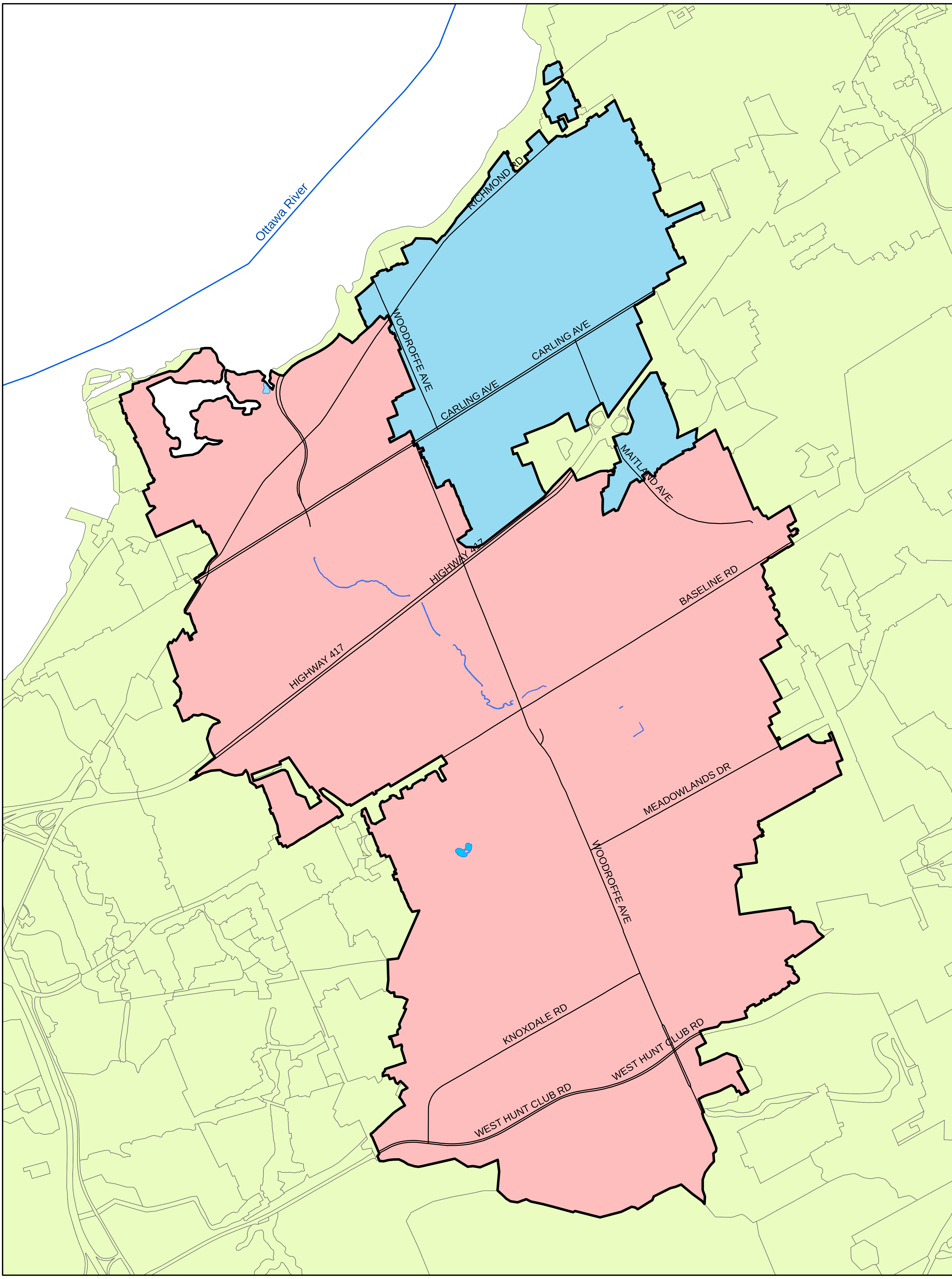
The geographical extent of the project's study area is described in Section 2 of this part of the report. A description of the study area's existing conditions is provided by Section 3 and supporting appendices. Descriptions of the field inventories and summaries of their results are provided in Sections 4 and 5 with further details in supporting appendices. This includes information on the end-of-pipe, conveyance system and lot level information.

The information gathered in Step 1 was used in the development of SWM retrofit opportunities (Step 3) and for the Assessment of Scenarios (Step 4). The findings from the second part of Step 1, the study inventories, were also used in the Development of the Implementation and Monitoring Plan (Step 5).

2. STUDY AREA

The Pinecrest Creek/Westboro SWM Retrofit study area is located in the west end of the City of Ottawa urban area and is composed of the entire Pinecrest Creek subwatershed as well as the seven storm sewer catchment areas immediately upstream of Westboro Beach. These sewer catchments are along the Ottawa River directly to the northeast of Pinecrest Creek and within the Westboro neighbourhoods. The total area of the Pinecrest Creek subwatershed is approximately 1,920 hectares. The Westboro drainage area within the study area is approximately 450 hectares. This area of Westboro is included in the study area because the stormwater management retrofit strategy needs to address not only the Pinecrest Creek subwatershed stormwater discharges but also the discharges from the storm water outfalls discharging directly to the Ottawa River upstream from Westboro Beach.

The locations of the Pinecrest Creek subwatershed and adjacent Westboro area are shown on Figure 1. The drainage areas in the Pinecrest Creek subwatershed and in Westboro are shown in more detail in Figures 2a and 2b, respectively. The drainage area information was obtained from the City's GIS database.



LEGEND:
- Ottawa River
- Main Roads
- Surface water within Study Area
- Westboro Study Area
- Pinecrest Study Area

CLIENT: Ottawa

BY: JFSA Water Resources and Environmental Consultants

NOTES:
- The background data was provided by the City of Ottawa

PROJECT: PINECREST CREEK / WESTBORO SWM RETROFIT STUDY

TITLE: Study Area

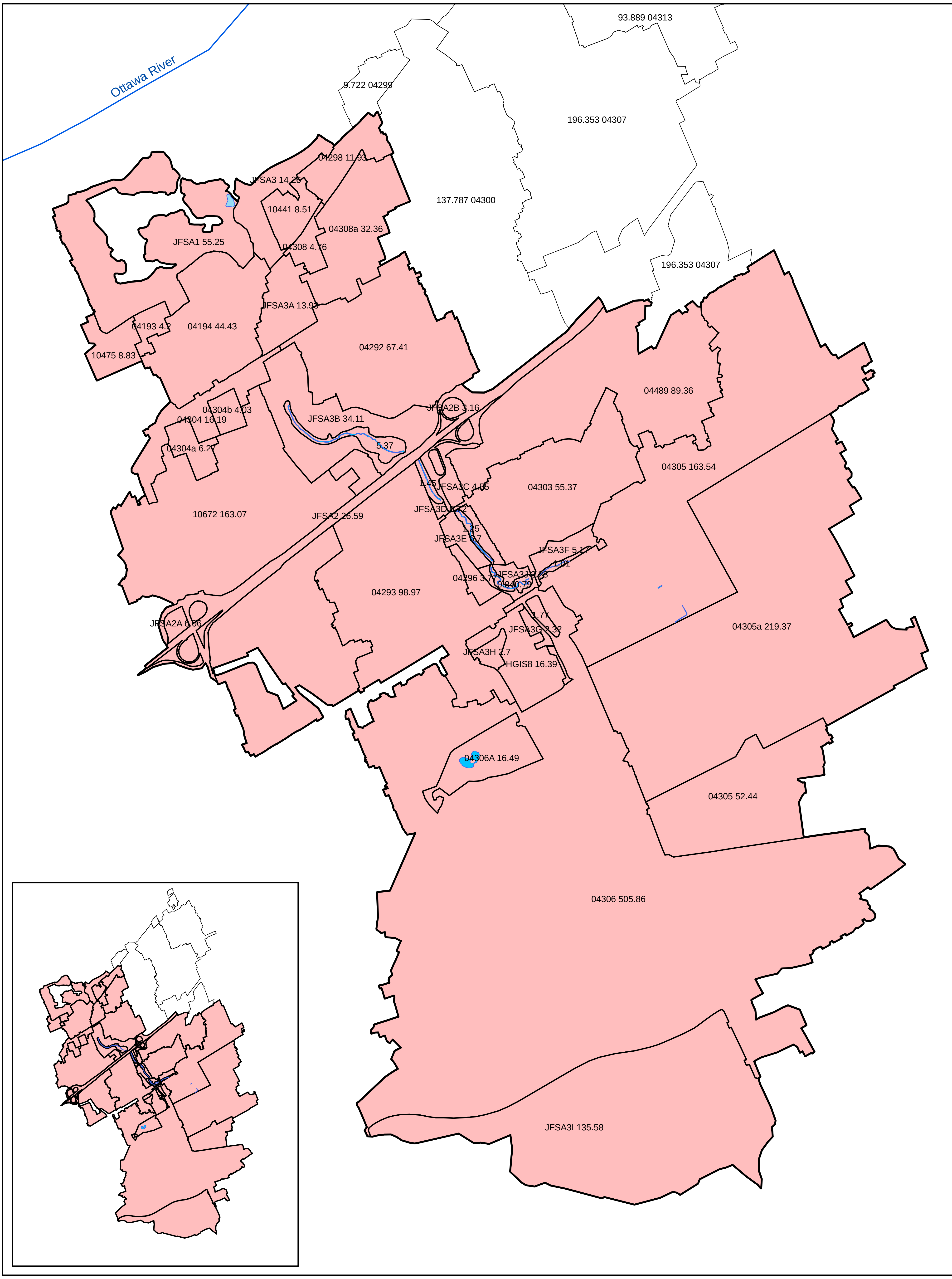
0 160 320 640 960 1,280 Meters

N

PROJECT No. 741-09			FIGURE 1
DESIGN	KM		
GIS	KM		
CHECK	JFS		MAP REF.: 741_09\Design\GIS\Maps\StudyArea_revised2011.mxd
REVIEW	JFS		

NOV 2010

REV. 2



LEGEND:

- Ottawa River
- Surface water within Study Area
- Pinecrest Storm Catchments

CLIENT: Ottawa

BY: JFSA Water Resources and Environmental Consultants

NOTES:

- The background data was provided by the City of Ottawa

0 140 280 560 840 1,120 Meters

N

PROJECT:

PINECREST CREEK / WESTBORO SWM RETROFIT STUDY

TITLE:

Drainage Area in Pinecrest Part of the Study Area

PROJECT No. 741-09

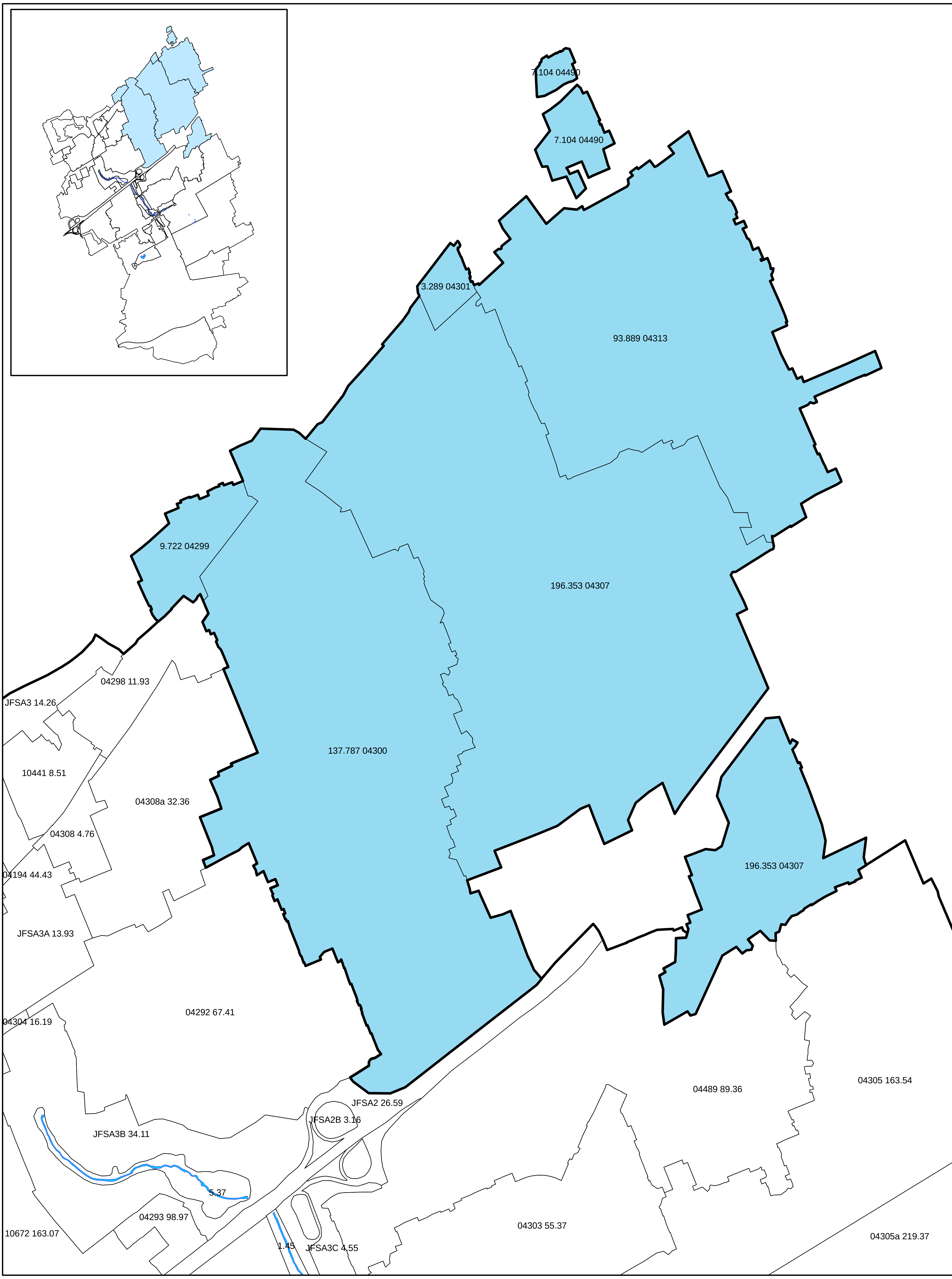
FIGURE 2a

DESIGN	KM
GIS	KM
CHECK	JFS
REVIEW	JFS

MAP REF.: 741_09\Design\GIS\Maps\StudyArea_Pinecrest.mxd

NOV 2009

REV. 2



LEGEND:
- Surface water within Study Area
- Westboro Storm Catchments
- Pinecrest Storm Catchments

CLIENT: Ottawa

NOTES:
- The background data was provided by the City of Ottawa

0 80 160 320 480 640 Meters

N

NOV 2009 REV. 2

BY: JFSA Water Resources and Environmental Consultants

PROJECT:
PINECREST CREEK / WESTBORO SWM RETROFIT STUDY

TITLE:
Drainage Area in Westboro Part of the Study Area

PROJECT No. 741-09

DESIGN	KM
GIS	KM
CHECK	JFS
REVIEW	JFS

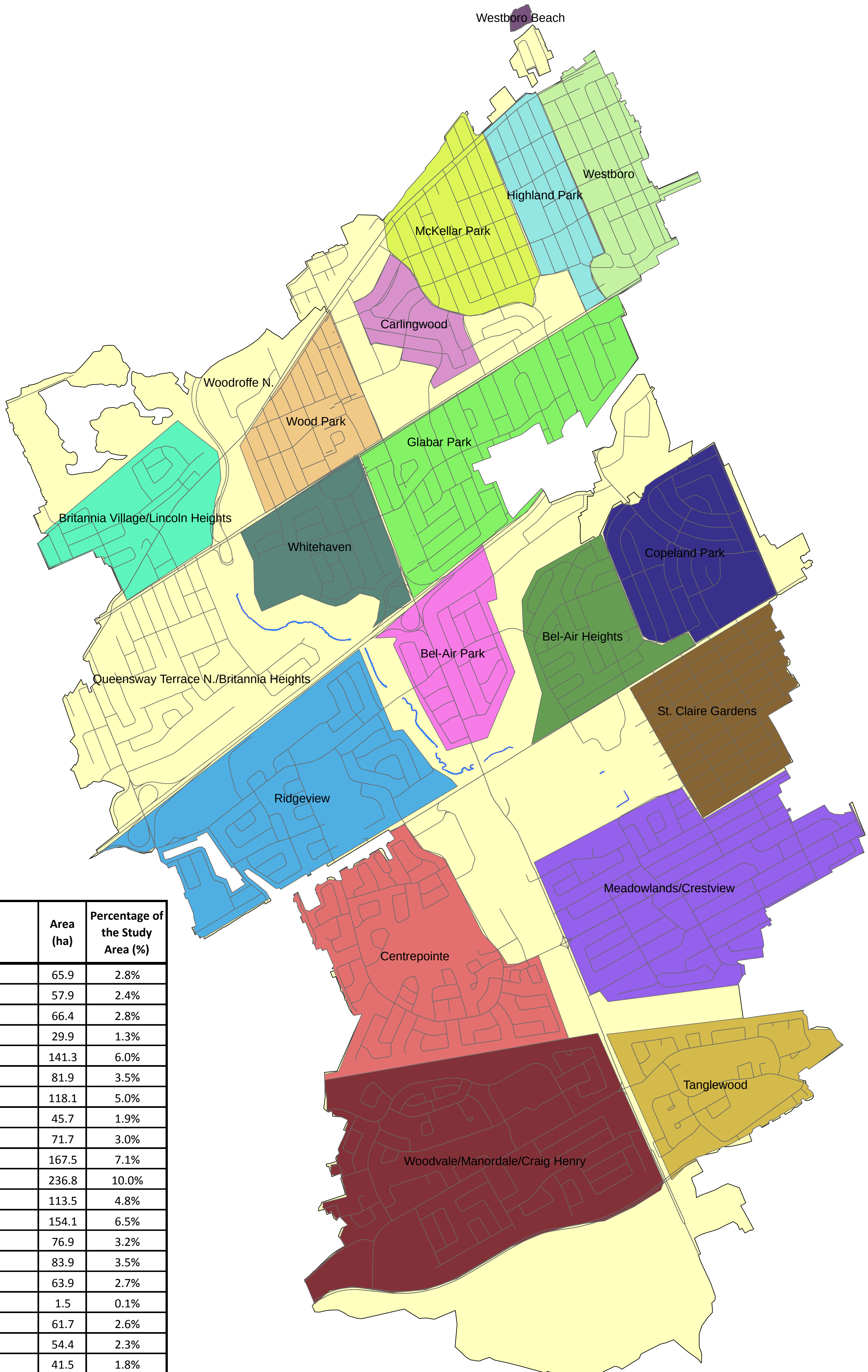
FIGURE 2b

MAP REF.: 741_09\Design\GIS\Maps\StudyArea_Pinecrest.mxd

The study area contains 20 residential neighbourhoods. The distribution of these neighbourhoods across the study area, in the Pinecrest Creek subwatershed and Westboro, is shown in Figure 3. The land area of each neighbourhood is noted in Table 1 below. The neighbourhoods listed in bold are in the Westboro part of the study area; the remaining neighbourhoods are in the Pinecrest Creek subwatershed. Additional information on the study area's land use is provided in Section 4.2.

Table 1: Study Area's Neighbourhoods

Communities/Neighbourhoods	Area (ha)	Percentage of the Study Area (%)
Bel-Air Heights	65.9	2.8%
Bel-Air Park	57.9	2.4%
Britannia Village/Lincoln Heights	66.4	2.8%
Carlingwood	**29.9**	**1.3%**
Centrepointe	141.3	6.0%
Copeland Park	81.9	3.5%
Glabar Park	**118.1**	**5.0%**
Highland Park	**45.7**	**1.9%**
McKellar Park	**71.7**	**3.0%**
Meadowlands/Crestview	167.5	7.1%
Woodvale/Manordale/Craig Henry	236.8	10.0%
Q-Way Terrace N./Britannia Heights	113.5	4.8%
Ridgeview	154.1	6.5%
St. Claire Gardens	76.9	3.2%
Tanglewood	83.9	3.5%
Westboro	**63.9**	**2.7%**
Westboro Beach	**1.5**	**0.1%**
Whitehaven	61.7	2.6%
Wood Park	54.4	2.3%
Woodroffe North	**41.5**	**1.8%**
Communities/Neighbourhood Total	1734.4	73.2%
Study Area's Open Space and Other Areas not included in Communities/Neighbourhoods	635.1	26.8%
STUDY AREA TOTAL	2369.5	100.0%



Communities / Neighbourhoods	Area (ha)	Percentage of the Study Area (%)
Bel-Air Heights	65.9	2.8%
Bel-Air Park	57.9	2.4%
Britannia Village/Lincoln Heights	66.4	2.8%
Carlingwood	29.9	1.3%
Centrepointe	141.3	6.0%
Copeland Park	81.9	3.5%
Glabar Park	118.1	5.0%
Highland Park	45.7	1.9%
McKellar Park	71.7	3.0%
Meadowlands/Crestview	167.5	7.1%
Woodvale/Manordale/Craig Henry	236.8	10.0%
Q-Way Terrace N./Britannia Heights	113.5	4.8%
Ridgeview	154.1	6.5%
St. Claire Gardens	76.9	3.2%
Tanglewood	83.9	3.5%
Westboro	63.9	2.7%
Westboro Beach	1.5	0.1%
Whitehaven	61.7	2.6%
Wood Park	54.4	2.3%
Woodroffe North	41.5	1.8%
Communities/ Neighbourhoods Total	**1734.4**	**73.2%**
Open Space and Areas not Included in the City Communities / Neighbourhoods	635.1	26.8%
STUDY AREA TOTAL	**2369.5**	**100.0%**

LEGEND:

Roads
Total StudyArea
Water

Communities

Bel-Air Heights
Bel-Air Park
Britannia Village/Lincoln Heights
Carlingwood
Centrepointe
Copeland Park
Glabar Park
Highland Park
McKellar Park
Meadowlands/Crestview
Queensway Terrace North/Britannia Heights
Ridgeview
St. Claire Gardens
Tanglewood
Westboro
Westboro Beach
Whitehaven
Wood Park
Woodroffe North
Woodvale/Manordale/Craig Henry

CLIENT: Ottawa

NOTES:
- The following background data was provided by the City of Ottawa

0 150 300 600 900 1,200 Meters

N

NOV 2009

REV. 0

BY: JFSA Water Resources and Environmental Consultants

PROJECT: PINECREST CREEK / WESTBORO SWM RETROFIT STUDY

TITLE: Neighbourhoods within Pinecrest Creek/ Westboro Study Area

PROJECT No. 741-09

DESIGN	KM	
GIS	KM	
CHECK	JFS	
REVIEW	JFS	

FIGURE 3

MAP REF.: 741_09\Design\Maps\Neighbourhoods.mxd

3. EXISTING CONDITIONS

Pinecrest Creek is a small, highly altered stream within an urbanized subwatershed. As an urban watercourse, Pinecrest Creek has been altered from its natural state both directly and indirectly. The Creek and its (former) tributaries have been straightened, buried and realigned and its riparian vegetation has been reduced, modified or removed.

The main channel of Pinecrest Creek is approximately four (4) km long, however only 2.5 km are open with the remaining length as culverts or piped. The culvert and piped sections of the Creek includes the reaches between West Hunt Club Road and Baseline Road and the reaches from just south of Carling Avenue to immediately upstream of the confluence with the Ottawa River where the Creek emerges at the Ottawa River Parkway. The open creek corridor extends from Baseline Road to just south of Carling Avenue. This open corridor is part of the green corridors and parklands owned by the National Capital Commission (NCC).

The Built Environment

The land use within the Pinecrest Creek subwatershed has changed over the years from forest, to agriculture, to its current state: predominantly urban development. The subwatershed has been influenced by urban development to such a degree that the area has been almost completely built-out, with only minor undeveloped areas remaining. Transportation networks transect the subwatershed and encroach upon the creek corridor. Overall, the Pinecrest Creek subwatershed is considered to be one of the City's most urbanized subwatersheds outside of the City's urban centre, having a total impervious cover of 35%.

The current conditions of Pinecrest Creek are a reflection of typical urban stressors:

- Transportation and recreational uses: encroachments of infrastructure into the creek corridor have constrained the Creek's ability to move and adjust to changes in flow regimes;
- Urban development within the subwatershed over time: increasing imperviousness and efficient storm drainage networks have resulted in much higher runoff volumes conveyed more quickly to the Creek; and
- A lack of stormwater management (SWM): The majority of development within the subwatershed occurred before current SWM requirements, resulting in significant changes to the pre-development hydrology (higher peak flows and runoff volumes, changed timing) and degraded water quality. Typical of urbanized areas, the greatest increases in runoff volume as a proportion of rainfall volume have occurred during the most frequent storm events. For Pinecrest Creek, this has resulted in greatly increased "work" being done on the channel over the years (as compared to pre-development conditions), creating accelerated erosion rates, damaging fish habitat and threatening infrastructure.

In addition to these on-going impacts of the existing development, there are continuing development pressures in the study area, including:

- Centrepointe Town Centre (redevelopment)
- Algonquin Campus expansion/redevelopment
- Southwest and West Transitway expansions
- Laurentian High School redevelopment
- Westboro infill and redevelopment.

The Natural Environment

The study area is in a relatively gently sloping landscape underlain by glacial and post-glacial deposits. These deposits or sediments range from fine-grained silt and silty clay to medium-grained sands. The silts and silty clays, which may include lenses of sand and be underlain by clay, silt and silty clay of marine origin, are found in the middle swath of the Pinecrest Creek subwatershed. They comprise approximately 37% of the study area. These fine-grained sediments are abandoned river channel deposits from a time when the Ottawa River was swollen with glacial melt waters. The underlying marine clay and silt are Champlain Sea deposits, an inland sea that flooded parts of the Ottawa valley following the retreat of the glaciers. The medium-grained sands, which are also abandoned channel or estuarine deposits, are located along the western edge of the Pinecrest Creek subwatershed and in the headwaters to the south where the subwatershed extends into the Greenbelt. The sands underlie approximately 20% of the study area. Approximately 35% of the study area is underlain by glacial till - a heterogeneous mixture of material ranging from clay to large boulders. Most of the Westboro part of the study area is underlain by the till. Approximately 4% of the study area is underlain by organic deposits located in relatively small areas along the northwest and southern limits of the Pinecrest Creek subwatershed.

The thickness of these sediments over the underlying bedrock ranges from 0 metres to 25 metres, with the thicker deposits in the southern part of the study area. Only a fraction of the area has sediments over 25 metres in depth and half of the study area is underlain by five (5) metres or less of sediments. There are parts of the study area with thin to nonexistent sediment cover over the underlying bedrock. These areas of exposed or thinly covered bedrock comprise approximately 4% of the study area and are located mostly in the northwest part of the subwatershed and in small parts of the Westboro area. The underlying bedrock across the area is Paleozoic sedimentary rock ranging from sandstone and shale to limestone.

The nature of the sediments and physiographic characteristics has shaped the natural drainage systems that developed in the study area. For example, the presence of the finer-grained sediments with relatively low permeability results in relatively high runoff volumes (compared to sandier soils) but also higher soil moisture conditions. These conditions influence the formation of vegetative and biological communities and the amount and timing of runoff that is conveyed to the receiving creek.

Further detail regarding existing conditions of the study area, including information on the natural and built environments, is included in Appendix A.

4. STUDY AREA INVENTORIES AND SURVEYS

The study area inventories used a combination of field work and desktop accounts of existing conditions within the subwatershed. The inventories were to focus on the following key aspects of the stream corridor conditions and the lands whose run-off discharges to the stream corridors:

1) Infrastructure inventory within stream corridor resulting in an outfall inventory;
2) Land use, including the classification of types of roads (and expected level of service) and development types;
3) Assessment of stream bank stability, erosion threats, and capacity of crossings and flood risk (e.g. sedimentation problems); and
4) Fluvial geomorphology inventory.

The following sections provide a brief overview of the intention of each inventory, the methodology used and a summary of what was found. More detailed information is provided in the appendices.

During the fieldwork and desktop review of existing conditions, information was also collected for the preliminary screening for end-of-pipe opportunities and for lot level and conveyance measures.

4.1 Stream Corridor Infrastructure Inventory

Data on the existing stream corridor infrastructure (outfalls, retaining walls, erosion protection, etc.) were extracted from the City's GIS database. This database includes information on the structure's name, location, properties such as size, span, year of installation, materials and bearings. This information was then verified in the field, and the outfall infrastructures found in the corridor (storm sewer outfalls, culverts, retaining walls, etc.), including those structures not included in the GIS database, were identified and inspected; Figure 4 provides an example of an outfall in the Pinecrest Creek corridor. The drainage areas connected to these outfalls may range from major sewersheds to relatively small localized drainage basins. The outlet conditions were documented with pictures and GPS coordinates.

The infrastructure inventory also included the identification of sites whose ground conditions may allow daylighting of sections of the Creek that are currently in underground structures.

4.1.1 Results of Infrastructure Inventory

The location of the study area's Creek corridor and Ottawa River outfalls, inlets, culverts, erosion structures, overflow channels, ponds and pedestrian bridges were plotted. Figure 5 shows the location of the identified infrastructures found in the corridor; more detailed figures are included in Appendix B (Figures B1 and B2a-e). The outfall locations are differentiated between those plotted from the City's GIS database and those located in the field by infrastructure inventory. The outlets located by the inventory either align with the GIS database information, appear to be part of the GIS database but the location recorded in the field differs from that in the GIS database, or the outlet does not appear to be in the GIS database. These differences between the two data sources were reconciled as much as possible. In all, the City's GIS database has records for 30 outlets. The field inventory located 52 outfalls which include outfalls for smaller drainage basins such as along the Ottawa River Parkway as well as sewershed outfalls.

Figure 4: Example of Outfall in Pinecrest Creek Corridor (Outfall 04313)

The outfall photo inventory and potential daylighting location figure are included in Appendix B.

4.2 Land Use, Road and Development Types Inventory

Information on land use within the study area was compiled from the City's GIS database. Minor adjustments in the land use categories were made to facilitate the analytical work of the study's next steps. For example, one land use category, "educational institutions", was created by combining the various school level categories.

Data on the distribution of land use across the study area and on the individual drainage areas were also collected for use in the development and assessment of the SWM retrofit plan. Roads and conveyance systems were classified as either residential or arterial and mapped accordingly. This classification of road types (and expected level of service) and development types within the study area was done to facilitate the identification of potential locations for alternative drainage methods and lot level control opportunities, respectively. This information was augmented by the lot level and conveyance system data collected (described in Section 5.2).

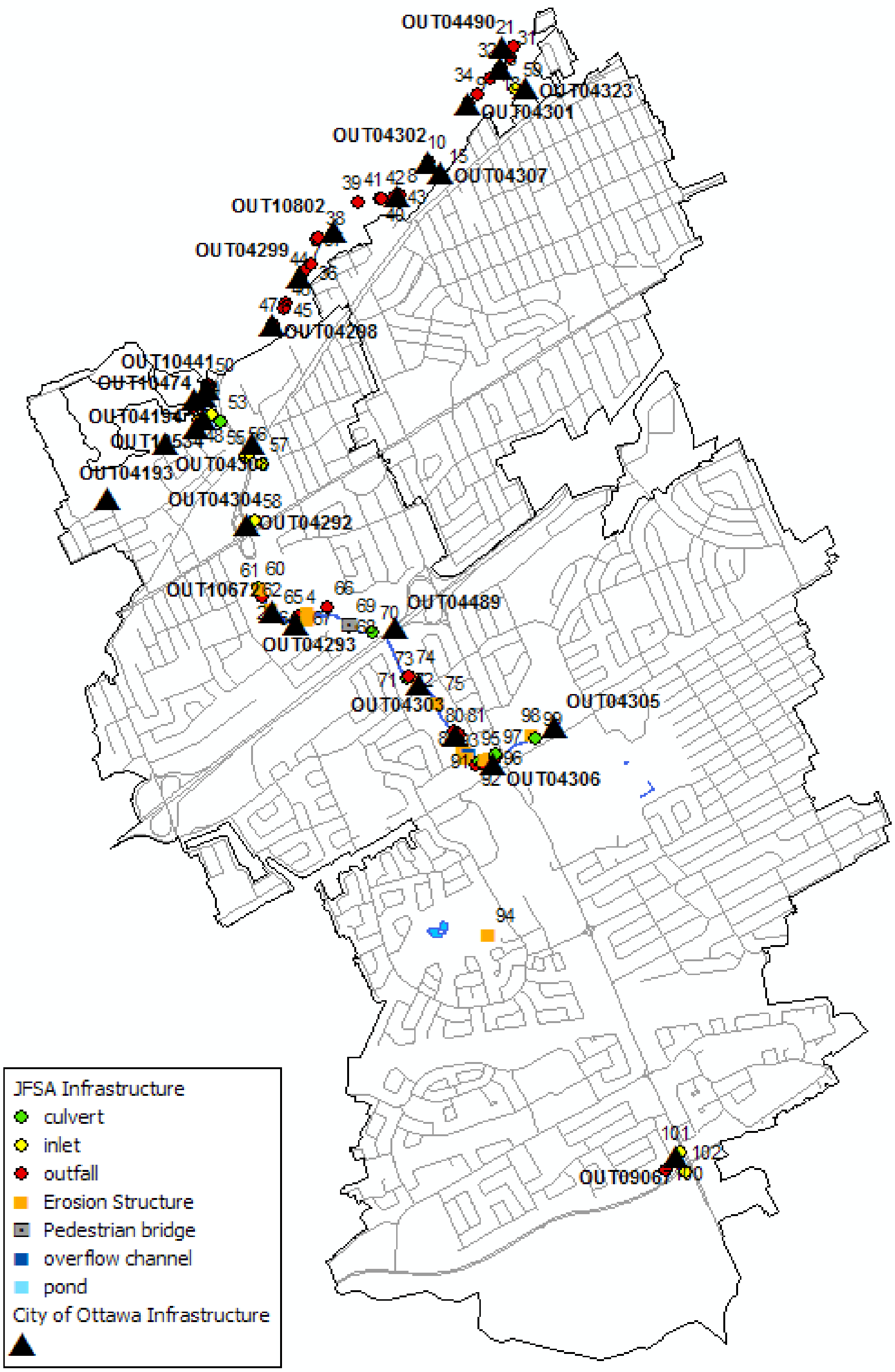


Figure 5: Location of Study Area's Stream Corridor and Ottawa River Outfalls

4.2.1 Results of Land Use, Road and Development Types Inventory

The percentage of land area occupied by each land use category is shown in Figure 6. The land used information is derived from the City's GIS database (2005 statistics).

The distribution of the following land use types across the study area is shown in a series of figures included in Appendix C (Figures C1 to C6):

- Residential
- Educational
- Institutional
- Commercial
- Industrial
- Recreational

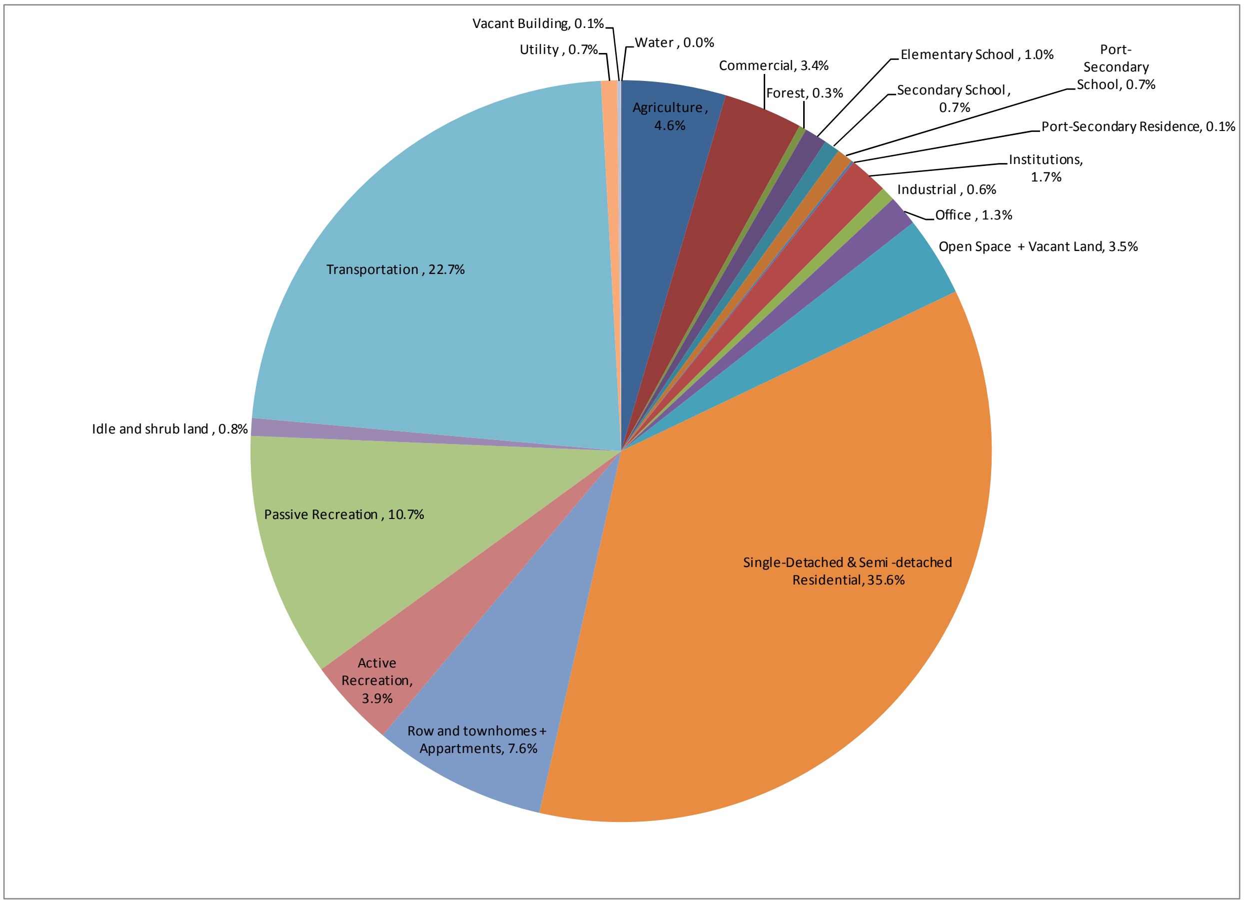


Figure 6: Land Use 2005 Breakdown for the Entire Pinecrest Creek/Westboro Study Area

4.3 Stream Bank Stability, Erosion Threats and Flood Risk Assessment

A detailed assessment of threats to infrastructure and property from erosion and bank instability was undertaken through field observations during this study as well as during previous studies on Pinecrest Creek since 2006. The purpose of the assessment was to document existing areas of concern which may undergo changes as a consequence of the implementation of stormwater retrofit practices. In addition, the scale of concern has been documented, which will become important if stream rehabilitation is deemed necessary. A geotechnical assessment may be required to further confirm threats to infrastructure due to slope instability. The second aspect of this assessment was the identification of flood sensitive areas and infrastructure based on previously documented events.

A fluvial geomorphology inventory was also undertaken to provide up-to-date information on the performance of the stream corridor's 2008 restoration works. The inventory also assessed those areas that were at moderate risk during the Pinecrest Creek Restoration Plan (2006-2007) and documented all areas of erosion risk as of 2009. These data were used to set the existing conditions for this study's SWM retrofit objectives and targets (provided in Part B of this report).

The assessment and inventory results are summarized in the following sections with more detail provided in Appendix D: Flood Risk Assessment and Appendix E: Fluvial Geomorphology Inventory.

4.3.1 Results of Stream Bank Stability and Erosion Threats Assessment

This section and referenced appendix were provided by JTB Environmental Systems Inc.

The existing conditions assessment of Pinecrest Creek shows that the Creek remains in a state of flux, attempting to respond to high energy storm inputs through expansion of its cross-section. That said the Creek is at the later stages of this readjustment, meaning that the amount of change in the system is beginning to diminish in frequency and intensity. Part of this decrease is a result of the Creek reaching a better form of equilibrium with existing storm flows, and part is due to the restoration of some severe erosion sites.

Currently there are 43 individual creek locations which can be categorized as severe erosion sites/unstable channel locations. These are shown in the Fluvial Geomorphology Inventory Report, Appendix E.

Under existing conditions, erosion remains a primary area of concern. Field results in comparison with the hydrologic modeling results indicate that there are four main causes of erosion along Pinecrest Creek.

The first cause is related to bank side obstructions along the Creek; in particular trees that have, over time and because of bank retreat, become part of the bank itself. As the natural stream bank continues to retreat, the tree/root ball protrudes into the active flow area, creating an obstruction which results in recirculation scour. This causes accelerated bank erosion around the base of the tree, and eventually the tree falls in and creates a further obstruction/deflection point.

The second cause of erosion on Pinecrest Creek relates to entrenchment. As high flows move through a channel, they exert erosive (shear) forces on the channel boundary causing it to deepen, become over steepened and undercut, resulting in failure. This creates a higher-than-normal sediment input to the system which needs to be redistributed under subsequent flow events.

The third cause of erosion on Pinecrest Creek is somewhat related to the second: mid-channel bars. Redistribution of excess bank material that has fallen into the Creek takes time, and in the interim the material constitutes a 'bar' that acts as a barrier. The bar becomes an impediment to flow and two things happen: rerouting of flow causes shear stress on the banks causing erosion and trapping of debris on the bar causing it to enlarge further exacerbating the problem. The fourth cause of erosion relates to the lack of quantity control structures (stormwater management). When there are no SWM ponds to control for quantity of runoff, larger volumes of fast-moving water are fed to the receiving watercourse resulting in erosion.

A secondary area of concern relates to sedimentation in the channel. As accelerated erosion occurs, the high sediment input to the system requires significant energy to redistribute that material. If there were well-spaced, individual bank failures along the system there would be enough energy to re-work the material in relatively short order. However, when there are multiple erosion sites dropping large quantities of sediment the system does not have the continuous energy to re-work all of the material until a very large storm occurs; this lends itself to stabilization of these deposits (in some cases through the growth of vegetation), making them a more permanent component of the channel.

4.3.2 Results of Fluvial Geomorphology Inventory

This section and referenced appendix were provided by JTB Environmental Systems Inc.

Pinecrest Creek remains in a state of flux. There are a number of factors combining to cause and exacerbate the erosion risk along this Creek, some of which are easily remediated and others which will require more intensive intervention.

In total, the inventory has documented:

• 21 Severe, 28 Moderate, and 51 non-Severe erosion sites;
• 22 Unstable, 27 Moderately Unstable and 36 Stable sites; and
• 23 High Priority, 27 Medium Priority and 42 Low Priority locations.

The number of Severe, Unstable and High Priority sites has decreased since the 2007 NCC Study as a number of the sites have been restored.

The photos in Figure 7 show examples of the priority class designations of low, medium and high priority sites in the Pinecrest Creek corridor.

The inventory results are provided in detail in the Fluvial Geomorphology Inventory Report, Appendix E.

A Note Regarding Recommended Future Rehabilitation Works
The inventory has identified a number of high priority locations for erosion risk; each of these will require intervention at some point in the future. As the Pinecrest Creek/Westboro SWM Retrofit recommendations are implemented, these sites (as well as the medium priority sites) will need to be monitored on a regular basis to ascertain the degree of change to these sites. If the changes that are documented exceed the targets for intervention, then action would be required to determine the degree of intervention and the timing of such works.

Low Priority
No Intervention
Required

Medium Priority
Monitoring
Required

High Priority
Immediate Action
Required

Figure 7: Examples of Low, Medium, and High Priority Erosion Sites in the Pinecrest Creek Corridor

4.3.3 Identification of Flood Sensitive Areas and Infrastructure

City's Basement Flooding Review

Subsequent to the September 9, 2004 large precipitation event (related to Hurricane Francis), City staff undertook detailed investigations to determine why certain areas of the city were more susceptible to repeated occurrences of basement flooding. City staff's subsequent report provided sewer system improvement options to increase the level of service and reduce the frequency of basement flooding occurrences. A number of the 36 neighbourhoods investigated are located in the study area:

Table 2: Excerpt from City of Ottawa 2005 Basement Flooding Review Summary of Investigations and Action Plan[1]

Neighbourhood	Scope of Solution(s)
McKellar Heights	Sanitary Sewer improvements and flow removal
Glabar Park	Sanitary Sewer improvements and flow removal
Carlingwood	Protective plumbing - due to low number of affected properties
Woodroffe	Increase reliability of the protective measures currently in place
St. Claire Gardens	Environmental Assessment (EA) required to confirm preferred solution
Meadowlands	EA coordinated with St. Claire Gardens
Belair	On-going flow monitoring. Results required before confirming cause and solutions
Westboro	Sewer alarms and protective plumbing
Champlain Park	Sewer alarms and protective plumbing

Most of the work noted under "Scope of Solution(s)" in Table 2 has been either studied/completed or is now under construction (e.g. St. Claire Gardens). From the solutions noted, it appears that most of the basement flooding was related to (wet weather) sanitary sewer back-up. Most of the study area's sewer systems are partially separated. Therefore, the inflow to the sanitary sewers from the foundation drains overloads the sewers in wet weather.

It is of interest to this SWM retrofit study that the City staff report (referenced above), in a section entitled "Removing Stormwater from the Sanitary Sewer Systems", refers to a number of "significant stormwater flow contributors to the sanitary system" that can have an impact on basement flooding. These included wading pools, flat roofs from buildings, cross-connected catch basins, depressed driveways and perforated maintenance covers. The role of homeowners in the improvement of the system capacity and reduction of the risk of basement flooding due to sewer backups is cited. A brochure has been developed and distributed to residents in neighbourhoods susceptible to basement flooding to increase the homeowners' awareness of what they can do to reduce flows to the sanitary system. The brochures checklist includes the following items:

a) Direct eavestrough and downspouts away from building foundations;
b) Ensure sump pump outlet discharges to the ground surface or storm drainage system and not to a laundry tub, floor drain or other sanitary plumbing fixtures;
c) Ensure lot is graded to drain away from the foundation; and

d) Disconnect foundation drains and catch basins in depressed driveways from the sanitary system and redirect to either the ground surface by means of a sump pump or by gravity to a storm drainage system.

Specific records of the use of sump pumps in residential areas are not kept by the City; however it is likely that there is a combination of sump pumps and laterals within the study area with most sump pumps and laterals being connected to the sanitary rather than the storm sewers (Personal Comm., D. Conway, City of Ottawa, Nov. 5, 2009).

Sedimentation in Transitway Culvert

The stream corridor infrastructure inventory, described in Section 5 below, and the fluvial geomorphology inventory (Appendix E) both identified the partial blockage in this two-cell transitway culvert (Appendix B: Outfall Photo Inventory – JFSA ID: 91). Pinecrest Creek flows through the culvert to pass beneath the transitway at a location just north of Baseline Road. Looking in the downstream direction, it is the right-hand cell which is partially blocked by sediment. The sediment accumulation was reported to be 0.74 m in depth (Appendix E, Section 2 – Reach 4). While this cell was observed to be partially blocked at the time of the Pinecrest/ Centrepointe SWM Criteria Study[2] the 0.74 m of blockage most recently observed is 0.29 m deeper than the previously reported value of 0.45 m as such, an updated hydraulic analysis was required. To determine the blockages potential impact on upstream water levels during higher flows a hydraulic analysis of flow through the culvert for 1: 100-yr 24-hour SCS Type II storm was conducted for both partially blocked and un-blocked conditions. The HEC-RAS model used in the Pinecrest/Centrepointe SWM Criteria Study[3] was used for this analysis. It was found that the blockage of 0.74 m results in an increase of 0.14 m from an elevation of 78.49 m to 78.63 m in water levels immediately upstream of the culvert. This increase in water levels tapers out upstream to 0.03 m at the downstream side of the next culvert (upstream at Woodroffe Avenue crossing) and is not observed upstream of the Woodroffe culvert. While this increase in water level is not predicted to result in an overtopping of the banks of Pinecrest Creek, it could potentially increase the risk of basement flooding along the sewers that discharge between the Woodroffe Avenue culvert and the partially blocked culvert. This potential risk should be investigated by the City through a hydraulic grade line (HGL) analysis of the connected storm sewer systems.

Ottawa River Parkway Culvert

There is a flood risk associated with the Ottawa River Parkway (ORP) culvert. This flood risk is noted in the Appendix A: (Existing Conditions – Section 2.8) and is also identified in the Pinecrest/Centrepointe Stormwater Management Criteria Study[4]. In that previous study a hydraulic bottleneck analysis was conducted to determine the existing hydraulic carrying capacity of the Creek corridor's channel culverts and pipes. The carrying capacity was compared to the amount of water to be drained to assess the culvert and pipe conveyance adequacies. The analysis determined that the limiting hydraulic structures along the length of the Pinecrest Creek corridor are the ORP culvert pipes located between the Parkway and the confluence of the Creek with the Ottawa River. A map delineating the potential extent of the resulting flooding, as would result from 1:100-year SCS event, is included in Appendix D (Figure D1).

In recognition of this flood hazard the City conducts regular inspections and clearing of the ORP culvert inlet grate including inspections before forecasted rain events and after rain events.

5. INFORMATION FOR PRELIMINARY SCREENING OF RETROFIT POTENTIALS

This section and supporting appendices summarises the information collected for the preliminary screening of end-of-pipe and lot level and conveyance opportunities in the study area. The end-of-pipe options considered included dry and wet ponds, underground storage and a version of Dunker's flow-balancing installation in the Ottawa River.[5]

The lot level surveys were conducted by neighbourhood. Neighbourhoods were also used to provide a graphic depiction of the connection between the neighbourhoods and the Creek and Ottawa River by identifying which part of the Creek receives stormwater discharge from which neighbourhood, and which part of the study area has runoff discharging directly to the Ottawa River.

5.1 Study Area Outfalls and End-of-Pipe Conditions

End-of-pipe (EoP) retrofit opportunities were identified by conducting a desktop review of existing outfalls, conducting site visits and gathering a photographic record of the sites, and then assessing the feasibility of installing new ponds or other EoP retrofits. Desktop reconnaissance and site visits were also made to the subwatershed's existing and potential dry pond areas and a photographic record made of the sites for assessing the feasibility of retrofitting any of the potential "dry ponds" for water quality objectives.

The records from this EoP preliminary reconnaissance and review are included in Appendix F. Also included in Appendix F is a map (Figure F1) showing the location of sewers within the Pinecrest Creek corridor. This information was used in the preliminary assessment of EoP opportunities.

It was noted during the preliminary screening that the outlets along the Ottawa River are for the most part too constrained by limited space and proximity to the shoreline, and too susceptible to the high variability in the water levels on the Ottawa River, to be suitable for conventional EoP retrofits. A potential site at the Ardmore and Wavell outfalls to the Ottawa River was eventually included in the EoP retrofit opportunities.

Following this preliminary assessment further work was done to identify additional potential EoP sites. In all 18 sites were considered and screened using a number of factors including drainage inverts, space limitations, mature vegetation impacts, existing servicing conflicts and location access. This screening process is described in Part B of this report.

5.2 Lot Level and Conveyance Systems Survey Information

The study area contains a range of residential developments from low to high density. Examples of types of residential development found in the study area are shown in Figure 8. Within those general types there is a range of site conditions which affect the type and extent of lot level and conveyance controls that can be implemented.

Low Density Residential

Medium Density Residential

High Density Residential

Figure 8: Examples of Low, Medium, and High Density Residential Areas in the Study Area

In order to gain a better understanding of lot level and conveyance system conditions that could potentially affect the applicability/suitability of various SWM measures within the study area a lot level survey was carried out. This data can be used to assess the potential feasibility of implementing the SWM measures and of the extent of the implementation or potential "uptake" (e.g. % of properties, relative number of sites). The survey was conducted neighbourhood by neighbourhood and the neighbourhoods in turn were related to sewer catchment areas.

Using the Street View and Bing Maps a subset of residential lots from each neighbourhood was surveyed so that one (1) lot/10 ha was included in the subset with a minimum of five (5) lots / neighbourhood survey. The lots were selected using a random point generator (www.geomidpoint.com/random). The following information was collected for each lot:

- Residential Density – a visual estimation which can be compared to the City's GIS classification of area
- Roads/Medians - four lane? median?
- Curbs - present? type?
- Sidewalks – present? one side, both sides?
- Sidewalk Locations (if sidewalk present) – attached to curb? separated from curb?
- Driveways – type? asphalt, interlocked, other
- Roofs – type? pitched, flat, combination
- Landscaping - % pervious, canopy-covered, proximity of trees/shrubs to road
- Street Level Obstacles - proximity of trees/shrubs to road, proximity to utility poles
- Retaining Walls – present?
- Water Bodies – present?
- Drainage – drainage system? Swales, ditches, culverts, curb inlets, catch basins
- Visible Roof Drains – number of roof drains? connected or disconnected?

A complete list of the parameters for which information was collected is included in Appendix G: Categories and Parameters used in Lot Level Survey.

In addition to the desktop survey, field checks were done in two randomly selected neighbourhoods. The same list of parameters was used. A subset of residential lots (again, one (1) lot per 10 ha) were surveyed by driving to randomly selected streets in the neighbourhood and picking a lot typical of the street.

5.2.1 Results of Lot Level and Conveyance Systems Survey

It was found that for some of the categories and parameters the desktop survey results and audit results were comparable. However for many of the parameters the results differed. This may be due to inherent heterogeneity within the neighbourhoods. (In future studies it is recommended that larger samples be used.) In any case the survey results do reflect the range of conditions that exist within the study area. The survey results are provided in Appendix G along with a data summary (Table G1).

The survey found that driveways in the study area were predominantly asphalt driveways but there are some interlocking, gravel or other types of driveways (e.g. in Westboro, Highland Park, McKellar Park). All of the roofs surveyed were pitched with the exception of some flat roofs in Westboro. Tree canopy exists and covers some of the lawn areas throughout the study area. The protection of trees needs to be taken into account in the implementation of the SWM measures.

The downspout data suggests that there are opportunities within the study area, potentially particularly in the low density residential development, for increasing the percentage of downspout disconnection/redirection to pervious surfaces. A sample of the downspout survey data is provided in Table 3. The table contains data on visible roof drains in various neighbourhoods in the study area including the average number of roof drains identified per house and what percentage of those roof drains were "connected" or "disconnected". (For the purposes of this survey, "connected roof drains" discharge directly to the sewer or discharge directly to impervious areas that drain directly to storm sewers and "disconnected roof drains" discharge to pervious areas.)

Table 3 is also colour coded. The colour of the header of each neighbourhood column is the colour used on Figure 9 to show the location of the neighbourhood. The same colour is used to delineate the reach of Pinecrest Creek to which the neighbourhood's storm sewers discharge. Six reaches are identified by the colour coding on Figure 9; each reach is potentially affected by the runoff, including runoff from connected rooftop drains, from the neighbourhood whose name in Table 3 is highlighted by the corresponding colour.

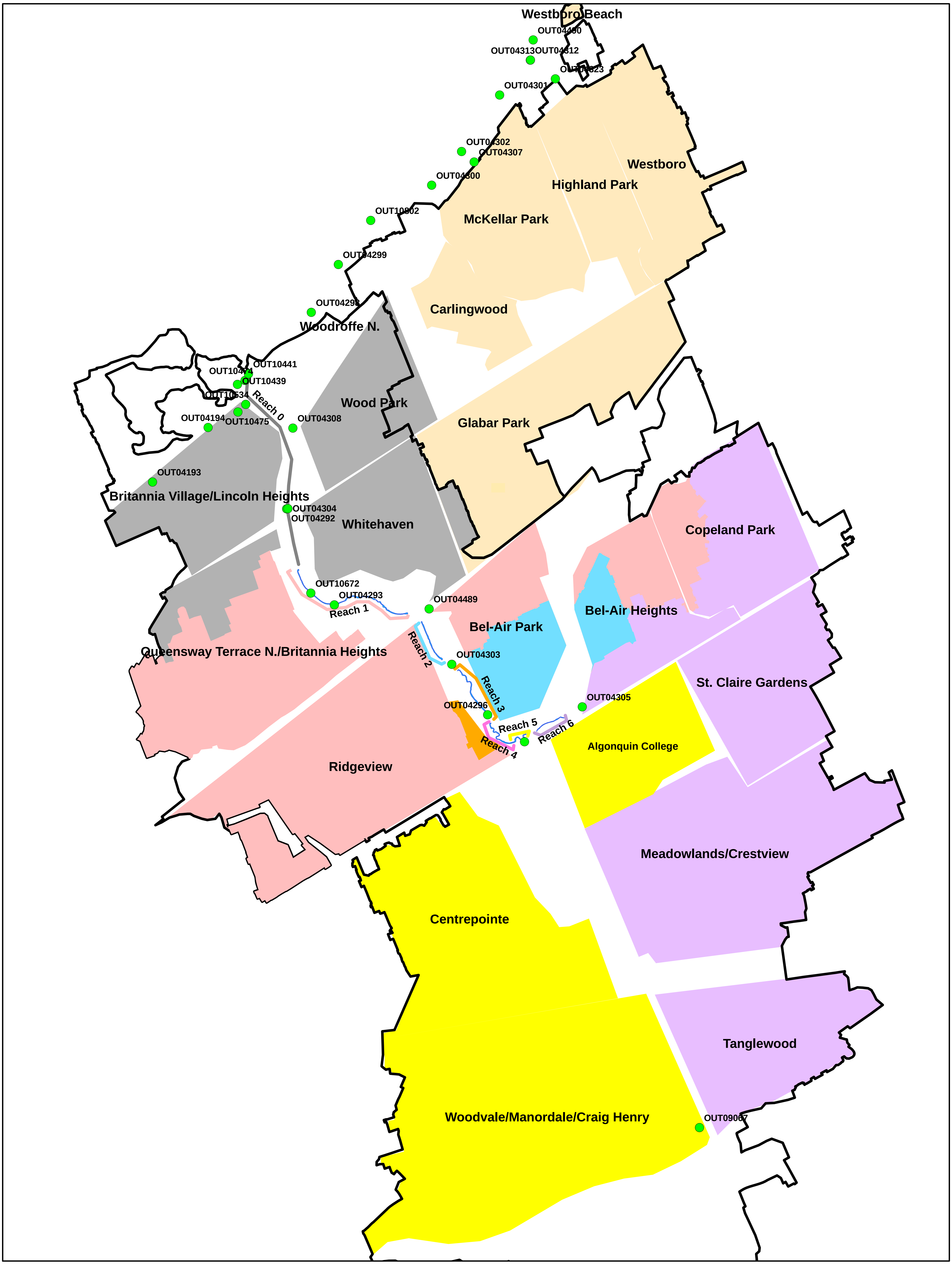
Table 3: Visible Roof Drains Percentages for a Selection of Neighbourhoods in the Study Area

Category	Parameter	Westboro	Whitehaven	Q-way Terrace N. / Britannia Heights	Centrepointe	Bel-Air Park	Meadowlands / Crestview
Visible Roof Drains (1)	Total Roof Drains (Avg No.) (2)	1.0	1.5	1.1	2.8	1.0	1.7
	Connected Roof Drains (%)	83	44	50	69	17	24
	Disconnected Roof Drains (%)	17	56	50	31	83	76

(1) For the purposes of this survey, all connected roof drains discharge directly to the sewer or discharge directly to impervious areas that drain directly to storm sewers and all disconnected roof drains discharge to pervious areas, unless otherwise noted.
(2) Avg. No – represents the average number of roof drains identified per house based on the randomly selected sample surveyed.

Note: Column heading colour indicates where the neighbourhood is located - see Figure 9 - and to which Creek reach the neighbourhood's storm sewers are discharging.

The downspout disconnection/redirections data was amalgamated using weighted averages based on neighbourhood areas to estimate an "average %" downspout disconnected for the larger catchment areas used in the water quality and quantity modelling and SWM measure implementation scenarios. These averages are the assumed downspout disconnection/redirection percentages for existing conditions. These average percentages for the catchment areas discharging to the following outfalls are: Pinecrest Creek subwatershed: 63%; Westboro outfalls 04298, 04299, 04300 and 04301: 61%; Westboro outfall 04307: 58%; Westboro outfall 04313: 54%; and Westboro outfall 04490: 47%.



LEGEND:

- reach0
- reach1
- reach2
- reach3
- reach4
- reach5
- reach6
- Storm Sewer Outlets_City of Ottawa
- Communities / Neighbourhoods
- Ottawa River Outfalls
- Water
- Total Study Area_ Lands not classified as a Community/ Neighbourhood

CLIENT: Ottawa

NOTES:
- The following data was provided by the City of Ottawa and JTB Environmental.

0 125 250 500 750 1,000 Meters

N

JAN 2011

REV. 0

BY: JFSA Water Resources and Environmental Consultants

PROJECT: PINECREST CREEK / WESTBORO SWM RETROFIT STUDY

TITLE: Neighbourhoods and Outfalls Affecting the Six Reaches of Pinecrest Creek

PROJECT No. 741-09

DESIGN	KM
GIS	KM
CHECK	JFS
REVIEW	JFS

FIGURE 9

MAP REF.: 741_09\Design\Maps\Reaches.mxd

5.3 SWM Measures Used by WinSLAMM Water Quality Assessment Tool

The WinSLAMM software program was selected by the City for the water quality modelling used in the evaluation of the various SWM measures and SWM retrofit scenarios. WinSLAMM was developed in the 1970s by the United States Environmental Protection Agency to evaluate non-point source pollutant loadings in urban areas using small storm hydrology. During the mid 1980s, the model was expanded to include more SWM management options based upon research and studies conducted in the United States and Canada. The model determines the runoff from a series of normal rainfall events and calculates the pollutant loading created by these rainfall events. The user is able to apply a series of control devices, such as infiltration/biofiltration, street sweeping, wet detention ponds, grass swales, porous pavement, or catch basins to determine how effectively these devices remove pollutants.

A determination of the SWM measures for which data can be entered into WinSLAMM and trial runs of the software were undertaken in preparation for the use of WinSLAMM for the SWM retrofit scenario evaluations. A summary of the SWM measures that can be applied in the program is provided in Part B: Section 4.1, Table 3. The use of the WinSLAMM program for the scenario evaluations is described in more detail in Part B of this report.

6. DATA GAPS

A number of gaps in the information base to be used for the SWM retrofit analysis were identified during Step 1. The data gaps range from inconsistencies in infrastructure details to the lack of detailed mapping of the sediments (soils) in the study area and unknown sump pump use across the study area. The data gaps will need to be filled, as required, when site specific assessments are done prior to the implementation of the various SWM measures.

ENDNOTES

[1] Report to City of Ottawa Planning and Environment Committee and Council, 25 October, 2005

[2] J.F. Sabourin and Associates Inc. and JTB Environmental Systems Inc. 2010. Pinecrest/Centrepointe Stormwater Management Criteria Study. Report prepared for the City of Ottawa, February 2010.

[3] *Ibid*.

[4] *Ibid*.

[5] Baird & Associates. 2011. Assessment of the Relative Impact of SWM Retrofit Alternatives Developed for the Pinecrest Creek Study. 27 p. plus Appendices. This report is included in Appendix J.

This concurrent study conducted by Baird & Associates for the City of Ottawa included

a) a review of the Dunkers Flow Balancing System (DFBS) which has been implemented at Lake Ontario shoreline at Bluffers Park, City of Toronto; and
b) a preliminary assessment of the potential for implementing a similar system as a retrofit for one of the Westboro outfalls in the Ottawa River.

PART B: STORMWATER RETROFIT

SELECTION OF THE PREFERRED SCENARIO

PART B: STORMWATER RETROFIT:

SELECTION OF THE PREFERRED SWM RETROFIT SCENARIO

CONTENTS

TABLES

FIGURES

1. INTRODUCTION

This report and supporting appendices summarize the work and results of Steps 3 and 4 of the Pinecrest Creek/ Westboro Stormwater Management Retrofit Study.

The main tasks of **Step 3: Definition of SWM Retrofit Opportunities and Retrofit Plan Scenarios** were: 1) to select the potential stormwater management (SWM) retrofit practices to be employed in the retrofit scenarios; 2) to identify potential retrofit locations and opportunities, and 3) to compose the retrofit scenarios to be assessed in Step 4. The retrofit scenarios are different combinations and amounts of SWM measures that would be retrofitted into the existing streetscape, open spaces, and public and private properties of the study area. The proposed scenarios could differ in terms of the type and number of SWM measures used as well as the extent to which each type of SWM measure is implemented, for example, the percentage of properties involved.

The purpose of **Step 4: Assessment of Scenarios** was to evaluate and rank the Scenarios using criteria which include the project's objectives and targets. The Scenarios were also compared against a "do nothing" option also referred to as "existing conditions". Water quality, quantity and fluvial geomorphologic modelling were used to predict the relative impact of each scenario in terms of reducing flood risk, pollution, erosion impacts, runoff volumes and peak flows. The modelling included an assessment of the water quality impacts at Westboro Beach on the Ottawa River.

2. PINECREST CREEK/WESTBORO SWM RETROFIT OBJECTIVES AND TARGETS

The SWM retrofit objectives and targets define the purpose of the retrofitting and state what the retrofitting is to achieve. The objectives and their specific targets address the problems to be mitigated in the watershed (local reach of Ottawa River) and subwatershed (Pinecrest Creek); problems such as water quality degradation, erosion, flooding, etc. A number of the objectives have a fluvial-process focus as, erosion impacts on the Creek are a key consideration. As the Pinecrest Creek corridor is owned by the NCC, the formulation of the SWM retrofit objectives and targets was done in the context of the NCC objectives for the corridor.

Much work has already been done on SWM objectives through the Lower Rideau Watershed Strategy[1] and the development of the City's SWM policies[2]. This information, along with a preliminary list of the subwatershed's existing stormwater-related challenges / problems were compiled in Step 1 (Data Collection, Review and Analysis) of the study and were used to draft the SWM Objectives and Targets.

2.1 Pinecrest Creek/Westboro SWM Retrofit Objectives

The Pinecrest Creek/Westboro SWM Retrofit Objectives are as follows:

1. Reduce flood risk to public health and safety and to property along the Pinecrest Creek corridor;
2. Reduce erosion impacts in the Pinecrest Creek Corridor that are detrimental to property, infrastructure and stream habitat;
3. Preserve and/or re-establish a more natural hydrologic cycle for the Pinecrest Creek subwatershed;
4. Improve water quality in Pinecrest Creek and the Ottawa River by reducing the impact of runoff;
5. Reduce the impacts of runoff on Westboro Beach;
6. Protect, enhance or rehabilitate natural features and functions along the Pinecrest Creek corridor; and
7. Increase public awareness of stormwater management and increase public involvement.

The targets for each of the SWM Retrofit Objectives are provided in Table 1.

Table 1: Objectives and Targets for the Pinecrest Creek/Westboro SWM Retrofit

1. Reduce flood risk to public health and safety and to property along the Pinecrest Creek corridor.

Indicator	Rationale	Measurable Parameter	Existing Condition	Target
A) Flood risk	*With potential infill and redevelopment, there is a need to ensure that flood risk to public health and safety and to property is not increased.*	*Flood elevations* *Flood flows*	*2010 flood levels generated in Pinecrest Creek/Westboro SWM Retrofit Study*	*Maintain or reduce existing flood elevations* *Maintain or reduce existing peak discharge rates for all design events, particularly high flows*
B) Flood-plain Storage	*Floodplain storage attenuates peak flows as the flood wave moves downstream through the system; maintaining this feature of the floodplain is important to avoid peak flow increases from future potential works within the corridor*	*Riparian storage volumes for 2 to 100 year events*	*As determined from 2010 hydraulic modelling generated in Pinecrest Creek/Westboro SWM Retrofit Study*	*Maintain existing riparian storage volumes for 2 to 100 year events*

2. Reduce erosion impacts in the Pinecrest Creek Corridor that are detrimental to property, infrastructure and stream habitat.

Indicator	Rationale	Measurable Parameter	Existing Conditions	Target
A) Sediment Regime and Sediment Size	*Sediment sources and sediment transport need to be maintained in dynamic equilibrium to control loadings to reaches.*	*Pebble count; visual inspection of channel substrate; sediment transport samples in-situ;* *photo record*	*Based on retrofit work, two or three sensitive reaches should be measured prior to implementation to determine baseline.*	*General maintenance of existing substrates; no increase or decrease in average sediment size (D_{50}) of more than 10 percent compared to existing conditions* *Maintenance of sediment transport rates over a range of transport events based on measured samples as opposed to theoretical transport results based on equations*
		Substrate Composition	*Based on retrofit work, two or three sensitive reaches should be measured prior to implementation to determine baseline.*	*- Due to the dynamic nature of the channel substrate, dimensional adjustment is anticipated* *- As a performance threshold, adjustment in grain size should not exceed an order of magnitude over the long term; short-term adjustments should not increase or decrease by more than 10 percent of the D50 size fraction compared to existing conditions.*
		Substrate Stability	*Based on retrofit work, two or three sensitive reaches should be measured prior to implementation to determine baseline.*	*- Degradation or aggradation of bed material in excess of 5 cm annually at measurement locations will act as a trigger.* *- Disturbance or reworking of the substrate in excess of 5 cm (with minimal vertical adjustment in bed surface elevation)*

Indicator	Rationale	Measurable Parameter	Existing Conditions	Target
				will be noted but will not necessarily be considered detrimental to channel stability
B) Channel Stability and Erosion Potential	*Channel stability is a function of time series flows and sediment regime, stabilizing bank features (e.g. woody vegetation, artificial hardening).* *Erosion potential needs to be reduced to more natural levels to stabilize and reduce erosion damage and loss of riparian/floodplain lands.* *Maintain channel stability to protect municipal and NCC infrastructure, to reduce annual maintenance costs and increase longevity of infrastructure*	*Cross-sectional form and area from available survey data*	*Based on retrofit work, two or three sensitive reaches should be measured prior to implementation to determine baseline.*	*- Cross-sectional area should not increase or decrease in excess of 20%* *- Cross-sectional form should be maintained within accepted limits (visual comparison only)*
		Longitudinal Profile	*Based on retrofit work, two or three sensitive reaches should be measured prior to implementation to determine baseline.*	*- Inter-pool and energy gradients should not differ in excess of 5%* *- Riffle grades should not increase or decrease in slope more than 20%* *- Riffle crest elevations should not increase or decrease to the point of impacting upstream bedforms (visual analysis)*
		Lateral Migration (meandering)	*Based on retrofit work, two or three sensitive reaches should be measured prior to implementation to determine baseline.*	*- Annual migration rates exceeding 15 cm per year in pools and 5 cm per year in riffles will trigger an assessment of the channel conditions at the site*

Indicator	Rationale	Measurable Parameter	Existing Conditions	Target
		Cross-sectional measurement of erosion-prone sites; review of hydrologic and hydraulic data to determine changes to erosion potential over time	*Based on retrofit work, two or three sensitive reaches should be measured prior to implementation to determine baseline.*	*No significant increase in bed and bank erosion; no significant decrease in erosion potential which could cause sedimentation in problematic areas within the channel*
C) Aquatic Habitat	*Improve the quality and quantity of in-stream aquatic habitat.* *Improving the potential for a sustainable fishery is a longer term objective.*	*For example:* *Average pool depth* *Percent cover* *Bank stability*	*Given the existing degraded conditions in the creek corridor, the immediate focus is reducing the impacts of uncontrolled runoff (water quality and quantity) – see other objectives and targets.*	*To be developed in future, subject to progress in achieving water quality and quantity targets and mitigating existing barriers.*

3. Preserve and/or re-establish a more natural hydrologic cycle for the Pinecrest Creek subwatershed.

Indicator	Rationale	Measurable Parameter	Existing Condition	Target
A) Peak Flows and Runoff Volume for more Frequent Storms	*Reduce flashiness of runoff from the watershed*	*Runoff volumes and peak flows for more frequent storms (e.g. up to 25 mm)*	*Retention assumed between 1.5-4.5 mm* *Detention assumed to be 0 mm*	*Retain runoff from first 10 mm of rain.* *Detain runoff from next 15 mm of rain.* ***(To be confirmed – subject to model calibration and confirmation of existing condition watershed peak flows and runoff volume targets)***

Indicator	Rationale	Measurable Parameter	Existing Condition	Target
B) Effective imperviousness (EI) *The proportion of a catchment covered by impervious surfaces directly connected to the stream by storm sewers*	*The degree of effective imperviousness can greatly impact the timing and amount of flows and pollutants into the receiving watercourse.*	*Area difference between total impervious area and indirectly connected area*	*Will be assessed on a site by site basis for infill and redevelopment areas*	*As a minimum, existing effective impervious should not be increased; to be implemented as a requirement for infill and redevelopment*

4. Improve water quality in Pinecrest Creek and the Ottawa River by reducing the impact of runoff.

Indicator	Rationale	Measurable Parameter	Existing Condition	Target
Instream Nutrients, Total Suspended Sediment, Total Phosphorus	*Targets are linked to achieving fish community targets, aesthetics and non-eutrophic conditions and avoiding the creation of in-situ contaminant concerns*	*TSS* *TP*	*Pinecrest Creek:** *Wet weather TSS- (min: 20 mg/L; max: 520 mg/L; avg: 189 mg/L)* *Wet weather TP - (min: 0.03 mg/L; max: 0.57mg/L; avg: 0.10 mg/L)* *Wavell outfall:** *Wet weather TSS- (min: 28 mg/L; max: 450 mg/L; avg: 224 mg/L)* *Wet weather TP - (min: 0.05 mg/L; max: 0.37mg/L; avg:0.15 mg/L)*	*TSS = less than 25 mg/L change from background* *TP =0 .03 mg/L (85th percentile)*

**River Input Monitoring Program: 1998 Ottawa River. Regional Municipality of Ottawa-Carleton (RMOC), 1999.*

5. Reduce the impacts of runoff on Westboro Beach.

Indicator	Rationale	Measurable Parameter	Existing Condition	Target
Instream E. coli *(at Pinecrest Creek Confluence and Adjacent Outfalls to Ottawa River)*	*Setting targets to approach the swimming beach PWQO in non-beach areas ensures that risks of contracting disease from incidental exposure to recreational waters are reduced (e.g. boating, water skiing, private dock swimming)*	*E. coli*	*Pinecrest Creek:** *Wet weather- (min: 1000 cts/100 mL; max: 8400 cts/100 mL; avg: 3054 cts/100 mL)* *Wavell outfall:** *Wet weather - (min: 1000 cts/100 mL; max: 135,000 cts/100 mL; avg: 8132 cts/100 mL)*	*Achieve PWQO (E.coli= 200cts/100mL) (80th percentile)* *E.coli (max.) not to exceed 2000 cts/100 mL* *To be confirmed subject to potential new Guidelines for Canadian Recreational Water Quality, and resulting modelled count at Westboro Beach.*

**River Input Monitoring Program: 1998 Ottawa River. RMOC, 1999.*

6. Protect, enhance or rehabilitate natural features and functions along the Pinecrest Creek corridor.

Indicator	Rationale	Measurable Parameter	Existing Condition	Target
A) Riparian Vegetation	*The Environment Canada Habitat Guideline recommends the natural vegetation within 30 m of a watercourse be retained or re-established on each side of a watercourse for 75% of its overall length. (This target was developed at a watershed level and may not be appropriate to or achievable within an urban subwatershed.)*	*Riparian vegetation (field visits or aerial photograph interpretation)*	*The City Stream Watch Annual Report[3] found that 19% of the stream sections were in natural condition, 46% were altered and 35% were highly altered, (although there may not be a direct equivalency of these values to the extent of existing riparian cover).*	*To be determined.*
B) Tree Canopy	*Increased tree canopy in urban areas can reduce runoff volume by intercepting rainfall, particularly for small events*	*Area of tree canopy.*	*Existing tree canopy = 6 %*	*Net increase in canopy* ***To be developed.***

7. Increase public awareness about stormwater management and increase public involvement.

Indicator	Rationale	Measurable Parameter	Existing Condition	Target
A) Increased Public Awareness	*Increased public awareness will lead to greater success and uptake of SWM Retrofit Plan recommendations*	*N/A*	*N/A*	***To be developed through monitoring and reporting***
B) Increased Public Involvement	*Increased public involvement required for successful implementation of SWM retrofit*	*N/A*	*N/A*	***To be developed through monitoring and reporting***

3. DEFINITION OF SWM RETROFIT OPPORTUNITIES & RETROFIT PLAN SCENARIOS

Stormwater management (SWM) is implemented to mitigate the impacts of urban stormwater runoff on receiving systems. The following types of SWM measures were considered for use in the SWM Retrofit Plan Scenarios:

- lot level;
- conveyance; and
- end-of-pipe.

Lot level measures are SWM practices situated closer to the source of the stormwater runoff. Lot level/source controls can prevent pollutants from being picked up by runoff and can minimize the amount of off-site drainage and therefore are considered to be the first line of protection for maintaining the health of a watershed. Though each lot (public or private) may be relatively small in size, the use of lot level practices on the sheer number of lots and properties in urbanized areas can combine to provide a powerful and effective means of controlling both the quantity and quality of water moving through an urbanized watershed.

Stormwater conveyance systems are the means by which stormwater is directed or conveyed from one location to another. Conveyance measures include drainage ditches and swales, and storm sewers. SWM measures along the conveyance route can include stormwater exfiltration systems, grassed swales, and pervious catch basins.

End-of-pipe facilities, the third line of protection (after lot level and conveyance measures), are larger scale SWM practices typically implemented within open spaces and greenways. Such areas have often been the venue for implementation of more conventional SWM methods such as settling ponds and detention basins. More recently, this has been expanded to include methods such as constructed wetlands and large sub-surface water retention structures.

Definition of the lot level and conveyance SWM retrofit opportunities was done by first selecting the most suitable and effective measures from a wide range of SWM lot level and conveyance controls. Suitability refers to the potential to implement the SWM measure throughout the study area and over the long-term, on both the public and/or private lands. The selection process used and the results are described in the next two sections.

The end-of-pipe facilities considered included dry and wet SWM ponds and oil-and-grit separators. These SWM measures and their selection are also described below.

3.1 Selection of SWM Retrofit Practices

The portfolio of SWM lot level and conveyance measures provided by the *SWM Selection Tool*[4] was used as a starting point. An initial short list of SWM measures, or Best Management Practices (BMPs), was created from the SWM Selection Tool's longer list using the selection criteria provided by the tool, the study area's characteristics (soils, depth to bedrock, land use, development types, etc.) and the project objectives. The selection tool allowed for cross-referencing between site and development characteristics and the potential SWM measures.[5]

The BMPs on the initial short list were then assessed to determine which measures provided the most benefit per percent of implementation across the study area. The water quality modelling software WinSLAMM[a] was used for this pre-screening. Based on this analysis, the following SWM measures were selected as the preferred lot level and conveyance measures to be used in the SWM Retrofit Scenarios:

1. Downspout Disconnection/Redirection
2. Rain Barrels / Cisterns
3. Porous Pavement or Concrete (Driveways, Parking Lots and Sidewalks)
4. Rain Gardens
5. Infiltration Trenches (Roadside and Lot Level)
6. Street Narrowing

Roadside grassed ditches and street cleaning are two conveyance measures that already exist in the study area and they were also included in the selected SWM measures. With respect to end-of-pipe facilities, depending on the site constraints (size, footprint impacts), wet ponds or subsurface oil and grit separators were considered. The potential to construct dry ponds along the Pinecrest Creek corridor and elsewhwere in the study area was investigated but this option was eliminated due to space limitations.

The SWM Measures selected for use in the Retrofit Scenarios are described in brief in the following sections. The selection of particular measures for the Retrofit Scenarios does not preclude the implementation of alternative measures, for example green roofs on public or institutional buildings, which may provide the same or similar benefits.

[a] A list of SWM measures that can be applied in WinSLAMM is provided by Table 3. The WinSLAMM software and its use in the project are described in Section 4 and in Appendix I.

3.1.1 Lot Level Measures (Private and Public Lots)

Downspout Disconnection/Redirection

Downspout disconnection/redirection is the diversion of flow from roof tops to pervious areas, as shown in Figures 1a and b. This SWM measure prevents the routing of stormwater onto impervious surfaces which drain directly to the storm sewer system. To produce a measurable benefit, simple downspout disconnection requires a minimum flow path length of 5 m across a pervious area before flowing onto an impervious surface or into the storm sewer system.[b] With respect to discharge and seepage, discharge locations for roof downspouts should be a distance of 3 m away from building foundations, however, this may not be necessary if the topography slopes 1 to 5% away from the building.[c]

- In the study area, the percent of downspouts that are currently connected or directed to pervious surfaces was estimated from the lot level survey information. It was assumed that the topsoil infiltration rate is equal to or greater than 25 mm/hr, and as such no soil amendments would be required for this lot level control to function effectively. (The potential low permeability of the underlying fine-grained sediments that exist in much of the study area was taken into account in the water quality and water quantity modelling.)

Figures 1a and 1b Downspout Redirection[6]

[b] Credit Valley Conservation and Toronto and Region Conservation Authority. 2010. Low Impact Development Stormwater Management Planning and Design Guide. Version 1.0.
[c] *Ibid*.

Rain Barrels and Cisterns

Rain barrels and cisterns are rain harvesting BMPs that capture roof runoff from frequent storm events and temporaily store it for reuse on site. This practice reduces runoff and pollutants, and can provide a benefit in terms of reduced water consumption. Figure 2 shows a private installation of a rain barrel, and Figure 3 shows the installation of a public cistern application.

- Two rain barrels were implemented on residential properties, sized at 208 L (55 gallons) each, and located at the front and rear of the house to collect runoff from either side of a typical roof. The water usage calculated for these barrels was based on the average lawn irrigation needs of 25 mm/week. Cisterns were located on institutional and industrial lands and were sized to capture three days of average (1980 City of Ottawa data) roof runoff. Based on an averaged roof size (for the study area), such cisterns would need to be 7,570 L (2,000 gallons) in size. The same average water usage used for the rain barrel calculation of 25 mm/week was used for the cistern calculations.

Figure 2: Connected Rain Barrel Application[7]

Figure 3: Connected Cistern Application[8]

Rain Gardens (Bioretention)

Rain gardens, or bioretention areas, are designed to include hydrophilic (water-loving) native species and amended soils in human-made depressions to aid in capturing rainfall runoff. This lot level measure decreases peak flows through additional on-site storage, and reduces pollutant loads through both runoff volume reduction and filtration prior to discharge. Figures 4a and 4b provide examples of Rain Gardens.

- The rain gardens are designed for residential and institutional lots to receive lot level runoff and rain barrel or cistern overflow. For the evaluation of the SWM retrofit scenarios, it was assumed that each rain garden would have a surface area of 5.6 m^2 (60 ft^2) and would capture 50% of runoff from the adjacent landscaped areas (e.g. front lawns).

Figure 4a: Rain Garden[9]

Figure 4b: Rain Garden[10]

Porous and Permeable Pavement/Concrete

Porous or permeable pavement or concrete, an alternative to impervious products, allows some surface runoff to flow through its surface to be stored in a granular base prior to being released slowly to the storm sewer system or infiltrated into the native soil beneath. An example of the use of permeable pavers in a walkway and parking lot setting can be seen in Figure 5a. Figure 5b shows water infiltrating through a slab of porous asphalt.

- For the evaluation of the SWM retrofit scenarios, it was assumed that porous pavement would be installed in the following runoff source areas: driveways, parking lots and sidewalks within various land uses e.g. residential, institutional, commercial and industrial.

Figure 5a: Porous Pavers used for a Walkway and Parking Area[11]

Figure 5b: Cross-Sectional View of Porous Asphalt [12]

3.1.2 Conveyance Measures

Grass Swales

Grass swales are vegetated, shallow, open channels designed for conveyance and treatment of stormwater runoff, particularly from roadway drainage. Grass swales reduce runoff volumes and pollutant loads by filtration through the vegetation and infiltration into the underlying soils, and provide discharge at lower rates. Grass channels are similar to ditch systems; however, they have lower design velocities for water quality treatment due to their flatter side and longitudinal slopes. See Figure 6a for an example of a roadside grass swale, similar to the existing ditches within portions of the Pinecrest and Westboro subwatersheds. Figure 6b is a digitally prepared image which illustrates the option of installing a sub-drain below a grass swale.

- For the SWM retrofit scenario evaluations, the study area's existing roadside grassed ditches and swales were modelled as "grass swales" which were represented as 30 cm (1 ft.) deep with a 0.9 m (3 ft.) bottom width and 4:1 side slopes. The extent of existing roadside grass ditches/swales assumed for the scenarios was based on the study area data in the City of Ottawa GIS data base. Grass ditches /swales are predominately located within residential areas.

Figure 6a: Roadside Grass Swale[13]

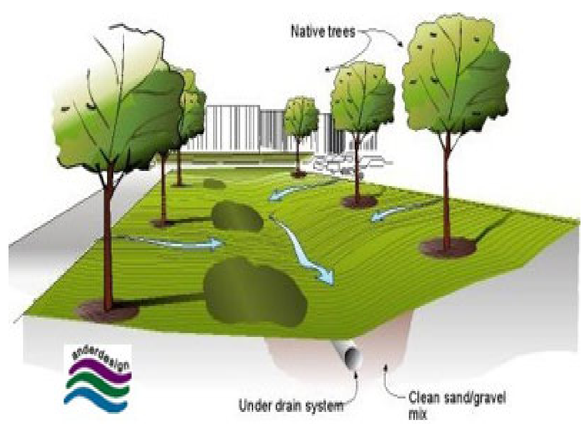


Figure 6b: Digital Rendition of a Grass Swale with Sub-Drain[14]

Infiltration Trenches

Infiltration trenches are long, narrow, rock-filled trenches (Figure 7) that receive stromwater runoff from roadways or landscaped areas. As the trenches have no outlet, the runoff is stored within the voids of the rocks and infiltrates into the soil below. These trenches are effective in removing fine particles and associated pollutants.

- For the SWM retrofit scenario evaluations, the infiltration trenches were sized at 10.7 m (35 ft) long, 0.5 m (1.64 ft) wide and 0.6 m (2 ft) deep, and the sub-surface native soil infiltration rates were set as 2.5 mm/hr (0.1 in/hr). The lateral dimensions were based on average residential lot widths less the driveway width and the depth was set to ensure that any underground structures or lateral services would not be compromised.

Figure 7: Side Yard Infiltration Trench[15]

Street Cleaning

Streets are a significant contributor of pollutants to urban runoff. Street cleaning can reduce this impact. The City of Ottawa uses tandem street cleaning machines (shown in Figure 8) that make use of brooms and vacuums**.**

- The street cleaning schedule currently used by the City of Ottawa is to clean streets in commercial or industrial areas once every two weeks and to clean streets in residential and institutional areas once every four weeks. This street cleaning schedule was the one assumed for all the SWM retrofit scenarios. The reason for this is explained in Section 3.2.

Figure 8: Street Cleaning[16]

Street Narrowing

Street narrowing reduces impervious cover, stormwater runoff, and associated pollutant loads. To maximize the benefits of street narrowing, the narrowed area can be designed to promote increased infiltration/filtration via granular media, plantings, etc. Figure 9a demonstrates a simple example of street narrowing, Figure 9b demonstrates a more ambitious design, which incorporates a vegetated infiltration trench in the narowed area.

- For the SWM retrofit scenario evaluations, it was assumed that the narrowing would be 0.5 m on either side of the street.

Figure 9a: Street Narrowing[17]

Figure 9b: Street Narrowing with a Vegetated Infiltration Trench[18]

3.1.3 End-of-Pipe Facilities

Oil and Grit Separators

Oil and Grit separators (OGS) are underground structures installed in conventional storm sewer systems to improve water quality downstream (shown in Figure 10). They come in different designs, sizes and materials; some are commercially available and others are custom designed and built.

OGS consists of separate chambers through which stormwater is conveyed to remove coarse sediments (grit), oils and other buoyant pollutants (floatables). The principal site constraints in using OGS is the depth of the drainage outlet that the device is to be connected to and the drainage area to be treated. The outlet must be sufficiently deep to accommodate the required size of the unit. In terms of SWM benefits, OGS provide quality control by capturing particulates, oil and grease. OGS are one of few SWM features that can effectively remove (retain) oil and grease from stormwater.

- There is a variety of proprietary and non-proprietary OGS available ranging from chamber designs to manhole types. The different types incorporate some combination of filtration medium, hydrodynamic sediment removal, oil and grease removal, or screening to remove pollutants.

- Non-proprietary systems include deep sump catch basins.

- Proprietary systems include:
  CDS® Technologies
  Stormceptor®
  Vortechs™
  Downstream Defender™

Figure 10: Oil and Grit Separator[19]

These systems represent only some of the systems currently available. CDS® units were the only OGS systems whose specifications were used in the SWM scenarios due to the size of drainage areas involved, as described below.

The presentation of the CDS® systems or any of the other OGS systems in this SWM retrofit document in no way represents or reflects an endorsement.

Screening Action Type of OGS (e.g. Continuous Deflection Separation Systems)

Continuous Defelection Separation (CDS) systems (shown in Figure 11a) are an example of screening action type of OGS. The CDS systems are designed to treat stormwater runoff from relatively large drainage areas. Stormwater runoff is conveyed through the CDS system's diversion chamber, where all flows are passed through the separation chamber, which screens, separates and traps sediments and debris. CDS units can be installed as pre-cast or cast-in-place structures, configured as in-line, off-line, grate inlet or drop inlet and have multiple screen aperature sizes (example in Figure 11b). In-line units can treat flows from drainage areas up to 12 ha, while single off-line units can treat drainage areas up to 120 ha. The use of multiple pre-cast, or larger cast–in-place off-line units, allows for treatment of drainage areas in excess of 120 ha[20].

- Specifications drawn from the CDS® Technologies literature were used to define the OGS used in the SWM Retrofit Scenarios. For the evaluation of the Scenarios the CDS units were included in the "other controls" option of the water quality assessment program. A removal rate of 80% influent TSS was assumed, which is an *Enhanced Protection Level* as per the Ministry of the Environment Stormwater Management Planning and Design Manual (MOE 2003).

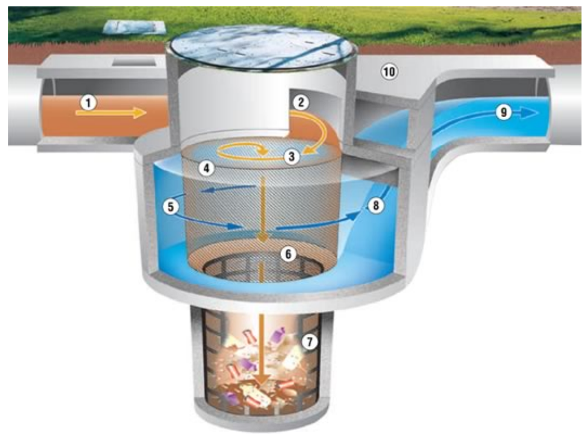


Figure 11a: Typical Schematic of a CDS Unit[21]

The presentation of the CDS® systems or any of the other OGS systems in this SWM retrofit document in no way represents or reflects an endorsement.

Figure 11b: Typical Installation of a CDS Unit[22]

Wet Ponds

Wet ponds are end-of-pipe facilities used to treat runoff from drainage areas of at least 5.0 ha, and preferably greater than 10 ha. If adequate space is available, these facilities can be designed and sized to provide erosion control, quality control and flood control benefits. The ponds shown in Figures 12a and 12b are examples of typical wet ponds in residential and commercial settings.

- For the evaluation of the SWM retrofit scenarios, the wet ponds were modelled in the "other controls" option of water quality assessment program. A removal rate of 70% of influent TSS was assumed, representing a *Normal Protection Level* as per the Ministry of the Environment Stormwater Management Planning and Design Manual (MOE 2003).

Figure 12a: Wet Pond in a Commercial Setting[23]

Figure 12b: Wet Pond in a Residential Setting[24]

3.2 Potential Retrofit Locations and Opportunities

Selection of the potential retrofit locations and opportunities, particularly the lot level and conveyance SWM measures, was based on the feasibility of retrofitting the measures into the study area's various land uses and development types to get widespread application of the measures on public and private property. Potential retrofit sites across the study area were identified in Step 1 and assessed in more detail in Steps 3 and 4 to confirm what, if any, retrofit options would be most practical and potentially most beneficial at a given location.

It is useful to note that street cleaning removes a large percentage of pollutants (compared to other SWM Measures studied) even if it is done infrequently. However, it was also found that any increase in frequency from the City's current schedule would provide a very small increase in pollutant removal compared to the increased cleaning frequency. As such, every Scenario was developed to maintain the City's current street cleaning schedule. As demonstrated in Figure 13, the current city street cleaning schedule of bi-weekly for larger streets and monthly for residential streets is providing 8% and 6% pollutant removal rates respectively, when using vacuum assisted vehicles as per the City's current practice. A daily cleaning schedule would provide the maximum theoretical pollutant removal of 13%, but this increase comes with significantly higher maintenance costs. These results were generated through a series of WinSLAMM test runs designed to identify the impacts of a single control over a preliminary test area based on the Pinecrest Creek subcatchment characteristics. For comparison purposes, all parameters were equal except the street cleaning control, which was modified as per the cleaning schedule tested.

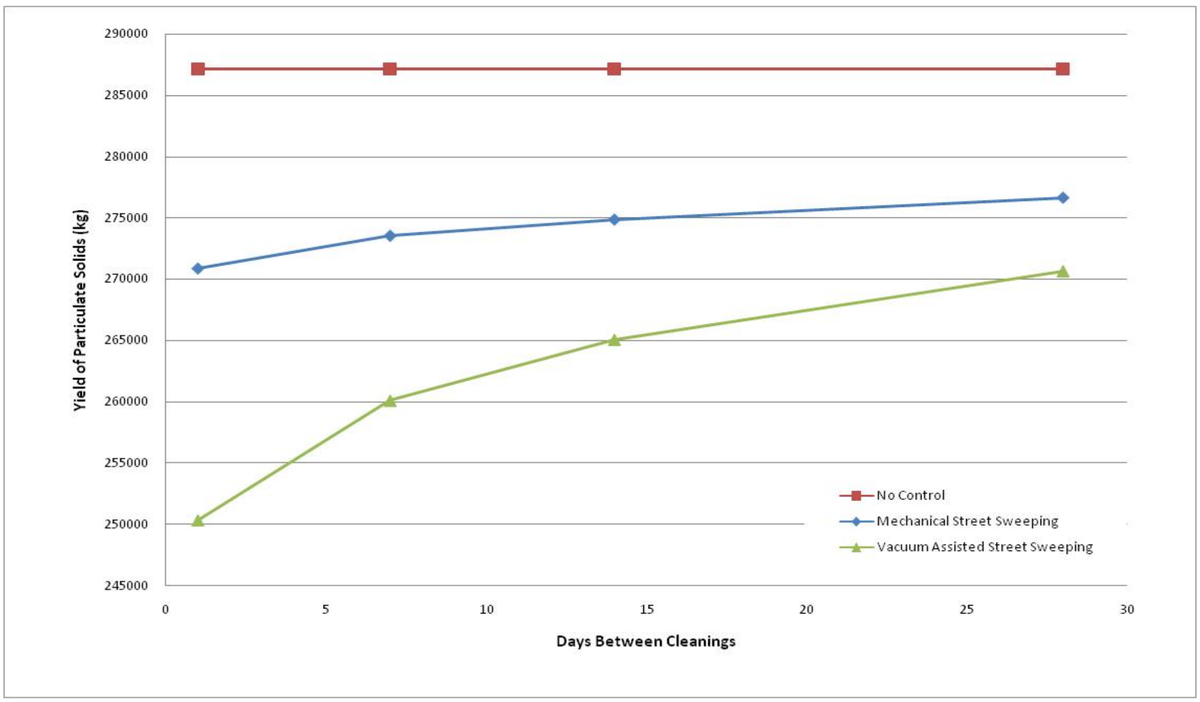


Figure 13: Comparison between Street Cleaning Frequencies

For end-of-pipe facilities (EoPs), an extensive screening process was conducted for the selection of potential locations, with a long list of 18 locations assessed. These 18 locations were chosen across the study area, spanning a number of the main outfall contributors to both Pinecrest Creek and the Ottawa River. Locations were originally selected based on available space, drainage area and minimal nearby infrastructure. This long list was then screened based a number of factors including drainage inverts, space limitations, mature vegetation impacts, existing servicing conflicts and location access. In the end, six (6) locations within the Pinecrest Creek and Westboro subwatersheds were identified as potential locations for EoPs: one within the Westboro catchments and five within the Pinecrest Creek subwatershed. The complete list of EoP locations assessed (18), information on each site and the selection factors used in the pre-screening are provided in Table H1 in Appendix H; the six (6) EoPs selected have been highlighted. Figure H1 in Appendix H shows the locations of the eighteen (18) sites originally considered. Figure 14 shows the locations of the six (6) end-of-pipe facilities that were considered for the retrofit scenarios.

Of the six selected EoPs described in Table H1, five (5) are located on NCC lands as a result of the space allocated within the creek corridor and along the shoreline of the Ottawa River. The NCC lands within the subwatersheds are typically located at the main outfall locations of interest. Therefore, use of these lands provides the most feasible solution with respect to meeting the project targets (i.e. reductions of TSS, TP and *E.coli*). The project team had several consultations with the NCC to arrive at the current list; however, it is to be noted that the short-list of locations recommended is still subject to NCC approval and any end-of-pipe facility will require further study prior to construction.

The selected SWM Measures, lot level, conveyance and EoP facilities were then used in various combinations to form the proposed SWM retrofit scenarios.

3.3 Stormwater Retrofit Scenarios

The five (5) stormwater management retrofit scenarios were developed by the project team to encompass a range of potential implementation levels for stormwater management measures within the study area. A primary consideration is the degree of “uptake” or the extent of implementation that can be expected. The uptake depends on a number of factors, for example:

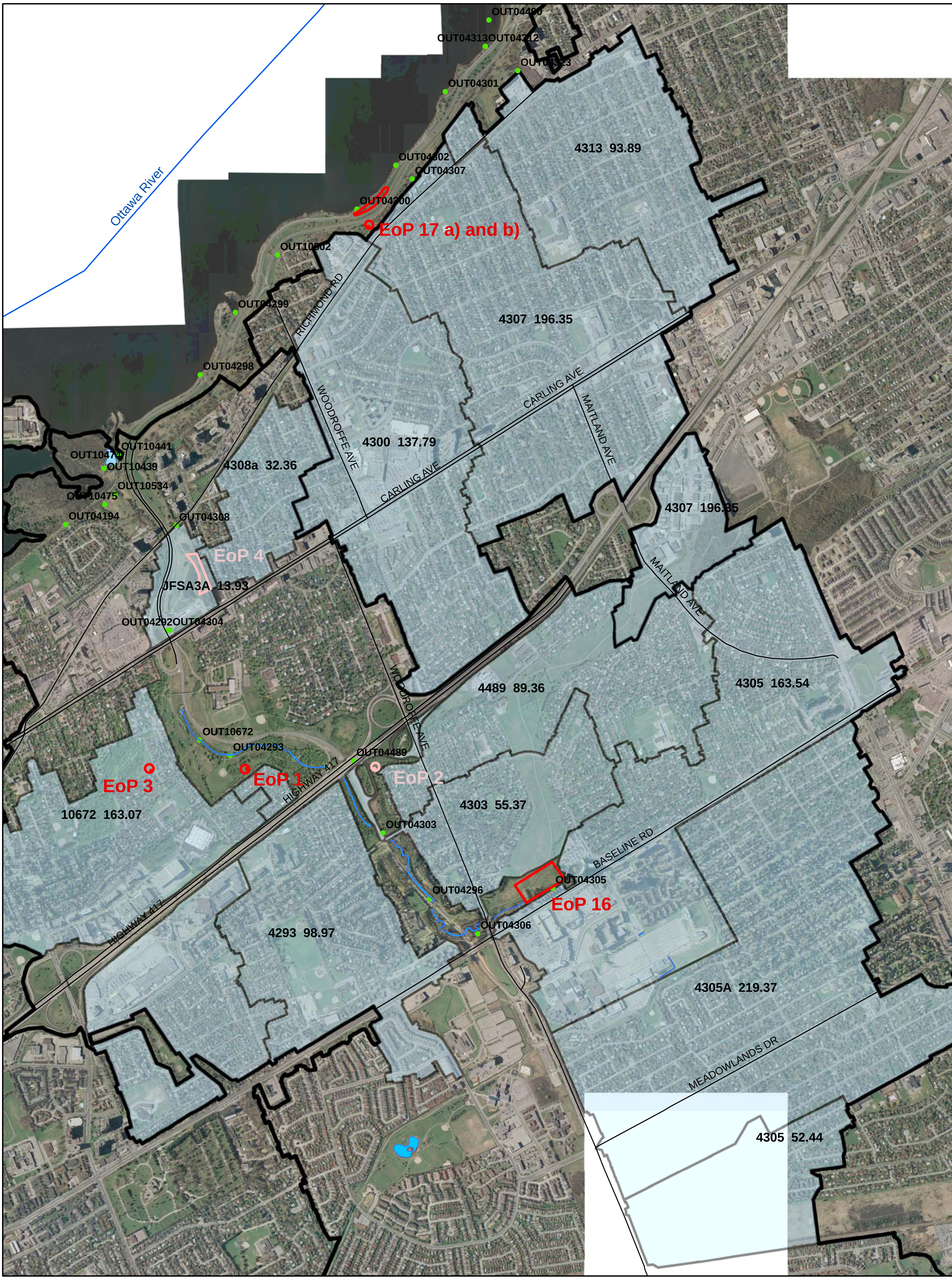
- Acceptance, that is: Will the homeowner be willing to disconnect the downspout and will they actually do it? Will the commercial establishment install porous paving?

- Feasibility: Can the downspout be disconnected? Are the lot level conditions suitable for downspout disconnection/redirection present?

In each case, the percentage “uptake” of lot level measures assigned was based on data collected from other SWM retrofit studies[25,26] and on the study area’s characteristics.

The resulting five scenarios are as follows:

1. Existing Conditions (Do Nothing)
2. Highest Practical SWM Implementation Without End-of-Pipe Facilities (HP SWM no EoP)
3. Highest Practical SWM Implementation With End-of-Pipe Facilities (HP SWM with EoP)
4. Moderate SWM Implementation With End-of-Pipe Facilities (Moderate SWM with EoP)
5. Public Property Only SWM Implementation With End-of-Pipe Facilities (Public Property Only with EoP)



LEGEND:

- Ottawa Storm Sewer Outlets
- Roads
- Moderate SWM Implementation Ponds and OGS
- Other Potential Implementation Ponds and OGS
- EoP_DrainageArea
- BritanniaSWMpond
- Pinecrest Creek

CLIENT: Ottawa

BY: JFSA Water Resources and Environmental Consultants

NOTES:
- The following background data was provided by the City of Ottawa

0 125 250 500 750 1,000 Meters

N

PROJECT: PINECREST CREEK / WESTBORO SWM RETROFIT STUDY

TITLE: End of Pipe Opportunities - Short List

PROJECT No. 741-09

DESIGN	KM
GIS	KM
CHECK	JFS
REVIEW	JFS

FIGURE 14

MAP REF.: 741_09\Design\Maps\EoPOpportunities_ModerateSWM.mxd

NOV 2010

REV. 6

3.3.1 Existing Conditions - Do Nothing

The Existing Conditions or Do Nothing Scenario is based on present land use and storm drainage conditions, which include the very limited stormwater management that currently exists in the study area. Information on existing conditions was derived from City of Ottawa land use and infrastructure data and a series of lot level inventories undertaken in Step 1 of the study. The Existing Conditions Scenario is the study area's baseline scenario. It reflects the impact of current practices and was used to determine areas where retrofit measures could be implemented for overall SWM improvements.

3.3.2 Highest Practical SWM Implementation Without End-of-Pipe Facilities

The Highest Practical Implementation Scenario is composed of the existing land use with the implementation of all the study's selected lot level and conveyance measures, but excluding end-of-pipe facilities. "Highest Practical" indicates the highest level of implementation presumed to be feasible. This scenario provides an indication of the improvements achieved by implementation of lot level and conveyance measures only.

3.3.3 Highest Practical SWM Implementation With End-of-Pipe Facilities

The Highest Practical Implementation Scenario is composed of the existing land use with the implementation of all the study's selected measures. "Highest Practical" indicates the highest level of implementation presumed to be feasible for lot level, conveyance and EoP facilities. The level of implementation of the EoPs, including oil and grit separators (OGS) and wet ponds was determined by the screening of possible EoP sites. As described in Section 3.1, the sites were screened for space limitations, servicing conflicts, aesthetics, natural features and property ownership. Six (6) EoP sites were selected. The OGS were included for their water quality benefits and for their below ground installation, which allows for other uses of the ground surface.

3.3.4 Moderate SWM Implementation With End-of-Pipe Facilities

The Moderate Implementation Scenario is comprised of the same types of measures and EoPs as the Highest Practical with EoP Scenario, however, the extent of the implementation is at a "moderate" rather than "high" level. The Moderate Scenario implementation percentages are based on a 5-30% reduction from the Highest Practical percentages. Four (4) of the six EoPs were selected for this scenario – one wet pond and one OGS less than the Highest Practical with EoP Scenario. The OGS were included for the benefits noted above in Section 3.3.3.

3.3.5 Public Property Only SWM Implementation With End-of-Pipe Facilities

The Public Property Only Scenario includes only measures located on publicly-owned lands. Public lands were defined as municipal, federal, provincial and local institutional (school board and school) lands. As all EoPs are located on public lands, all the EoPs included in the Highest Practical Scenario are included in the Public Property Only Scenario. The implementation percentages used in this scenario are the same as those used in the Highest Practical Scenario. This scenario provides an indication of the improvements that can be achieved without requiring participation from private landowners and individual homeowners. The OGS were included for the benefits noted above in Section 3.3.3.

The potential retrofit locations and opportunities for the selected SWM Measures are summarized as follows:

Table 2: SWM Measure Opportunities Included in the Retrofit Scenarios

SWM Measures	SWM Retrofit Scenarios			
	Highest Practical SWM no EoP	Highest Practical SWM with EoP	Moderate SWM with EoP	Public Property Only with EoP
Lot Level Public	All Included	All Included	Some Included	All Included
Lot Level Private	All Included	All Included	Some Included	None Included
Conveyance	All Included	All Included	Some Included	All Included
End-of-Pipe (EoP)	None Included	6 Included: 3 OGS and 3 Wet Ponds	4 Included: 2 OGS and 2 Wet Ponds	4 Included: 2 OGS and 2 Wet Ponds

The uptake percentages for lot level and conveyance measures for each Scenario are documented in Appendix H, in Tables H2 to H8 for Pinecrest Creek and the seven (7) Ottawa River outfalls from Westboro.

4. WATER QUALITY ASSESSMENT

Water quality modelling was used to predict the relative effectiveness of each of the SWM Scenarios in mitigating the impacts of runoff on water quality within Pinecrest Creek, and at various storm sewer outfalls to the Ottawa River. The WinSLAMM water quality software program was used for this modelling. Additional modelling was done by Baird & Associates Ltd., making use of a hydrodynamic model of the Ottawa River to determine the relative impact of the SWM Scenarios on peak *E.coli* counts at Westboro Beach.

A description of the water quality modelling completed and a summary of the results are provided in the following sections.

4.1 WinSLAMM Modelling

WinSLAMM[d] is composed of a series of spreadsheets programmed to evaluate non-point source pollutant loadings in urban areas using small storm hydrology. The model determines the runoff from a series of rainfall events and calculates the pollutant loading from the modelled area(s) resulting from these rainfall events. The software can simulate stormwater management measures such as infiltration/biofiltration controls, street sweeping, wet detention ponds, grass swales and porous pavement to determine how effectively these measures remove pollutants from stormwater runoff. Appendix I contains a description of the origins and basic functions of WinSLAMM, as well as a flow chart describing the model's calculation algorithm. Table 3 below lists the SWM Measures that can be modelled using WinSLAMM, and the source areas to which each measure can be applied.

[d] "WinSLAMM, the Source Loading and Management Model, was developed starting in the mid 1970's as part of early EPA street cleaning and receiving water projects in San Jose and Coyote Creek, California. While much of the runoff characterization and stormwater control data used in the model are based upon research conducted since the early 1970s, the model is being continually updated as new research data becomes available. More information on WinSLAMM is included in Appendix I.

Table 3 – SWM Measures and the Source Areas to which they are Applied in WinSLAMM

Source Area	Drainage Controls							
	Infiltration Trenches	Biofiltration Rain Gardens	Cisterns/ Rain Barrels	Wet Detention Ponds	Grass Drainage Swale	Street Cleaning	Catch-basins	Porous Pavement
Roof	x	x	x	x				
Paved Parking/ Storage	x	x	x	x				x
Unpaved parking/Storage	x	x		x				
Playgrounds	x	x	x	x				x
Driveways		x	x					x
Sidewalks		x	x					x
Streets/Alleys		x				x		
Undeveloped Areas	x	x		x				
Sm. Landscaped Areas	x	x						
Other pervious areas	x	x		x				
Other impervious areas	x	x	x	x				x
Freeway lanes / Shoulders	x	x		x				
Lg. Turf areas	x	x		x				
Lg. Landscaped Areas	x	x		x				
Drainage System		x			x		x	
Outfall	x	x		x				

Note: Infiltration devices are not referred to specifically in the software; instead biofiltration devices would be used for input along with infiltration information cited in the literature.

WinSLAMM is primarily an empirical model and requires calibration and verification against local stormwater samples in order to produce accurate absolute pollutant concentrations. While a detailed monitoring and calibration process was beyond the scope of this study, local water quality monitoring results were used to adjust the WinSLAMM default values to ensure the existing condition model generated results that could be considered reflective of local conditions. However, without a calibration and verification effort, the WinSLAMM results reported here are relative rather than absolute. Therefore, while the resultant concentrations and loadings will not necessarily match actual values, the relative improvement that any given retrofit Scenario would provide is given by the difference in pollutant concentrations between said retrofit Scenario and the existing conditions model.

To begin the modelling process, a series of WinSLAMM models were prepared for the entire study area based on the catchment areas discharging to the outfalls along Pinecrest Creek and the Ottawa River. The GIS mapping of drainage boundaries, land use and source area breakdown was provided by the City. The predominant sediment types underlying the study area, which according to published mapping are relatively fine-grained, were also taken into account in the WinSLAMM modelling.

The discretization of the subwatershed areas was carried out based on the drainage area delineations to each outfall from the study area to the Ottawa River. Pinecrest Creek and a total of seven (7) major storm sewer outfalls servicing Westboro discharge directly to the Ottawa River upstream of Westboro Beach (see Table 4 for a general description of the outfall and subwatershed characteristics). The Pinecrest Creek WinSLAMM model was then further discretized based on potential EoP facilities along the Pinecrest Creek corridor. This more detailed analysis was required due to modelling limitations within WinSLAMM. WinSLAMM is only capable of applying EoP facility per model, so the drainage area to each facility had to be modelled individually. The drainage areas within Pinecrest Creek that did not drain to EoP facilities were lumped in one model.

Table 4: Ottawa River Outfall and Subwatershed/Sewershed Characteristics

Outfall Characteristics				Watershed Characteristics							
City of Ottawa OUTLET ID	Ottawa River Model OUTLET ID	Street Name Reference	Outfall Diameter (mm)	Drainage Area (ha)	Impervious (%)	Land Use 2005 Classification (ha)					
						Residential	Commercial	Industrial	Institutional	Freeways	Other
Pinecrest Creek	CK-9	N/A	N/A	1909	35%	1481	98	11	129	40	149
04298	ORC-13	New Orchard Ave.	900	12	62%	7	4	0	1	0	0
04299	N/A	N/A	900	10	42%	10	0	0	0	0	0
04300	ORC-18	Ardmore	1500	138	49%	101	25	0	12	0	0
04301	ORC-20	Mansfield Ave.	600	3	49%	3	0	0	0	0	0
04307	ORC-19	Wavell Ave.	1800	196	42%	157	14	8	14	0	3
04313	ORC 21 & 22	Highland Park East and West	750 & 900	94	46%	80	3	0	10	0	2
04490	ORC-23	Workman Ave.	750	7	49%	7	0	0	0	0	0

Modelling results confirmed that the sum of the results from the discretized Pinecrest Creek subwatershed models yielded the same results (within a 1.0 % difference) as a lumped model for the entire Pinecrest Creek subwatershed. This was expected, as WinSLAMM does not take into account any routing along watercourses, nor does it account for pollutant concentration changes due to water chemistry. The practical application of this equality is that when the results from the multiple Pinecrest Creek WinSLAMM models are added together, they provide an appropriate estimate for the outflow and pollutant concentrations from Pinecrest Creek to the Ottawa River.

All of the WinSLAMM models were set up using the same continuous rainfall data. The City of Ottawa has identified rainfall data from 1980 monitored at MacDonald-Cartier International Airport as reflective of a 'typical year' of rainfall for the City. Therefore, the 1980 rainfall data were used to generate runoff within each WinSLAMM model. These records range from dry weather to a maximum event of 28.8 mm. Three (3) of the eighty-two (82) storms recorded in 1980 had been analyzed previously in the Ottawa River hydrodynamic model[e] and therefore these same events were used for the WinSLAMM modelling to produce pollutograph results. The three storms are listed below:

1. June 20 – 21, 1980 – Total Rainfall Depth = 10.8 mm
2. July 7 – 9, 1980 – Total Rainfall Depth = 28.8 mm
3. July 14 – 15, 1980 – Total Rainfall Depth = 20.9 mm

[e] The Ottawa River hydrodynamic model is the model used by Baird & Associates Ltd. to assess the impacts of runoff from Pinecrest Creek and the Westboro outfalls on Westboro Beach.

The water quality results from WinSLAMM are presented in the form of pollutographs. Pollutographs contain outflow with respect to time results (hydrographs) combined with pollutant concentrations. The project objectives and targets identify three (3) pollutants of interest: *E.coli*, Total Phosphorus (TP), and Total Suspended Solids (TSS); therefore, the pollutographs reported here only contain concentration results for these three pollutants. As noted, the pollutograph results were used as input for the Ottawa River hydrodynamic model to determine what impact Pinecrest Creek and the Westboro outfalls have on *E.coli* counts at Westboro Beach. This Ottawa River modelling was carried out by Baird & Associates. The complete Baird & Associates report - *Assessment of the Relative Impact of SWM Retrofit Alternatives Developed for the Pinecrest Creek Study* - is included in Appendix I.

4.2 Parameter Value Adjustment

The default pollution parameter values in the WinSLAMM data tables produced results that were more than ten (10) times greater than the City's water quality monitoring results for Pinecrest Creek and the Westboro outfalls for *E.coli* and total phosphorous (TP). Therefore, JFSA completed an exercise to adjust these values to more closely match local monitored data. The parameter value adjustments were based on literature values from the *Urban Subwatershed Restoration Manual No. 3 – Urban Stormwater Retrofit Practices vs. 1.0* prepared by the Center for Watershed Protection. Table B.4 from this report (included in Appendix I), provides alternate median event concentrations for various pollutants. The reference documents for this table were prepared by one of the authors of WinSLAMM, Dr. B. Pitt. The proportions for each source area from the original parameter files were maintained. To perform the parameter value adjustment, the original default average was calculated, and then replaced with the value from Table B.4. This exercise was performed for dissolved phosphorous and fecal coliforms. This parameter value adjustment produced results that are in the same order of magnitude as the City's monitoring data for *E.coli*, TP and TSS. This process does not constitute a calibration but provides existing condition modelled results that better reflect local observed water quality data. An example of the modification is shown in Table 5 below, which shows pollutant concentrations from Pinecrest Creek before and after the adjustment.

Table 5: Comparison of Pollutant Concentrations Before and After Parameter Value Adjustment

Storms	Pinecrest Creek Pollutant Concentrations					
	Before			After		
	E. coli (cts/100 ml)	Total Suspended Solids (mg/l)	Total Phosphorus (mg/l)	*E. coli* (cts/100ml)	Total Suspended Solids (mg/l)	Total Phosphorus (mg/l)
20-21 June 1980	39,489	672	0.88	3,622	152	0.32
7-9 July 1980	39,409	626	0.66	3,622	143	0.30
14-15 July 1980	39,117	615	0.65	3,591	140	0.29

The default pollutant probability file originally selected was WI_GEO01.ppd, as it was the most detailed default file available. However, this file did not contain concentration values for fecal coliforms, so the fecal coliform pollutant proportions from the default file BHAM_PPD_CALIB_June07.ppd were added to WI_GEO01.ppd. Then, the median event concentration from Table B.4 for dissolved phosphorus and for fecal coliforms were applied to WI_GEO01.ppd; the parameter file was then renamed J_WI_GEO01.ppd. J_WI_GEO01.ppd was the pollutant probability distribution file used for all WinSLAMM models. While WinSLAMM only predicts levels of fecal coliforms, the presence of fecal coliforms is related to *E. coli* in a 200:126 relationship. That is to say, for every 200 fecal coliforms present, there are 126 *E. coli* present[f]. The *E. coli* concentrations in the pollutographs prepared for Baird & Associates for the Ottawa River hydrodynamic modelling (see Section 4.1) were calculated from the WinSLAMM generated fecal coliforms using this relationship.

The original default file chosen as the particulate solids concentration file was PART.psc. The proportions per source area from this file were retained, but the median event concentration was changed to equal the values from Table B.4 for each land use. The modified particulate solids concentration file was then renamed J_PART.psc; this file was used in all WinSLAMM models.

4.3 *E.coli* Reduction – Wet Pond Treatment

City of Ottawa pond monitoring data demonstrate that treating stormwater with wet ponds can produce a measurable reduction in *E.coli* loading and concentration.

In order to make a reasonable determination of the percent removal of *E.coli* through wet pond treatment, JFSA reviewed monitoring data collected by the Toronto and Region Conservation Authority (TRCA) through the Stormwater Assessment and Monitoring Program (SWAMP) and the City of Ottawa (Stormwater Facility Annual Performance Summary & Water Quality Summary Table), included in Appendix I. Based on those data, JFSA concluded that a conservative estimate of the percent removal of *E.coli* in a wet pond with at least a Normal level of treatment (as per the Ministry of Environment (MOE) guidelines), is 50 %. Unfortunately, the WinSLAMM software does not allow for the simulation of *E.coli* removal through wet pond treatment. The WinSLAMM produced pollutographs were instead modified in Excel by JFSA to account for the 50 % *E.coli* reduction in all wet ponds.

Note: Following the water quality modelling completed for the Scenario evaluation, the wet pond EoP17 a) and b) was reduced in size as a mitigating measure to reduce impacts to mature trees at the site. The assumption of 50 % *E.coli* reduction used in the water quality modelling was, however, maintained given the planning level assessment undertaken. As with all wet ponds that have been recommended via this retrofit plan, the extent of *E.coli* reduction that can be achieved will require further investigation and confirmation at the detailed design stage.

[f] Ministry for the Environment, Government of New Zealand website: http://www.mfe.govt.nz/issues/water/water-quality-faqs.html#question4. Information retrieved in 2010.

5. WATER QUANTITY ASSESSMENT

5.1 Hydrologic Modelling

Hydrologic modelling was used to predict the relative effectiveness of each of the retrofit Scenarios in mitigating the impacts of runoff volumes and peak flows discharging to Pinecrest Creek. SWMHYMO[g] software was used for this modelling. Each of the five (5) SWMHMYO models (representing the 5 retrofit Scenarios) was ran for the 1:2 year to 1:100 year single events for the City of Ottawa four (4) hour Chicago and twenty-four (24) hour SCS design storm distributions. Scaled-down versions of the Chicago storm distribution were used for modelling the 5 mm, 10 mm, 15 mm and 25 mm storms. The 25 mm storm is often used to represent the 1:1 year event. The 10 mm and 15 mm events are sometimes referred to as "first flush" events. Since the SCS storm events for the 1:2 year to the 1:100 year return periods proved more critical than the Chicago storms for both peak flows and runoff volumes, only the SCS results were used for analysis.

Results from the hydrologic modelling were used to determine the potential effects of the Scenarios on the creek geomorphology, the existing flooding concerns and the hydrologic cycle within Pinecrest Creek. Peak flows from the full range of design storms were used in hydraulic modelling to determine the maximum water surface elevations (WSELs) and the associated flood risk along Pinecrest Creek. The hydrographs from the 5 mm to the 1:5 year design storm events for the five (5) Scenarios were provided to JTB Environmental Systems Inc. to conduct the fluvial geomorphological assessment.

The predominant sediment types underlying the study area, which according to published mapping are relatively fine-grained, were also taken into account in the SWMHYMO modelling.

5.2 SWMHYMO Models

The SWMHYMO hydrologic model prepared in the *Pinecrest / Centrepointe Stormwater Management Criteria Study*[27] was used as the basis for the SWMHYMO models prepared for this study. The models from the previous study were modified to reflect the detailed land use and source area breakdowns that were used for the WinSLAMM modelling. In addition, in order to simulate the effect of the various proposed retrofit Scenarios on runoff volumes and peak flows, the lot level, conveyance and end-of-pipe measures were incorporated into the SWMHYMO models.

While the ‘existing conditions’ have not changed significantly since the previous study, each subcatchment was analyzed in greater detail in this study. These model modifications resulted in slight increases in both peak flow and runoff volume results. The driving force behind these increases is the percent of directly connected impervious areas (Ximp), which was slightly underestimated in the previous study due to less specific data extraction and general percentages given across certain land use types. In total, 1498 ha of the total Pinecrest Drainage area of 1908 ha have an impervious ratio of 20 % or higher (i.e. modelled using the CALIB STANDHYD command). The Ximp parameters for all of these urbanised lands have revised Ximp values compared to the last study. The total impervious value was calculated in detail in the 2010 project, and has been maintained at 41 %. The directly connected imperviousness, however, increased from 21% to 31%. Table 6 below summarizes the modifications in imperviousness between the current and last study. Note that these impervious values are higher than the overall Pinecrest Creek subwatershed values, as this analysis does not include the Creek corridor or the large greenspace areas to the North end of the watershed.

[g] SWMHYMO is hydrologic modelling software for the management and simulation of stormwater runoff in either small or large rural and urban areas.

Table 6 – Directly Connected Imperviousness Modifications

SWMHYMO Parameters	Values from 2010 Study	Modified Values
Drainage Area	1498	1498
Total Imperviousness (%)	41	41
Directly Connected Imperviousness (%)	21	31

SWMHYMO models were prepared for all of the five (5) retrofit Scenarios. The original model was setup such that the area draining to each outfall along Pinecrest Creek was modelled using a single CALIB STANDHYD command. In order to incorporate various levels of implementation of the seven (7) SWM measures proposed in the retrofit Scenarios that effect peak flows and runoff volumes, the single lumped CALIB STANDHYD command was broken down into various CALIB STANDHYD commands, modelling the precise areas to be treated by each different SWM measure. The seven (7) SWM measures modelled in SWMHYMO are: downspout redirection, rain barrels, cisterns, infiltration trenches, rain gardens, porous pavement and wet ponds.

Four (4) methods were used to simulate all of the proposed SWM measures. Redirection of roof runoff was modelled by reducing the directly connected areas (Ximp) for any roof area to be redirected. Porous pavement for sidewalks, driveways and parking lots was modelled by increasing the initial abstraction (IA) value to represent the total storage volume available within the porous pavement and sub-structure. Rain barrels, cisterns, rain gardens and infiltration trenches were all modelled using the COMPUTE DUALHYD command. The Cinlet, Ninlet and TMJSTO values were modified depending on which control was being modelled and the level of implementation. As OGS have no effect on peak flows or runoff volumes, they were not accounted for in the modelling. The two (2) wet ponds within the Pinecrest Creek subwatershed were modelled using ROUTE RESERVOIR commands. A more detailed description of how the variables for each lot level control DUALHYD were calculated is included in Appendix J. (The SWMHYMO input files included on the CD in Appendix R contain a detailed description explaining the use of each command.)

The peak flow and runoff volume results for each Scenario for the 5 mm to 100 yr Type II SCS design storm event are included in Appendix J. Table 7 presents the results from the SWMHYMO modelling for the indicators which have been set out to assess how effecticely a given Scenario meets the project targets. This Table specifically presents the indicator results which address the hydrologic cycle within Pinecrest Creek. The complete set of peak flow and runoff volume results for each Scenario are included in Appendix J.

Table 7 – Hydrologic Cycle Indicator Results within Pinecrest Creek

Targets	Scenarios				
	Do Nothing - Maintain Existing Conditions	Highest Practical no EoP	Highest Practical with EoP	Moderate with EoP	Public Property Only with EoP
Volume of the first 10 mm of runoff that is retained[1]	7.67 mm	8.22 mm	8.22 mm	7.86 mm	7.78 mm
Volume of the first 10 mm of runoff that is retained (x1000 m^3)	180 x 1000 m^3	194 x 1000 m^3	194 x 1000 m^3	185 x 1000 m^3	182 x 1000 m^3
Percent of First 10 mm that is retained	76%	82%	82%	78%	77%
Percent Improvement in retaining the first 10 mm of runoff compared to the Existing Conditions Scenario	0%	8%	8%	3%	1%
Percentage of Drainage Area over which the next 15 mm of runoff is detained[2]	0%	0%	25%	23%	25%
Decrease in Effective Impervious Area[3]	0 ha	124 ha	124 ha	55 ha	34 ha
Total Percent Impervious[4]	35%	32%	32%	33%	34%
Total Effective Percent Impervious[4]	28%	22%	22%	25%	26%

Note 1 The SWMHYMO results for total runoff volume from the 10 mm design storm event have been used.
Note 2 Only those drainage areas which are treated by wet ponds meet this criterion.
Note 3 Porous Pavement, downspout redirection and street narrowing decrease effective imperviousness, replacing a pervious surface with a wet pond increases effective imperviousness.
Note 4 The total percent imperviousness and effective percent impervious values are for both Pinecrest Creek only.

5.3 Hydraulic Modelling

The flows generated by the hydrologic modelling were used for hydraulic modelling of Pinecrest Creek to determine the flood risk along the Pinecrest Creek corridor. HEC-RAS[h] software was used for this modelling.

5.4 HEC-RAS Model

5.4.1 Existing Hydraulic Conditions

The hydraulic modelling for existing conditions was performed using the HEC-RAS model developed as part of the *Pinecrest/Centrepoint Stormwater Management Criteria Study*[28]. The peak flows for each of the Scenarios were used in the HEC-RAS model to determine their effect on flood risk along Pinecrest Creek.

[h] HEC-RAS (Hydrologic Engineering Center – River Analysis System (U.S. Army Corps of Engineers 2002)) models. HEC-RAS is well recognized and widely accepted modelling software designed for this type of analysis.

As in the previous study, modelling results predict that the flows from the less frequent return period events will "back-up" at the Ottawa River Parkway (ORP) pipe inlet and cause flooding of the transitway/Ottawa River Parkway. To more accurately model this, a split flow analysis was performed to identify the portions of the total flow that would be conveyed overland by the transitway/Ottawa River Parkway and via the ORP pipe.

All proposed Scenarios produce lower peak flows than the existing conditions. Also, a wet pond which provides measurable quantity storage is included in three (3) of the proposed Scenarios. As such, the level of service (LOS, defined as the highest return period a pipe can convey without resulting in flooding upstream) provided by the ORP pipe is improved for some of the proposed Scenarios. Table 8 summarizes the resulting level of service provided by the ORP Pipe for each Scenario.

Table 8 – Level of Service (LOS) of the Ottawa River Parkway (ORP) Pipe

Retrofit Scenario	LOS (Return Period)
Existing Conditions	2 year
HP SWM without EoP	2 year
HP SWM with EoP	10 year
Moderate SWM with EoP	10 year
Public Property Only with EoP	5 year

6. FLUVIAL GEOMORPHOLOGICAL MODELLING

This section and referenced appendix were provided by JTB Environmental Systems Inc.

The main assessment criteria for the physical functioning of the Creek are related to erosion impacts. This connection is important because under conditions of no stormwater management, rapid delivery of surface runoff to creeks via piped flow is a major contributor to erosion. In Pinecrest Creek, the lack of stormwater management has, over time, created an evolutionary cycle where the Creek has responded to the delivery of stormwater with significant erosion.

Over the fullness of time, erosion in the Creek has decreased in magnitude and extent as the Creek has adjusted to flows incident upon it; however there are still erosion areas that have not completed the adjustment cycle, so the Creek, while it remains in a state of flux, is not showing uncontrolled response to flows through erosion at this time.

Indicators of erosion assessed for the purposes of this study were:

1. Sediment Regime and Size
2. Channel Stability
3. Erosion Potential
4. Aquatic Habitat

In terms of targets in the analysis, the following scoring criteria were used:

Scenarios which have potential to improve habitat and increase fishery potential are scored high; those which maintain existing conditions are scored medium; and those Scenarios which decrease habitat and fishery potential are scored low.

A methodology was developed to determine the potential impacts of the retrofit Scenarios on the indicators. The method involved:

1. Point-of-discharge for SWM flows directly to Pinecrest Creek
2. Determination of runoff hydrographs for specific storm events
3. Determination of representative cross-sections for analysis
4. Grain size analysis of bed materials along Pinecrest Creek
5. Calculating change in indicators according to targets outlined above through direct quantification with respect to cross-sections and flows

Calculations were completed on the following parameters as part of the overall analysis:

Discharge: Average, minimum and maximum discharge results were determined from the hydrographs to interpret change in peak flows and average flows. Peak flow change affects impact forces and sediment transport, while average discharge over the course of the hydrograph indicates change to cross-sectional area (wetted flow area) for the storm event;

Velocity: Average, minimum and maximum velocity was determined from the flows at each cross-section. Peaks and average conditions affect sediment transport and erosion potential;

Depth: Average, minimum and maximum depths for each cross-section was assessed to determine change in cross-sectional area. Depth is the actual depth of flow during each flow event;

Boundary Shear Stress: Average, minimum and maximum shear for the cross-sections was analyzed; this is a factor in erosion potential, channel stability and sediment regime and size. Critical shear stresses for entrainment were also determined for the representative grain sizes indicated above;

Erosion Potential: Average, minimum and maximum erosion potential for each of the representative grain sizes was determined to assess transport function and deposition of material in the sections. Erosion potential is the product of velocity and the relationship between boundary shear stress and critical shear stress for entrainment;

Exceedence of Critical Velocity: Average, minimum and maximum for each of the representative grain sizes indicated above was determined to assess transport function and deposition of material in the sections. Exceedence is the product of critical velocity for entrainment (according to the Komar equation) and the modeled velocity in the channel at the cross-sections.

Analysis was completed for each of the representative cross-sections for hydrographs representing each of the flow Scenarios. Full results are found in Appendix B of the Fluvial Geomorphology Assessment report. (The Fluvial Geomorphology Assessment report is provided in Appendix K and that report's appendices are included on the CD in Appendix R.)

By virtue of the fact that the upstream catchment contained a SWM pond (EoP 16) in the model and that pond is responsible for significantly attenuating frequent peak event flows, the impact of that pond on flows at the upper end of the Creek is significant. Additionally, the impact is also a function of the specific storm event.

Results from upstream sections (e.g., Station 5020 – see Figure 1 in Appendix K) can be summarized as follows. For the 10 mm storm:

1. For the 10 mm storm, peak discharge decreases from existing by values ranging from 40% (HP SWM) to 96% (HP SWM with EoP), while average discharge over the entire hydrograph decreases by between 77% to 82%;
2. In-channel velocities decrease by 30% to 33% for the average hydrograph condition to between 11% to 22% for peak discharges;
3. Depth of flow decreases by approximately 45% for all Scenarios under the average discharge condition, and decreases by between 16% and 78% for the peak discharge condition;
4. Decrease in shear stress under the average discharge condition is relatively consistent at approximately 46%, while under the peak discharge condition decreases range from 16% to 78%.
5. Erosion potential decreases significantly under all Scenarios by about 60%;
6. Exceedence of critical velocity decreases under all Scenarios, indicating a potential depositional environment for all grain sizes prevails under these flow conditions.

For the 25 mm storm, each of these patterns is repeated, though there is a slight difference in the magnitude of decrease.

As distance from the upstream SWM pond increases, the magnitude of effect from that pond decreases, though the impact of other measures becomes apparent in the results.

As a means of comparison, the same storm results are presented for a representative downstream section. Results for the 10mm storm show:

1. Decrease in average discharge is on the order of approximately 80% from existing and between approximately 40% and 60% for peak discharge;
2. Velocity actually increases under two Scenarios (Moderate and Public Only) as more flow is contained in the channel cross-section and access to floodplain roughness is limited;

3. Decreases in flow depth are significant and support the result in item 2 above;
4. Boundary shear stress decreases by about 50% to 60% under average flow conditions and between 17% and 35% under peak flow conditions;
5. Erosion potential decreases for all grain sizes in the analysis;
6. Critical velocity decreases in all cases except under the Moderate and Public Only Scenarios.

As with the upstream section, the pattern of results is consistent at the 25 mm flow event.

Analysis of the full range of results indicates that there are impacts created by the implementation of the proposed SWM measures extend from the upstream limit of the exposed channel to the downstream culvert at the Ottawa River Parkway. These impacts have been interpreted and summarized to evaluate the scoring of targets for the indicators of Erosion Impacts in the Scenario Evaluation.

This evaluation is based on the existing conditions of the Creek and its process functioning at the time of the study. Criteria are evaluated based on the full implementation of the SWM Scenarios presented. It is recognized that full implementation will take a period of time and that all impacts assessed will not be realized in full until a period of time after the final implementation is in place. That said, the cumulative impacts of sequential implementation will result in an inability of the Creek to reach the dynamic equilibrium that it is currently attempting to achieve. This prolongs the period of instability under which the Creek currently exists and has the potential to create problem areas which do not currently exist (or may exacerbate areas of concern which are at this point in time considered 'moderate' concerns (refer to the Fluvial Geomorphology Inventory in Appendix E) and which will require intervention.

Ultimately, maintaining the existing structure and process within Pinecrest Creek may not be a preferred outcome, given that it is artificially maintained by uncontrolled flows. If there is a desire to rehabilitate Pinecrest Creek to a more historic flow pattern, implementation of the end-of-pipe measures (particularly the stormwater ponds in Reach 6 and downstream of Iris Street) will go a long way in determining the final form of the Creek. However, to avoid a complete reconstruction of the Creek, the detailed design of the ponds must balance water quality improvements with Creek function (reduction of erosion/sedimentation along sensitive reaches of the Creek). Notwithstanding this, some localized Creek rehabilitation may be required in conjunction with pond construction to ensure that operation of the pond does not exacerbate any existing condition.

With respect to timing, it is preferred that the end-of-pipe measures are put in place early in the retrofit schedule, so the maximum benefit to water quality, quantity and fluvial process is achieved.

7. EVALUATION OF SCENARIOS

An evaluation process was developed to determine the preferred SWM Retrofit Scenario. The evaluation included scoring and ranking the Scenarios using the results of the water quality, quantity and fluvial geomorphologic modelling, and the predicted ability of each Scenario to reduce flood risk, erosion impacts, runoff volumes and peak flows and pollutant concentrations and loads. The evaluation addressed five (5) main considerations: Project Objectives and Targets, Social & Cultural, Natural Environment, Timing & Ease of Implementation, and Costing. Each consideration was covered by a group of criteria with indicators. For the Project Objectives, the criteria, indicators and targets established in Step 1 were used for the scoring. The project team established an overall scoring method to best capture the benefits and/or limitations of each Scenario. The scores used for the individual indicators were as follows (listed in order of the scores for the most beneficial to least beneficial results): high (=3), medium (=2), low (=1) or none (=0).

Therefore, the evaluation was split into two steps: a numerical scoring followed by comparison of the Timing & Ease of Implementation and Costing. The criteria groups, individual criteria, indicators, indicator rationale and explanation of the scoring used for each indicator are presented in Table 9.

Table 9: Criteria and Scoring used for Scenario Evaluation

Criteria		Indicators	Rationale	Scoring	Weighting
Project Objectives	1) Flood Risk	Flood risk	With potential infill and redevelopment, there is a need to ensure flood risk to public health and safety and to property is not increased.	Scenarios that have the potential to reduce flood risk along the creek corridor are scored high; scenarios which result in no change to the flood risk along the creek corridor are scored medium; and scenarios which increase the flood risk along the creek corridor are scored low.	75
		Floodplain storage	Floodplain storage attenuates peak flows as the flood wave moves downstream through the system; maintaining this feature of the floodplain is important to avoid peak flow increases from future potential works within the corridor.	Scenarios which increase riparian storage volumes for 2 to 100 year events are scored high; scenarios which maintain existing conditions are scored medium; and scenarios which decrease riparian storage are scored low.	
	2) Erosion Impacts	Sediment regime and size	Sediment sources and sediment transport need to be maintained in dynamic equilibrium to control loadings to reaches.	Scenarios that result in either an increase or decrease in sediment transport/mobility of 10 percent from existing are scored high, those that result in an increase or decrease between 10 and 20 percent from existing are scored medium, those that result in an increase or decrease of greater than 20 percent from existing are scored low.	
		Channel stability	Channel stability is a function of time series flows and sediment regime, stabilizing bank features (e.g. woody vegetation, artificial hardening).	Scenarios that result in estimated change in cross-sectional area from existing of plus or minus 10% are scored high, those that result in estimated change in cross-sectional area from existing of plus or minus 20% are scored medium, and those that result in estimated change in cross-sectional area from existing of greater than 20% are scored low.	
		Erosion potential	Erosion potential needs to be reduced to more natural levels to stabilize and reduce erosion damage and loss of riparian/floodplain lands. Maintain channel stability to protect municipal and NCC infrastructure, to reduce annual maintenance costs and increase longevity of infrastructure.	Scenarios that reduce erosion potential, damage, and loss of riparian/floodplain lands are scored high, those that maintain channel conditions are scored medium, and those that increase erosion potential, damage, and loss of riparian/floodplain lands are scored low.	
		Aquatic habitat	Improve the quality and quantity of in-stream aquatic habitat. Improving the potential for a sustainable fishery is a longer term objective.	Scenarios which have potential to improve habitat and increase fishery potential are scored high; those which maintain existing conditions are scored medium; and those scenarios which decrease habitat and fishery potential are scored low.	
	3) More Natural Hydrologic Cycle	Peak flows and runoff volumes for the 10 mm and next 15 mm storms	Reduce flashiness of runoff from the watershed. An increase in the "flashiness" represents the loss of water storage capability of soils and vegetation due to urbanization.[1] Retaining the first 10 mm storm and detaining the next 15 mm, will results in lower peak flows and runoff volumes.	Scenarios with the greatest retention and detention of runoff from first 10 mm and next 15 mm respectively are scored high; scenarios that retain and detain some runoff from first 10 mm and next 15 mm respectively are scored medium; scenarios that retain and/or detain the least amount of runoff from first 10 mm and next 15 mm respectively are scored low.	
		Effective imperviousness (EI)	The degree of effective imperviousness can greatly impact the timing and amount of flows and pollutants entering the receiving watercourse.	Scenarios with the greatest decrease in effective impervious area from existing conditions are scored high; scenarios with some decrease are scored medium; those with little decrease in effective imperviousness are scored low; and those with no decrease are scored as none.	
	4) Water Quality	TSS, TP	Targets are linked to achieving fish community targets, aesthetics and non-eutrophic conditions and avoiding the creation of in-situ contaminant concerns.	Scenarios that reduce TSS by 25mg/L or more from existing conditions, attain a TP concentration of 0.03 mg/L and reduce the total yield of both TSS and TP are scored high; scenarios that attain two of those three targets are scored medium; scenarios that attain one target are scored low; and scenarios that achieve zero targets are scored as none.	
	5) Runoff impacts on Westboro Beach	Instream *E.coli* (Ottawa River at Westboro Beach)	Setting targets to approach swimming beach PWQO in non-beach areas ensures that risks of contracting disease from incidental exposure to recreational waters are reduced (e.g. boating, water skiing, dock swimming)	Scenarios which result in at least 40% reduction in E. coli concentrations at Westboro Beach, or higher, are scored high; scenarios which result in at least 20% reduction in E. coli concentrations at Westboro Beach are scored medium; scenarios with less than a 20% but more than 0% reduction in *E.coli* concentrations at Westboro Beach are scored low; and scenarios with 0% reduction are scored as none.	
	6) Natural Features	Riparian vegetation	The Enviro. Canada Habitat Guideline recommends natural vegetation within 30 m of a watercourse be retained or re-established on both banks for 75% of its overall length. (Target was developed at a watershed level and may not be appropriate to or achievable within an urban subwatershed.)	Scenarios that increase riparian vegetation are scored high, those that maintain the existing vegetation are scored medium, and those that reduce the existing features are scored low.	
		Tree Canopy	Increased tree canopy in urban areas can reduce runoff volume by intercepting rainfall, particularly for small events .	Scenarios that increase tree canopy are scored high; scenarios that maintain canopy are scored medium; and scenarios that reduce it are scored low.	
	7) Public Awareness	Increased public awareness	Increased public awareness will lead to greater success and uptake of SWM Retrofit Plan recommendations .	Scenarios that involve a high level of public awareness are scored high; scenarios that involve a moderate level are scored medium; and scenarios that involve a low level are scored low.	
		Increased public involvement	Increased public involvement required for successful implementation of SWM retrofit.	Scenarios that involve a high level of public involvement are scored high; scenarios that involve a moderate level are scored medium; and scenarios that involve a low level are scored low.	

Table 9: Criteria and Scoring used for Scenario Evaluation (page 2)

Criteria		Indicators	Rationale	Scoring	Weighting
Social / Cultural	Open Space / Parks	Adverse effects on parks and open space	Potential to have adverse effect on parks and open space.	Scenarios which have no adverse effects on parks and open space are scored as high; scenarios which have minimal adverse effects on parks and open space are scored medium; and scenarios which have the most adverse effects or remove parks and open space are ranked low.	10
Natural Environment	Terrestrial Systems	Impact on terrestrial habitat	Potential to impact terrestrial habitats or systems, including possible impacts on wildlife (including mammals, reptiles, birds) and terrestrial features/functions (including but not limited to designated features). This factor is intended to capture direct positive and negative impacts on natural terrestrial features, for example, by maintenance, physically building or habitat disturbances	Scenarios which Improve or have no impact on terrestrial habitats or systems are scored high; scenarios which have minimal impacts are scored medium; and those scenarios which have the most impacts on terrestrial habitats or systems are scored low.	15
	Aquatic Systems	Impact on aquatic habitat	Potential to impact aquatic habitats or systems, including possible impacts on aquatic life, features, and functions. This factor is intended to capture direct negative impacts through, for example, maintenance, physically building in or disturbing stream habitats, or wetlands.	Scenarios which improve or have no impact on aquatic habitats or systems are scored high; scenarios which have minimal impacts are scored medium; and scenarios which have the most impacts are scored low.	
				TOTAL	**100**

Timing / Ease of Implementation	Timing to Implement	Estimated implementation time	Length of time it will take until recommended retrofit strategy is implemented and operational.	Estimated time to implement shown per scenario.	N/A
	Degree of Control	Degree of implementation in public realm	Degree that the implementation of the scenario rests within the public realm in terms of: being maintained over time; authority to proceed.	Estimated time to implement shown per scenario.	N/A
Economic	Cost to Municipality and other Agency Landowners	Relative total cost	Total present value life cycle costs, which include operation and maintenance.	Estimated costs shown per scenario.	N/A
	Cost to Private Landowners	Relative total cost of lot level component	Total present value life cycle costs for implementation of lot level measures	Estimated costs shown per scenario.	N/A

[1] http://www.b-sustainable.org/natural-environment/basins-closed-to-further-water-appropriations

Calculation of the Scenarios Scores for Ranking

* high = 3
* medium = 2
* low = 1
* none = 0

Scenario Scoring and Ranking Process

The score for each criterion is multiplied by its portion of the weighting and then the weighted scores are added up to produce the scenario's total score.

The highest total score = the highest rank.

8. COSTING OF SCENARIOS

In order to compare the costs of the proposed retrofit Scenarios, a 50 year lifecycle cost analysis was undertaken. For the purposes of the lifecycle cost exercise, a discount rate of 5% was applied for the lifespan of the SWM measure or installation. This value has been chosen to provide an estimate of lifecycle costs for the various retrofit Scenarios and is not an indicator of what the average discount rate over the next 50 years will be. For this cost analysis, the capital cost, replacement costs and maintenance costs of all lot level, conveyance and end-of-pipe facilities were taken into account. A summary of the 50 year lifecycle costs for each Scenario is presented in Table 10 below.

Table 10 – Summary of Total Scenario Costs for a 50 year Lifecycle

	Highest Practical SWM with EoP Facilities	Highest Practical SWM without EoP Facilities	Moderate SWM	Public Property Only
Present Value : Total Cost	$63,997,000	$49,312,000	$42,900,000	$30,739,000
Present Value : Maintenance Cost	$8,965,000	$7,379,000	$6,157,000	$4,362,000
Amortized : Maintenance Cost	$491,000	$404,000	$337,000	$239,000
Present Value : Capital Cost	$55,033,000	$41,933,000	$36,743,000	$26,317,000
Amortized : Capital Cost	$3,015,000	$2,297,000	$2,013,000	$1,442,000

The overall costs have been presented as a present value in 2010 Canadian dollars. Tables L1 through L4 in Appendix L present the itemized lifecycle cost breakdown for the retrofit Scenarios.

9. SCORING AND RANKING OF SCENARIOS

Weighting of the evaluation criteria was applied to the scoring of the Scenarios. In total, the project objectives comprise 75% of the weighting due to the scope of the environmental concerns and social factors addressed by those objectives. Weighting within project objectives was based on the relative significance of the criteria and indicators with respect to achieving the desired target or outcome and the impact that the Scenarios could potentially have with respect to that indicator. For example, producing a more natural hydrologic cycle within Pinecrest Creek was a salient objective for the SWM retrofit plan. The parameters indicative of a more natural hydrologic cycle were assigned a relatively high weighting. While flood risk is very important from the public safety point of view, none of the Scenarios are predicted to have any potential to increase flood risk, so less weight is assigned for flood risk than other criteria that are directly addressed by each Scenario. The remaining Social/Cultural and Natural Environment criteria comprise 25% of the weighting.

The weighted scores for each indicator were calculated as follows:

$$(\text{weighted score}) = (\text{indicator score}) \times (\text{weight})$$

The total score for each Scenario is the sum of the Scenario's weighted scores for each indicator.

9.1 Results of Scenario Scoring and Selection of Preferred SWM Scenario

The results of the Scenario numerical scoring are presented in Table 11. The modelling and assessment results upon which the indicator scores are based are also included in Table 11. The Scenario scores and ranking are presented in Table 12.

Table 11: Scenario Evaluation

Criteria		Indicators	Do Nothing - Maintain Existing Conditions		Highest Practical		Highest Practical with EoP		Moderate		Public Only		Weighting	
			Result	Score	Result	Score	Result	Score	Result	Score	Result	Score		
Project Objectives	1) Flood Risk	Flood Risk	No Change in Flood Risk	2	No Change in Flood Risk	2	Potential to Decrease Flood Risk	3	Potential to Decrease Flood Risk	3	Potential to Decrease Flood Risk	3	75	5
		Flood Plain Storage	Maintains Flood Storage	2	Maintains Flood Storage	2	Maintains Flood Storage	2	Maintains Flood Storage	2	Maintains Flood Storage	2		
	2) Erosion Impacts	Sediment Regime and Size	Maintains Existing Conditions	3	Significant Decrease	1	Significant Decrease	1	Significant Decrease	1	Significant Decrease	1		3
		Channel Stability	Maintains Existing Conditions	2	Significant Decrease	1	Significant Decrease	1	Significant Decrease	1	Significant Decrease	1		5
		Erosion Potential	Maintains Existing Conditions	2	Significant Decrease	3	Significant Decrease	3	Significant Decrease	3	Significant Decrease	3		5
		Aquatic Habitat	Maintains habitat	2	Maintains habitat	2	Maintains habitat	2	Maintains habitat	2	Maintains habitat	2		2
	3) More Natural Hydrologic Cycle	Peak Flows and Runoff Volumes for the 10 mm and next 15 mm storms	10 mm Retention = 76 %	1	10 mm Retention = 82 %	2	10 mm Retention = 82 %	3	10 mm Retention = 78 %	3	10 mm Retention = 77 %	3		15
			15 mm Detention = 0 %		15 mm Detention = 0 %		15 mm Detention = 25 %		15 mm Detention = 23 %		15 mm Detention = 25 %			
		Effective Imperviousness (EI)	Change = 0 ha	0	Change = -124 ha	3	Change = -124 ha	3	Change = -55 ha	2	Change = -34 ha	1		
	4) Water Quality	Total Suspended Solids (TSS)†	TSS = 2.24x10^5 kg	0	Change = -12%	1	Change = -44 %	2	Change = -37 %	2	Change = -39 %	2		15
		Total Phosphorus (TP)†	TP = 1,165 kg		Change = -13 %		Change = -32 %		Change = -26 %		Change = -25 %			
	5) Runoff impacts	Instream *E.Coli* (Ottawa River at Westboro Beach)	145 cts / 100mL	0	113 cts / 100mL	2	83 cts / 100mL	3	92 cts / 100mL	2	97 cts / 100mL	2		15
			Change = 0%		Change = -22%		Change = -43%		Change = -37%		Change = -33%			
	6) Natural Features	Riparian Vegetation	No Change in Vegetation	2	No Change in Vegetation	2	No Change in Vegetation	2	No Change in Vegetation	2	No Change in Vegetation	2		5
		Tree Canopy	No Change in Canopy	2	No Change in Canopy	2	No Change in Canopy	2	No Change in Canopy	2	No Change in Canopy	2		
	7) Public Awareness	Increased Public Awareness	Low Level	1	High Level	3	High Level	3	High Level	3	Low Level	1		5
		Increased Public Involvement	Low Level	1	High Level	3	High Level	3	Moderate Level	2	Low Level	1		
Social / Cultural	Open Space / Parks	Adverse effects on parks and open space	Minimal adverse effects	2	Minimal adverse effects	2	Most adverse effects	1	Most adverse effects	1	Most adverse effects	1	10	
Natural Environment	Terrestrial Systems	Impact on terrestrial habitat	Minimal Impact	2	Minimal Impact	2	Most Impact	1	Most Impact	1	Most Impact	1	15	7.5
	Aquatic Systems	Impact on aquatic habitat	Minimal Impact	2	Minimal Impact	2	Minimal Impact	2	Minimal Impact	2	Minimal Impact	2		7.5
		TOTAL WEIGHTED SCORE		116		195		217		192		177	100	

† The values shown for existing conditions are the total yields (and percent change) of suspended solids and total phosphorus.

Table 11: Scenario Evaluation (Page 2)

Criteria		Indicators	Do Nothing - Maintain Existing Conditions	Highest Practical	Highest Practical with EoP	Moderate	Public Only	Weighting
			Result	Result	Result	Result	Result	
Timing / Ease of Implementation	Timing to Implement	Estimated implementation time	N/A	Significant Time Required	Significant Time Required	Moderate Time Required	Moderate Time Required	N/A
	Degree of Control	N/A	Completely in Public Domain	Slightly in Public Domain	Moderately in Public Domain	Moderately in Public Domain	Completely in Public Domain	N/A
Economic	Cost for works on public property (City, NCC, public institutions)	Total present value lifecycle costs	Costs (tangible and intangible) associated with existing water quality, flooding, erosion problems and beach closures.	$16,000,000	$31,000,000	$21,000,000	$31,000,000	N/A
	Cost for works on private property (residential and non-residential)	Total present value lifecycle costs	No cost	$33,000,000	$33,000,000	$22,000,000	No cost	N/A
		SUM OF COSTS	N/A	$49,000,000	$64,000,000	$43,000,000	$31,000,000	

Calculation of the Scenarios Scores for Ranking

* high = 3
* medium = 2
* low = 1
* none = 0

Scenario Scoring and Ranking Process

The score for each criterion is multiplied by its portion of the weighting and then the weighted scores are added up to produce the scenario's total score.
The highest total score = the highest rank.

Table 12 – Scenario Numerical Scores and Ranking

Scenario	Overall Score	Rank	50 Year Lifecycle Cost
Do Nothing - Maintain Existing Conditions	116	5	N/A
Highest Practical SWM without EoP	195	2	$49 M
Highest Practical SWM with EoP	217	1	$64 M
Moderate SWM with EoP	192	3	$43 M
Public Property Only with EoP	177	4	$31 M

As would be expected, Highest Practical SWM with End-of-Pipe Facilities has the highest numerical score and the Do Nothing option the lowest numerical score. Based on these scores, the Do Nothing option was eliminated as it does not meet most objectives and targets.

The Scenario assessment and scoring process also revealed that with the full implementation of the remaining Scenarios there is a potential for adverse impacts on the Pinecrest Creek channel stability and the sediment regime. The project team reviewed the predicted impacts on the Creek and noted that the predictions are based on the results of modelling the SWM ponds, including EOP16, to optimize water quality benefits. The project team concluded that in order to address the potential Creek impacts, the final configuration of the pond and its outflow will be designed to balance the water quality with the need to avoid destabilizing the Creek. However, in order to realize the greater water quality benefits, the end-of-pipe facilities would need to be part of the SWM retrofit implementation. Therefore, the preferred Scenario would be selected from the Highest Practical SWM with EoP, the Moderate and the Public Property Only Scenarios. This eliminated the Highest Practical without EoP Scenario. Of the three Scenarios with EoP, the Public Property Only Scenario was eliminated based on its lower score and ranking.

The Timing & Ease of Implementation and Costing criteria were then considered for the selection of the Preferred Retrofit Scenario from the two remaining Scenarios: the Highest Practical SWM with EoP and the Moderate.

- Timing to Implement: A more moderate amount of time is required for implementation of the Moderate Scenario as compared to the significant time of implementation required for the Highest Practical SWM with EoP Scenario.

- Degree of Control: The degree of control is comparable between the two Scenarios.

- Costing: The Highest Practical SWM with EoP Scenario has much higher projected costs than the Moderate SWM Scenario. In addition, the Moderate SWM Scenario has the potential of being more cost effective than the Highest Practical SWM with EoP Scenario based on the results versus targets achieved. To determine the relative cost versus benefit ratio for each Scenario, the total scenario costs were converted to a unit cost per kg, number of bacteria or m^3 of pollutant (TSS, TP, *E.coli*, and Runoff Volume) removed. Based on this analysis, the Moderate SWM Scenario is more cost effective than the Highest Practical SWM with EoP.

Based on the results of this second step of the scenario evaluation, the Moderate SWM Scenario was selected as the preferred SWM Retrofit Scenario for the Pinecrest Creek/Westboro study area.

10. DAYLIGHTING

Under existing conditions, Pinecrest Creek is conveyed underground though the Ottawa River Parkway (ORP) pipe, from approximately 300 m upstream of Carling Avenue to the Creek's outlet to the Ottawa River. The total length of the ORP pipe is approximately 1.4 km, with an overall elevation drop from inlet to outlet of approximately 8.0 m. The piped section of the Creek is a significant loss in terms of aquatic habitat, and the reduced capacity of the piped enclosure increases flood risk to the transitway. The piped section also eliminates the possibility of fish migrating from the Ottawa River upstream into Pinecrest Creek. Replacing sections of this pipe with an open channel, referred to as daylighting, could provide a wide range of benefits. Based on the local topography and surrounding infrastructure above the ORP Pipe, three (3) sections of the pipe were identified as potential locations where daylighting the pipe would be feasible based on available space. Preliminary potential open-channel cross-sections have been developed based on existing space constraints. A 5 horizontal to 1 vertical side slope was used wherever there was sufficient space, although there are locations where a 2:1 side slope would be required. A hydraulic analysis was then conducted on these cross-sections to ensure that daylighting would not increase flood risk to any infrastructure along the Pinecrest Creek corridor, and most specifically, flood risk to the Ottawa River Parkway and transitway.

Based upon this exercise, approximately 900 m of daylighting appears to be feasible. Additional work would be required to more fully assess existing and future constraints, and additional consultation with the NCC would be required regarding their vision for the future corridor.

Plan, profile and cross-sectional views of the proposed open-channel sections are included in Appendix M.

10.1 Hydraulic Conditions Modified with Daylighting

The existing conditions HEC_RAS model was modified to reflect the potential daylit reaches (i.e., where daylighting appears to be achievable). The proposed sections were all designed such that they had greater hydraulic capacity than the pipes they would replace. However, the limiting control along the ORP pipe is the pipe section below Richmond Road. Therefore, despite the localized improvements in hydraulic capacity that could be provided by the proposed open channel sections, the present analysis indicates the overall flood risk to the Ottawa River Parkway remains unchanged with the incorporation of the daylighting as compared to the existing hydraulic conditions. To fully assess the potential of reducing flood risk through daylighting, improvements in the hydraulic capacity of the pipe below Richmond Road would need to be investigated.

It is important to note that the proposed sections for the three (3) daylit reaches have only been designed to consider the minimum hydraulic requirements and the physical space available within the surrounding infrastructure. Further assessment would be required to ensure that these sections would be stable with respect to the Creek's existing and anticipated future hydrology. Furthermore, due to the large drop in elevation, velocities in the most downstream section are currently above 3.0 m/s, which would be unacceptable for an open-channel. There are various measures that can be employed to reduce the water velocities though this section that would also need to be further investigated at a later design stage.

ENDNOTES

[1] Lower Rideau *Watershed Strategy Executive Summary*- Appendix A2: Tributaries to Reaches 1, 2, 3 And 4 - Reach indicators and targets identified represent conditions necessary to support a healthy ecosystem.

[2] City of Ottawa Stormwater Management Strategy –Stage 2: FINAL POLICIES – May 2007

[3] Nichol, G. 2006. *City Stream Watch 2006 Annual Report.* Prepared for the Rideau Valley Conservation Authority (RVCA), December 18, 2006.

[4] J.F. Sabourin and Associates Inc. 2000 An Evaluation of Roadside Ditches and Other Related Stormwater Management Practices- Addendum – Revised Cost Analysis and Selection Tool. Prepared for Toronto and Region Conservation Authority, February 2000.

[5] *Ibid.*

[6] http://www.amazoneaves.com/images/ddp01.jpg

[7] http://www.devilsbackyard.com/2010/04/22/rain-barrels-for-your-home

[8] http://www.lakecountyil.gov/Stormwater/LakeCountyWatersheds/BMPs/RainBarrelCistern.htm

[9] http://baywatersheds.org/wp-content/uploads/2010/07/rain-garden-from-www.carolstream.org_.jpg

[10] www.sws-sssd.org

[11] http://greenvalues.cnt.org/national/images/permeable_pavement.jpg

[12] http://www.inhabitat.com/wp-content/uploads/perviouspaving-ed04.jpg

[13] http://www.preinnewhof.com/images/Projects/Porous-Pavement-IRS/IRS-Lot-3.jpg

[14] http://www.wbdg.org/resources/lidtech.php

[15] http://www.cob.org/services/environment/water-quality/homeowner-incentive-program.aspx

[16] http://www.westlafayette.in.gov/egov/gallery/1251236693426196.jpg

[17] http://www.lakelandgov.net/publicworks/Traffic/TrafficCalming/TrafficCalmingProjects.aspx

[18] http://switchboard.nrdc.org/blogs/rhammer/managing_stormwater_and_making.html

[19] www.watertectonics.com

[20] http://www.shawpipe.com, 2010

[21] http://www.shawpipe.com/cds_stormwater.aspx

[22] http://www.contech-cpi.com/Products/Stormwater-Management/Treatment/CDS.aspx

[23] http://www.rwmwd.org/index.asp?Type=B_BASIC&SEC=%7B82D57109-E41C-4CE8-B838-477FF4A2DDFD%7D

[24] http://www.co.thurston.wa.us/stormwater/facilities/facilities-home.html

[25] D'Andrea, M.A. Wet Weather Flow Management. City of Toronto. Toronto, Ontario. November 2006.

[26] Sabourin, J.F., Keep the Rain Out of the Drain – Making it work in the City of Toronto. Ottawa, Ontario. December 1997.

[27] J.F. Sabourin and Associates Inc. and JTB Environmental Systems Inc. 2010. Pinecrest/Centrepointe Stormwater Management Criteria Study. Report prepared for the City of Ottawa, February 2010.

PART C: PUBLIC CONSULTATION AND COMMUNICATIONS

PART C: PUBLIC CONSULTATION AND COMMUNICATIONS

CONTENTS

FIGURES

Part C was provided by Kidd Consulting.

1. INTRODUCTION

The process of retrofitting stormwater management measures into existing urban areas is not just a technical and financial challenge, but also a social challenge. How does a municipality effectively promote stormwater retrofit programs? Will communities support the changes that may come to streetscapes and public lands? Will individuals be willing to disconnect downspouts and install rain barrels? What promotion, education, or incentive tools are needed to turn the concept of a rain garden into a functioning reality? The aim of the consultation program carried out as part of the Pinecrest Creek/Westboro Stormwater Management Retrofit Study was to begin to answer these questions within the budget available.

This section of the *Pinecrest Creek/Westboro Stormwater Management Retrofit Study Final Report* describes the approach taken for communication and public consultation in the Study. It outlines the tools used for communication, the opportunities for consultation, and the key issues raised by the public as the study unfolded. Copies of the communications materials used, meeting reports and other supporting documentation are provided in Appendix O.

2. OVERALL APPROACH

As an initial step, a Communications and Consultation Plan (November 11, 2009) was developed. It was developed through:

- a review of background studies relating to Pinecrest Creek and Westboro Beach;
- discussions with the Study Team (J.F. Sabourin and Associates and JTBES Environmental Systems);
- liaison with City communications staff and staff involved in the Ottawa River Action Plan; and
- feedback obtained from the Public Advisory Committee who contributed advice on audiences, messaging, how to reach people, how to engage the public in the study, and the nature and content of consultation events.

The Communications and Consultation Plan outlined: the approach to be taken for communication and consultation; communication tools, audiences, messages, content and language; and consultation opportunities and reporting. The overall approach for communications and consultation was:

- to meet the requirements of the Class EA process with respect to notification and consultation;
- use multiple avenues to inform stakeholders and the community about the study and opportunities for involvement;
- work through the 19 established Community Associations in the area, other Non-Governmental Organizations such as Ottawa Riverkeeper and user groups;
- as a long-term strategy, attempt to interest schools in the study area in SWM projects;
- emphasize the links to the Ottawa River and build on the interest generated by consultation on the Ottawa River Action Plan that took place in November and December of 2009; and
- allow for the flexibility to capitalize on communication and consultation opportunities that may arise or to address unforeseen circumstances.

3. COMMUNICATION TOOLS

A broad range of communication tools were used to notify the public and community members about the study and the opportunities to become involved in it. These are described below. Copies of communications materials are provided in Appendix P.

- ***Ads:*** Advertisements for Open Houses (including the Notice of Study Commencement) were placed in local newspapers two weeks in advance of the events.
- ***Flyers:*** Flyers were developed in advance of the Open Houses to provide basic information about the study and promote the Open Houses. These were e-mailed to those on the study mailing list, which included individuals, environmental groups and community associations. Prior to Open House #2, staff also delivered the flyer to community centres and other venues in the study area.
- ***E-Newsletters:*** E-newsletters were developed to introduce the study and provide updates on progress. These were sent out to individuals, environmental groups, community associations and ward councillors in July 2010, October 2010 and November 2010.
- ***Website***: The City website was an important tool for getting information out. The materials placed on the site included a Study Backgrounder, a FAQ (Frequently Asked Questions) section that provided information on the study process and existing conditions in the study area, notices for Open Houses and Meeting Notes from Open Houses.
- ***Participation in other City Consultation Processes:*** Staff provided information about the Pinecrest Creek/ Westboro study at Ottawa River Action Plan Open Houses held November 23, 26, and 30 and December 1, 2009.
- ***Participation in Community Events:*** On November 14, 2009 staff attended and made a presentation at the annual Community Associations Forum on Environmental Sustainability, a gathering of city-wide community associations. In June 2010, staff made a presentation to the Westboro Beach Community Association.
- ***Supporting Materials for Open Houses:*** For each Open House, the study team developed a display and a PowerPoint presentation. Participants were given Workbooks that provided context for the meeting and included Comment Forms that were used to gather feedback on key aspects of the study.

All communications materials were prepared in French and English.

4. CONSULTATION OPPORTUNITIES

Three major avenues of consultation were used in the Study. Meeting notes are included in Appendix O.

- ***Technical Advisory Committee***: The Technical Advisory Committee (TAC) was comprised of City staff from a variety of departments, and representatives from the National Capital Commission, Ministry of the Environment, Rideau Valley Conservation Authority and Algonquin College. The TAC met three times during the study, on December 3, 2009, June 17, 2010 and November 30, 2010 and provided advice and guidance to the study team on a range of issues.
- ***Public Advisory Committee:*** The Public Advisory Committee (PAC) for the study met four times during the study – on October 6, 2009, January 13, 2010, June 17, 2010 and November 30, 2010. The PAC provided valuable comments on how best to reach people in the study area, reviewed interim reports, and constructively critiqued the study.
- ***Open Houses:*** Two Open Houses were held. Both began with a typical “open house” format with displays and later included a formal presentation with a facilitated discussion. Verbal feedback from the meeting and feedback from comment forms and e-mails was incorporated into Meeting Reports that were posted on the website. Open House #1 (December 3, 2009) focused on the Existing Conditions in the study area and the objectives of the retrofit strategy. Open House #2 (December 1, 2010) focused on how future

stormwater management retrofit scenarios were identified and evaluated and what the proposed Stormwater Management Retrofit Strategy would mean for the creek and river, the community and the City.

In addition to the above, a meeting was held with two local school teachers on June 17, 2010. The teachers provided staff and the study team with information on existing environmental projects and initiatives in primary and secondary schools in the study area and the current environmental curriculum. A number of opportunities were identified for possible future collaboration relating to retrofitting stormwater management measures. This included possible tie-ins to the curriculum, involving students in monitoring activities and liaising with School Boards on potential stormwater management projects that would involve the physical plant, such as disconnections/ redirections of downspouts or the construction of rain gardens.

5. KEY ISSUES AND OBSERVATIONS

A complete list of the issues raised during the consultation process can be traced through the Meeting Notes included in Appendix O. A detailed response to specific comments received is provided in Appendix O. Some of the key issues raised and observations are provided in this section.

5.1 Support for SWM Retrofitting

In general, the PAC and those who participated in Open Houses were supportive of:

- The general approach being taken for retrofitting stormwater management measures (the “moderate SWM implementation” scenario);
- The use of a broad range of SWM measures rather than reliance on end-of-pipe treatment;
- The placement of considerable emphasis on lot level controls on private land; and
- The use of specific SWM lot level measures (rainbarrels, downspout re-direction, rain gardens and pervious products on driveways when they are re-done).

Many individuals attending the Open Houses were willing to implement SWM measures on their own property. The Westboro Community Association has agreed to promote the use of rainbarrels to its members.

5.2 Need for Increased Emphasis on Making the Creek Healthier

Many attendees at the Open Houses felt strongly that there should be a stronger emphasis in the Retrofit Strategy on making the Creek healthier. This should include:

- Rehabilitation of the creek corridor;
- Restoration of the natural landscape in the study area (e.g., widening existing vegetation buffers along the creek, re-establishing native vegetation where it doesn’t presently exist, tree-planting, habitat restoration, etc.); and
- Integrating the daylighting of the Creek (i.e., the restoration of its form and function) into the Retrofit Strategy.

Participants felt that this increased emphasis would lead to improvements in the health of the Creek, quality of life for humans, wildlife habitat and biodiversity. It was also suggested that daylighting the Creek, in particular, is a good way to build community interest in SWM retrofitting and engage the community.

5.3 Coherence in City Planning

Some PAC members and attendees at Open Houses suggested that:

- The City needs a coherent SWM policy and needs to integrate SWM retrofitting into the regular business of all departments; and
- The City needs to be consistent in its requirements for SWM in new developments and re-developments.

5.4 The Importance of Implementation and Monitoring

Some PAC members and attendees at Open Houses noted that:

- It is vital to ensure that the Retrofit Strategy is implemented;
- There is a need to monitor the progress using the measurable objectives that have been set for the Strategy.

5.5 The Challenge of Engaging the Community

While those who participated in the study were generally supportive of its direction and recommendations, the turnout for the study Open Houses was low (22 in total). As a result of the study, the Westboro Beach Community Association has agreed to promote the use of rainbarrels to its members, but other community associations in the study area did not become engaged in the study process, nor did local environmental groups. This suggests that:

- There is a need to learn more about how best to reach and engage individuals in retrofitting SWM measures on their properties;
- The City should explore engagement methods that go beyond “traditional” mass marketing to embrace approaches such as Community-Based Social Marketing;
- As part of the above, the City should explore the value of piggybacking communication efforts onto existing (non-City) forums and mechanisms, such as community festivals, newsletters and websites; and
- In particular, it is vital to know more about the barriers that prevent participation in retrofitting SWM measures on private property and how to overcome those barriers.

6. PROGRAM EVALUATION

An Effectiveness Survey was included in materials handed out at Open House #1. Participants gave a very good to excellent rating to the display, the printed materials, the presentation and the facilitated discussion.

The count of visits to the study site on the City's website shows that the site had 896 visits in 2010, an average of 75 a month.

Month	Visits	Views
January	44	57
February	56	66
March	83	95
April	84	98
May	67	74
June	63	71
July	27	30
August	114	169
September	70	73
October	80	83
November	106	116
December	102	105
Total	**896**	**1037**

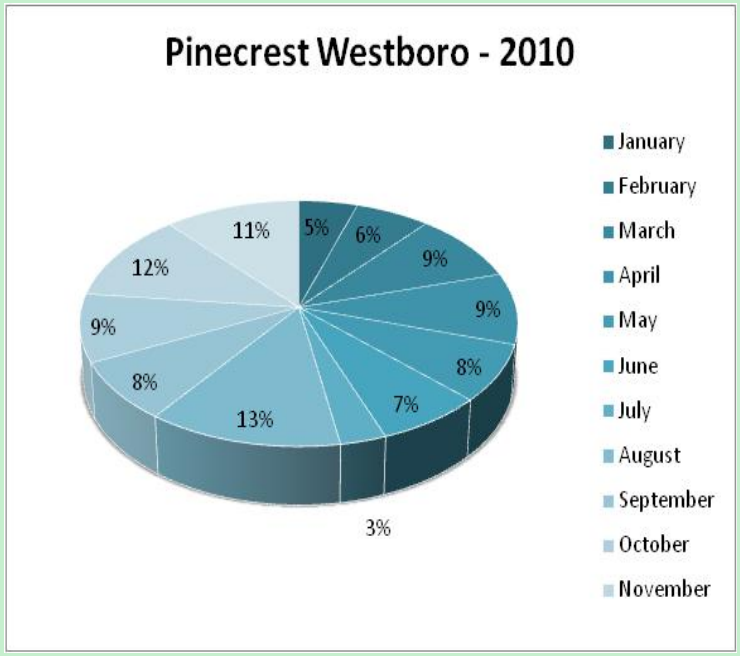


Figure 1: Ottawa.ca 2010 Analytic Results for Residents/Public Consult in Pinecrest/Westboro

PART D: IMPLEMENTATION AND MONITORING PLAN

PART D: IMPLEMENTATION AND MONITORING PLAN

CONTENTS

TABLES

FIGURES

1. INTRODUCTION

This part of the report describes the Implementation and Monitoring Plan for the preferred SWM Retrofit Plan.

The study area, like much of the core of the City, was developed before there was a requirement for municipalities to manage stormwater. This study has examined ways in which SWM measures can be retrofitted into the community. A range of retrofit scenarios was defined and evaluated to identify a preferred Retrofit Plan for the study area. The “Moderate SWM Scenario” was selected as the SWM Retrofit Plan with which to proceed based on a combination of criteria including the scenario’s ability to meet the study objectives and targets, the potential sociocultural and natural environment impacts, and the relative cost. Anticipated results of the selected Retrofit Plan are summarized in Table 1.

When implemented, and over the long term, this SWM Retrofit Plan will help provide the following significant benefits:

- Improve water quality in Pinecrest Creek and the Ottawa River;
- Reduce flooding and erosion in the Creek;
- Improve the health of the Creek; and
- Reduce closures at Westboro Beach.

The Pinecrest Creek/Westboro SWM Retrofit Study is one of 16 short-term projects of the Ottawa River Action Plan (ORAP). ORAP’s objective is to address the full range of watershed health issues. The Implementation and Monitoring Plan described here is consistent with that objective.

2. PURPOSE OF THE IMPLEMENTATION AND MONITORING PLAN

The purpose of the Implementation and Monitoring Plan is:

- to provide a plan for implementing the range of SWM measures that comprise the Moderate SWM Retrofit Scenario in a cost-effective and timely manner;
- to describe the monitoring required to determine if the implemented measures are having the effects they are intended to have with respect to the SWM retrofit objectives and targets (see Table 1: Results of the Preferred SWM Retrofit Plan); and accordingly
- to provide a framework that will guide adaptive management of implementation of the proposed SWM retrofit plan for the study area.

The Implementation and Monitoring Plan includes the identification of specific projects, priorities and where more detailed studies are required.

Table 1: Results of the Preferred SWM Retrofit Plan ("Moderate SWM Scenario")

Criteria		Indicators	Results[a]
Project Objectives	Flood Risk	Flood Risk	Potential to Decrease Flood Risk
		Flood Plain Storage	Maintains Flood Storage
	Erosion Impacts	Sediment Regime and Size	Significant Decrease[b]
		Channel Stability	Significant Decrease[b]
		Erosion Potential	Significant Decrease
		Aquatic Habitat	Maintains habitat
	More Natural Hydrologic Cycle	Peak Flows and Runoff Volumes for the first 10 mm and the next 15 mm of rain	10 mm Retention = 78 %
			15 mm Detention = 23 %
		Effective Imperviousness (EI)	Decrease of 73 ha
	Water Quality	Total Suspended Solids (TSS)	Decrease of 37 %
		Total Phosphorus (TP)	Decrease of 26 %
	Runoff impacts	In-stream *E.coli* (Ottawa River at Westboro Beach)	Decrease of 36 %
			Decrease of 37%
	Natural Features	Riparian Vegetation	No Change in Vegetation
		Tree Canopy	No Change in Canopy
	Public Awareness	Increased Public Awareness	High Level
		Increased Public Involvement	Moderate Level
Social / Cultural	Open Space / Parks	Adverse effects on parks and open space	Reduction in Open Space[b]
Natural Environment	Terrestrial Systems	Impact on Terrestrial Habitat	Loss of Terrestrial Habitat[b]
	Aquatic Systems	Impact on Aquatic Habitat	Minimal loss of Stream Length[b]

[a]Part B, Tables 9 and 11 provide for further details on the Evaluation, Scoring and Ranking of the Moderate SWM Scenario**.**

[b] These potential outcomes are due to the construction of the proposed SWM ponds. The effects on sediment regime and size and channel stability due to the construction of the proposed SWM ponds will be addressed and mitigated through the design of the proposed SWM ponds.

3. IMPLEMENTATION AND MONITORING PLAN PRIORITIES

The preferred Retrofit Plan is composed of a series of SWM measures to be installed within various land use types. The SWM measures are of three main types: lot level, conveyance and end-of-pipe. The main land use types are: residential, institutional, commercial, industrial, recreational, and transportation routes and roadways. The predominant land use type in the study area is residential. The Retrofit Plan is summarized in Table 2.

The **Implementation Plan**, described in detail in Section 4, was developed in accordance with the following considerations and priorities:

a) Provide a long term strategy for the overall SWM retrofit based on a 50 year implementation time span which, for example, will allow for retrofits within the rights-of-way to be done “opportunistically” as streets come up for rehabilitation; and include more detailed plans for the first 5 and 10 years of implementation.

b) Initiate implementation of lot level and conveyance SWM measures on publicly-owned properties early on as demonstration projects to inform the community about these measures and encourage participation of private landowners – this is to include pilot installations undertaken by the City to gain experience in certain SWM measures before their broader application; some selected pilot projects should also be undertaken for private residential lot level measures.

c) Promote implementation of lot level SWM measures on private, commercial and industrial properties soon after the implementation of the public and private property pilots in order to engage various communities and to realize the benefits of SWM retrofitting into the predominant land uses of the study area;

d) Undertake the planning, design and implementation of the upstream end-of-pipe SWM facility (EoP 16) early on: while the design of EoP 16 is to balance water quality benefits and minimize impacts to channel stability and sediment transport within Pinecrest Creek, having the pond in place early on will provide immediate water quality benefits and allow for any Creek rehabilitation work adjustments, that may be necessitated by the impacts on flow regimes, to be done at one time;

e) In the early years of implementation include a focus on implementation of SWM measures in Westboro and/or those parts of the study area that are closer to the outlet to the Ottawa River to realize the water quality benefits for the River and Westboro Beach;

f) Where the implementation is being done by or within neighbourhoods, implement in certain areas at a scale sufficient to allow for monitoring of the impacts and measurement of the performance;

g) Recognize the need to significantly restore natural landscape values within the Creek corridor and to encourage the growth and on-going survival of tree canopy in the study area as part of the retrofit strategy; and

h) Engage area residents and business owners through an on-going consultation, education and outreach program.

The intent of the **Monitoring Plan**, described in Section 5, is to establish baseline conditions where required and to track the impacts of the SWM retrofits and overall progress in achieving the study’s objectives and targets.

Adaptive Management Approach:
An adaptive management approach is proposed for the implementation of the SWM Retrofit Plan. Adaptive management provides a way to achieve desired objectives while dealing with uncertainties through an iterative learning process. Successful adaptive management requires the clear articulation of the desired objectives and targets as well as the exploration of alternative actions.[1] The desired objectives and targets were identified in Part B of the Study based on current understanding and knowledge. The next steps require the careful monitoring of the

impact of the retrofit implementation and the use of the new knowledge so gained to adjust future actions and implementation, as may be required. The careful monitoring of the outcomes not only increases the understanding of the natural system and its response, it also helps in the adjustment of policies and operations as part of the iterative learning process. Monitoring with an adaptive management approach is an effective means of “closing the loop”. The emphasis on a systematic approach and measured learning while doing differentiates this approach from “trial-and-error”.

As required by the Municipal Class Environmental Assessment process, the Retrofit Plan and its implementation will be reviewed at least every 5 years.

Table 2: Description of the Preferred SWM Retrofit Plan ("Moderate SWM Scenario")

	SWM MEASURES	SWM Measure Implementation by Land Use with Number of Installations and/or Area Converted			
		Residential Area	Institutional Area	Commercial Area	Industrial Area
LOT LEVEL PUBLIC	Downspout Redirection	N/A	46	N/A	N/A
	Rain Gardens	N/A	23	N/A	N/A
	Porous Pavement - Parking	N/A	6.80 ha	N/A	N/A
	Porous Pavement - Sidewalks	10.34 ha	0.94 ha	0.78 ha	0.10 ha
LOT LEVEL PRIVATE	Downspout Redirection	2639	N/A	66	8
	Rain Gardens	1885	N/A	N/A	N/A
	Rain Barrels	9425	N/A	N/A	N/A
	Porous Pavement - Driveways	16.16 ha	N/A	N/A	N/A
	Porous Pavement – Parking lots	N/A	N/A	10.97 ha	1.40 ha
	Side and Rear Yard Infiltration Trenches	942	N/A	N/A	N/A
CONVEYANCE	Street Narrowing (by 1 m) and Infiltration Trench Installation	0.77 ha & 943 trenches (10.1 km)	0.04 ha & 11 trenches (118 m)	0.07 ha & 17 trenches (182 m)	0.01 ha & 2 trenches (21 m)
EoP	EoP 1 (O&Gs) : O4293	N/A	1	N/A	N/A
	EoP 3 (O&Gs) : O10672	N/A	1	N/A	N/A
	EoP 16 (Wet Pond) : 04305	N/A	1	N/A	N/A
	EoP 17 a) and b) (Wet Pond & O&Gs) : O4300 + O4307	N/A	1	N/A	N/A

4. DESCRIPTION OF THE 50 YEAR IMPLEMENTATION PLAN

The proposed SWM Retrofit Plan represents a long term vision: a suggested 50 year schedule for implementation provides a timeframe that is commensurate with the broad scope of the overall undertaking and recognizes the considerable challenges associated with retrofitting existing communities. Notwithstanding the suggested 50 year timeframe, more detailed plans are also provided for the initial 5 and 10 years of implementation. Based upon what is learned from these initial years of implementation, the 50 year timeframe may be revisited.

The implementation is organized around four major components:

A. Awareness and Engagement
B. Leading by Example – SWM Measures on Public Properties
C. Promotion of SWM Measures on Private Residential Properties
D. Promotion of SWM Measures on Commercial and Industrial Properties

The first component, *Awareness and Engagement*, focuses on what is required to gain the individual and public support required to complete the SWM Retrofit Plan. This is a major initiative identified during the study's public consultation as being vital to the success of the Retrofit Plan. Each of the next three components focuses on a property type in which the retrofits are to occur, the SWM measures involved, potential sites and uptake targets.

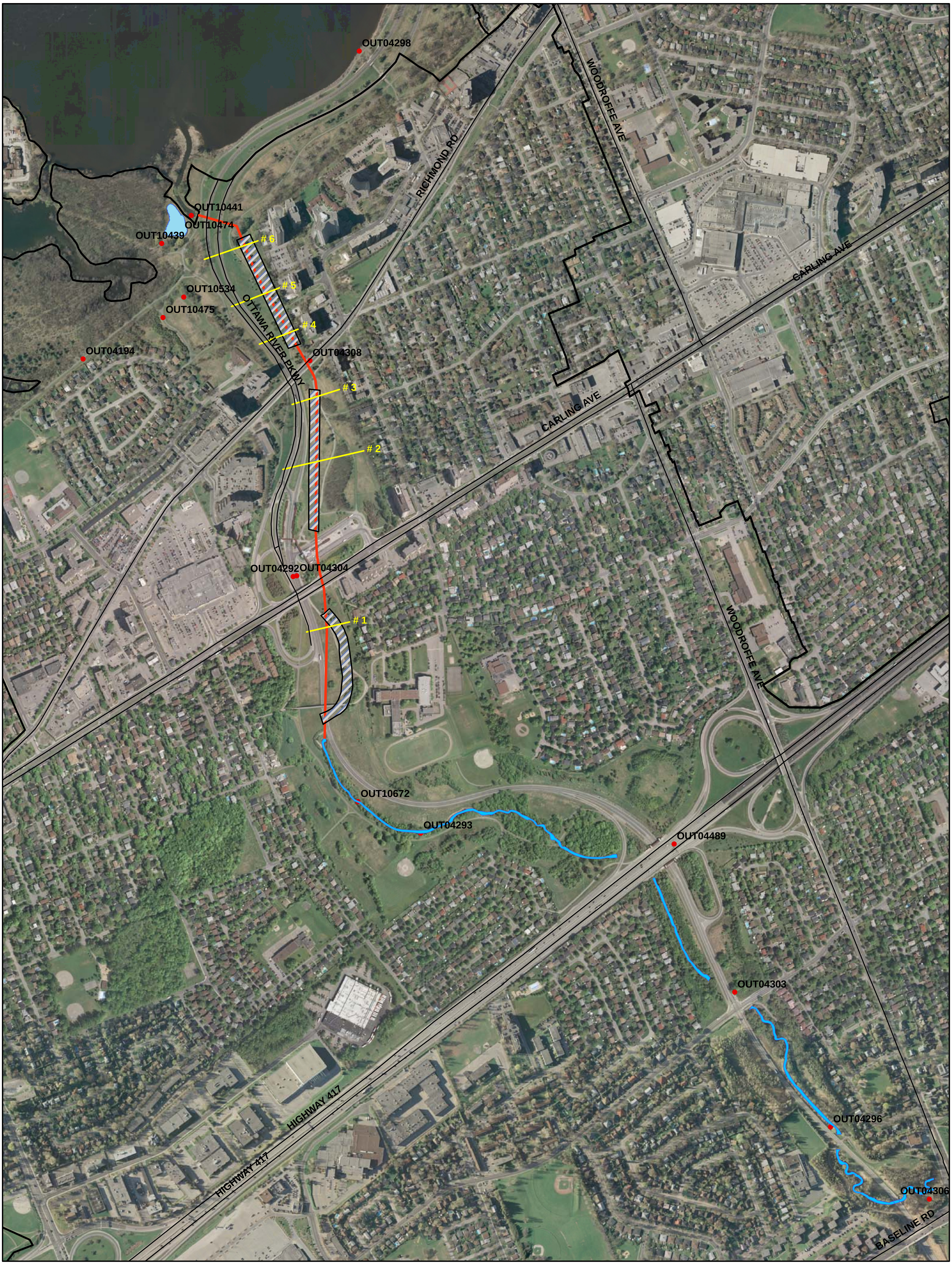
The components are inter-related and complementary. For example, demonstration projects put in place under *Leading by Example - SWM Measures on Public Properties* can be used to increase awareness, knowledge and enthusiasm about SWM measures that would be used on other property types. The *Awareness and Engagement* in particular addresses the consultation, education and outreach strategies that can be used in the other components. "Audiences" targeted by the *Awareness and Engagement* component will necessarily play key roles in the other implementation components whether they be on public, commercial/institutional or private residential properties if the overall Retrofit Plan is to achieve success. Nevertheless, the components which focus on specific property types are independent from one another in that a lack of progress on one of the components does not necessarily preclude advancement in any of the others. SWM retrofit implementation for each property type differs in the SWM measures to be implemented, the audiences and participants involved, the promotion mechanisms to be used, the level of effort required for implementation, and the abilities and resources available.

Each component is described in full in the following pages (Sections 4.1 to 4.4 inclusive) followed by the implementation schedule for the 50-year plan (Section 4.5), the future studies and pilot projects (Section 4.6), and the priorities, schedules, proposed projects and costs for the first 5 years (Section 4.7) and following 5 years (Section 4.8) of implementation.

A Note about the Daylighting of Pinecrest Creek

"Daylighting" is the re-establishment of an open channel at the surface to replace the piped section of Pinecrest Creek. The approximate 1.4 km long piping of the Creek has resulted in a loss of fish migration potential and aquatic habitat and, due to the reduced capacity of the pipe involved (the Ottawa River Parkway pipe), an increase in flood risk to the transitway. This study included a preliminary analysis on the potential for daylighting the Creek (See Part B: Section 10). Based on the results of this analysis it appears there is potential for daylighting three piped sections for a total length of approximately 900 m (Figure 1).

Daylighting and naturalization of significant sections of Pinecrest Creek would be of benefit for many reasons including a fisheries re-connection to the Ottawa River, an increase in aquatic habitat which may improve the potential for a sustainable fishery, improved recreational opportunities, the potential for decreasing existing flood risk, as well as being a very important demonstration project of best practices. There is, however, considerable work to be done on the Creek's hydrology and water quality before all these benefits could be realized**.** This study has identified the daylighting of the Creek as a longer-term objective, possibly to be considered in association with future transit projects and any on-going corridor naturalization efforts. Such an undertaking would ultimately be subject to the full support of the National Capital Commission (NCC), owner of almost the entire creek corridor. Through this study, the NCC has commented that a comprehensive landscape and watercourse naturalization plan for the corridor may be required as well as potential changes in responsibilities for existing infrastructure, depending on the City's requirements for NCC lands.



LEGEND:
- Ottawa Storm Sewer Outlets
- Roads
- Ottawa River Parkway Culvert
- Daylighting Cross-Sections
- Daylighting Opportunities

CLIENT: Ottawa

BY: JFSA Water Resources and Environmental Consultants

NOTES:
- The background data was provided by the City of Ottawa

0 50 100 200 300 400 Meters

N

PROJECT: PINECREST CREEK / WESTBORO SWM RETROFIT STUDY

TITLE: Daylighting Opportunities

PROJECT No. 741-09		
DESIGN	KM	
GIS	KM	
CHECK	JFS	
REVIEW	JFS	

FIGURE 1

MAP REF.: 741_09\Design\GIS\EoP\Daylighting_cross_sections.mxd

NOV 2010

REV. 2

4.1 Awareness and Engagement

This section was provided by Kidd Consulting.

4.1.1 Background

Success in retrofitting SWM measures in urban areas requires gaining passive support from the community for measures such as road narrowing on public lands and gaining the active support of individuals to implement measures such as downspout disconnection/redirection on their properties. Achieving this support requires strategies to raise awareness of the need for and benefits of retrofitting SWM measures as well as strategies to engage community members in actions to address stormwater issues. Although awareness and engagement strategies are linked, they are not the same. One can be aware of the benefits of water conservation, for example, yet not be sufficiently motivated to install low flow toilets. Awareness is necessary for action, but awareness by itself is not sufficient to make things happen.

The individuals who participated in the Pinecrest Creek/Westboro Stormwater Management Retrofit Study were generally supportive of its direction and recommendations. This suggests that the public will generally be supportive of attempts to retrofit SWM measures in the study area and across the City. However, despite "traditional" communications that included advertising in local papers and contacting community associations, the number of stakeholders and members of the public who attended the two study Open Houses was low (22 in total) and the amount of feedback obtained was limited. This suggests the following:

- There is a need to learn more about how best to reach and engage individuals in retrofitting SWM measures on their properties. While the City has some experience with promoting the use of rain barrels and the redirection of downspouts, it has little experience with the building of rain gardens, or the replacement of impervious materials on driveways with pervious materials.
- The City should explore engagement methods that go beyond "traditional" mass marketing to embrace approaches such as Community-Based Social Marketing. For example, one area community association – the Westboro Beach Community Association – was open to promoting the use of rain barrels to its members and could be engaged in a pilot level engagement project.
- As part of the above, the City should explore "non-traditional" methods of communication to build awareness. This includes exploring the value of piggybacking communication efforts onto existing (non-City) forums and mechanisms, such as community festivals, newsletters and websites and exploring "word-of-mouth" communications mechanisms such as peer support groups or block leaders. In particular, it is vital to know more about the barriers that prevent participation in retrofitting SWM measures on private property and how to overcome those barriers.

4.1.2 What Needs to be Achieved

The preferred SWM Retrofit Plan identifies five SWM measures that could be used on private residential properties. The targets for these measures are listed in Table 3.

Table 3: Targets for SWM Retrofit Measures

SWM Measures	Target Description
Downspout Disconnection / Redirection	70% of the total roof area in residential neighbourhoods will drain to downspouts which are directed to pervious surfaces (an estimated increase of 7 to 23% over the existing % of homes with disconnected downspouts).
Rain Barrels	25% of the properties found in residential neighbourhoods will have two rain barrels receiving runoff from roof downspouts on their lots.
Rain Gardens	10% of the residential neighbourhood lots will have rain gardens installed in depressions and planted with local native species.
Side and Rear Yard Infiltration Trenches	5% of the properties found in residential neighbourhoods will install either side or rear yard infiltration measures.
Porous Pavement - Driveways	15% of the driveway surfaces in residential neighbourhoods will be paved with either porous asphalt (or concrete) or permeable pavers.

These are significant targets: they amount to 2,639 redirected downspouts, 9,425 rain barrels, 1,885 rain gardens, and 942 infiltration trenches and the equivalent of 16 ha of driveways with porous pavement (or equivalent materials).

4.1.3 Using Social Marketing to Build Awareness and Engage the Community

It is increasingly apparent in the health, safety and environmental fields that "traditional" mass marketing approaches are of limited help in changing behaviour. If traditional mass marketing worked, all Canadians would exercise daily, be non-smokers, drink alcohol only in moderation and never drive drunk. This is not the case, however. An alternative (and more successful) approach to achieving behaviour change is to use "social marketing." Social marketing is defined as "the systematic application of marketing, along with other concepts and techniques, to achieve specific behavioural goals for a social good."

Two Canadian initiatives – Fostering Sustainable Behaviour, which focuses on Community Based Social Marketing, and Tools of Change, which focuses on Social Marketing – provide guidance on how to apply social marketing to achieve behaviour change (see Appendix O for links to Social Marketing Resources). Their websites provide links and case studies to social marketing programs that have been used for a wide range of environmental issues including clean air, climate change, energy conservation, pollution prevention, waste reduction and recycling, and water conservation.

Community Based Social Marketing is based on identifying the barriers that stand in the way of behaviour change – barriers such as lack of information, cost, and time commitments – and devising ways to overcome these barriers. The Tools of Change approach to Social Marketing is slightly different, beginning with a decision on how you will motivate people to undertake the desired activity, and then designing a social marketing campaign to achieve it. Both approaches use similar tools to inform people and engage them in the desired activity (see Table 4). Social marketing has been used to address some aspects of stormwater management such as green landscaping.

Table 4: Typical Social Marketing Tools

Communication Tools	Engagement Tools
Home visits	Norm appeals
Neighbourhood/block leaders	Financial incentives and disincentives
Peer support groups	Obtaining commitments
Word-of-mouth	Using prompts
School programs that involve the family	Building motivation over time
Mass media	Making it convenient
Use of vivid communication materials	Providing feedback

There are existing communication resources available online for some of the SWM retrofit measures that are included in the Retrofit Plan. Appendix O provides some links to communications materials on rain gardens. These tend to deal with the technical ("how to") aspects of rain gardens – how to design and construct a rain garden, how to select appropriate plants, and how to maintain them. There are similar kinds of information available for downspout disconnection/redirection, which is widely used in municipalities across North America. Fewer examples of communication materials, however, are available for the replacement of impervious material on driveways with pervious materials and little or no information is available for the installation of side and rear yard infiltration trenches.

Communication materials like these are needed once a commitment has been made to install a rain garden, redirect a downspout, replace the paving surface on a driveway or install an infiltration trench. In many ways, the development of "how to" communication materials is the easy part: the challenge is to gain the commitment to install the measure(s).

4.1.4 Learning What Works in the City of Ottawa

The following is proposed as a way to develop a robust and effective Awareness and Engagement Program for the Pinecrest Creek/Westboro SWM Retrofit Plan.

Step 1: Identify the Barriers to Implementation on Residential Properties
This involves using focus groups to identify the barriers to implementation of the five SWM measures that are targeted for use on residential properties.

Step 2: Develop an Awareness and Engagement Program
The Program should use the principles and approaches of social marketing and include strategies to address the barriers to implementation for each SWM measure.

Step 3: Develop Appropriate Communications Approaches and Materials
Depending on the strategies, this could involve educating block captains or training summer students to do home visits. It will also include the development of two types of communications materials: those that can help raise awareness of the issue and those that will provide the necessary technical information to allow homeowners (or their contractors) to implement the five SWM measures.

Step 4: Carry Out a Pilot Project
This could optimally be done in the Westboro Beach community or in a part of it as the community association has indicated their willingness to promote the use of rain barrels. As the community closest to Westboro Beach, the Westboro Beach community may be easier to engage than others in the study area in retrofitting SWM measures on their properties. A Pilot Project would take at least a year to show results.

Step 5: Evaluate the Pilot
Evaluate the response to the Pilot and its effectiveness through surveys of participants and non-participants. Adjust the Awareness and Engagement Program accordingly.

Step 6: Implement Study Area-Wide
Implement the revised Awareness and Engagement Program across the Pinecrest Creek/ Westboro study area.

4.2 Leading By Example – SWM Measures on Public Properties

One of the most effective tools for increasing public involvement is to lead by example. Demonstration and communal projects also provide an opportunity to increase the public's familiarity with the full breadth of suitable SWM measures. Leading by Example is important. It is also an opportunity for City staff to gain more experience in certain SWM lot level and conveyance measures before these measures are implemented on a broader scale (Implementation Plan Priority (b) (Section 3)).

The SWM lot level and conveyance measures slated for implementation on public properties can be used to Lead By Example and are therefore prioritized for early implementation. Those SWM measures are listed in Table 5.

Table 5: Public SWM Measure Implementation Percentage Over 50 Years

	SWM Measures	Implementation over 50 Years	Explanation of Implementation %
Lot Level Public	Downspout Disconnection / Redirection (Institutional)	10%	10% of the total institutional roof area will drain to downspouts which are directed to pervious surfaces.
	Rain Gardens (Institutional)	10%	10% of the institutional properties within the study area will have rain gardens installed in depressions, and planted with local native species.
	Porous Pavement – Parking (Institutional)	25%	25% of institutional parking lots will be paved with either porous asphalt (or concrete) or permeable pavers.
	Porous Pavement – Sidewalks	50%	50% of the sidewalks found in institutional sectors will be re-paved with porous concrete (or equivalent).
Conveyance	Street Cleaning VAC (using vacuum type street cleaners)	equals existing conditions	The City street cleaning schedule of twice a week will be maintained in institutional areas.
	Street Narrowing and Infiltration Trenches	5%	5% of the study area's streets will be narrowed and infiltration trenches (or equivalent measures) will be installed in the gained pervious space.
	Grass Swales (roadside ditches)	equals existing conditions	The current extent of grass swales and roadside ditches found in the study area will be maintained (or if replaced, their equivalent benefits maintained via appropriate design).

The following is recommended as a general approach to the implementation of this component of the plan:

a) As a priority, implement a range of lot level and conveyance measures on City lands/rights-of-way and/or other institutional land with City assistance. This work can also be used to inform the preparation of design standards for various lot level and conveyance SWM measures (See Part B of this Report).

b) Consider school sites for specific demonstration projects such as porous paving, rain gardens, rain harvesting and downspout disconnection/redirection as a learning tool for the students, parents and teachers. Students can "log" the planning, installation and operation of the SWM measures to produce empirical data as well as becoming more familiar with lot level SWM measures. Experience gained with these projects can be used in the promotion of further SWM retrofits.

c) Integrate the implementation of conveyance measures with the City's existing road and sewer rehabilitation program so that SWM retrofit can be achieved over time, i.e., in an opportunistic fashion.

d) Implementation will require the involvement of various City branches/divisions (communication, asset management, design and construction, monitoring, standards preparation, etc.) and associated training.

e) Protecting Existing Trees: Ensure that the health of mature trees in the study area is not compromised by the implementation of SWM measures that may require excavation in their vicinity.

The full range of public properties includes:

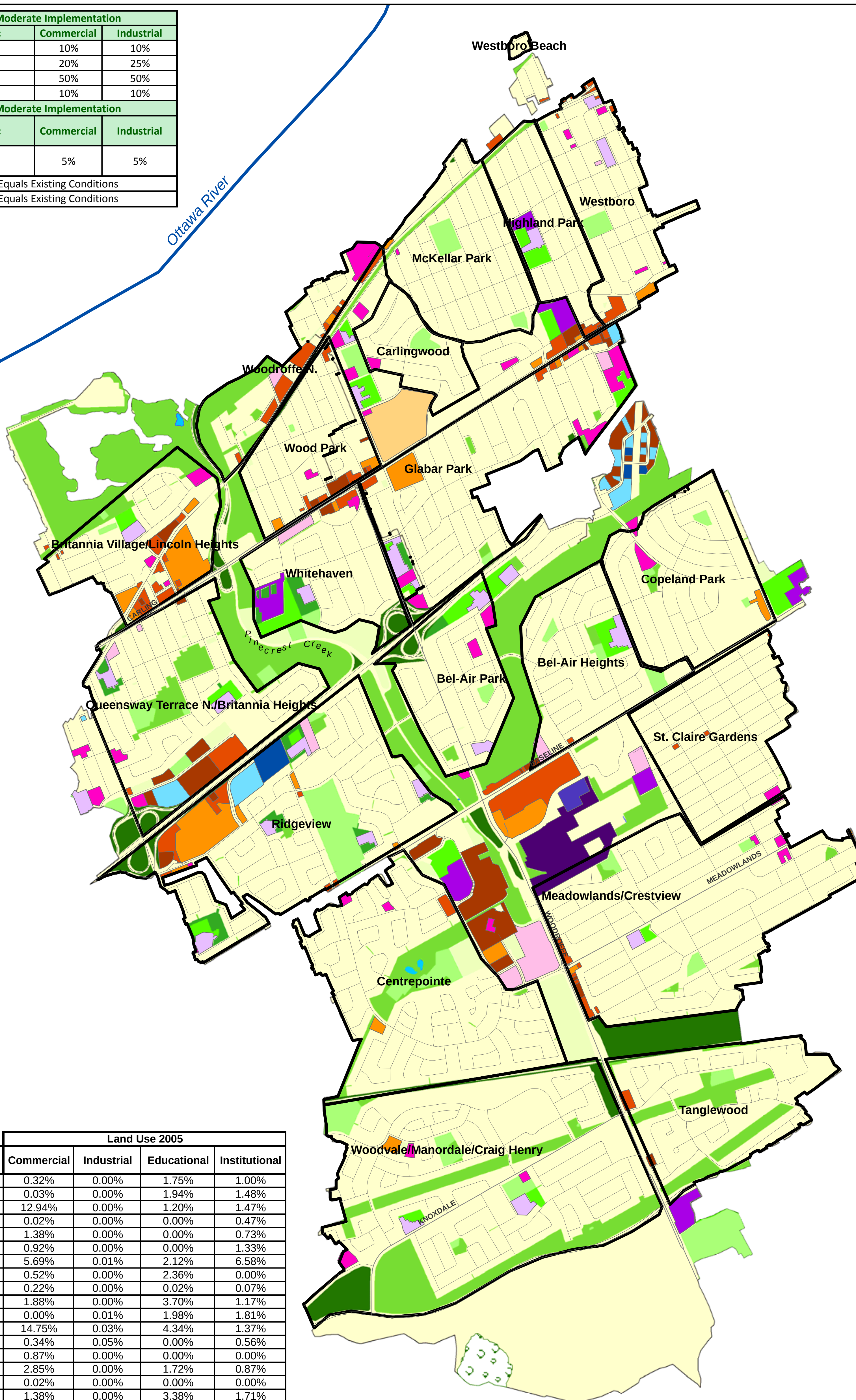
Institutional -
Hospital, Rehabilitation, Nursing Home
Other Institutions

Educational -
Elementary School
Secondary School
Post-Secondary School
Post-Secondary Residence

Recreational -
Parks and Recreation (e.g., associated parking lots/ buildings)

For locations of these potential implementation sites within the study area please refer to Figure 2: Potential Sites for Public Property, Commercial and Industrial SWM Measure Implementation

Potential Public Lot Level SWM Measures	Moderate Implementation		
	Public	Commercial	Industrial
Downspout Disconnection	10%	10%	10%
Porous Pavement - Parking Lots	25%	20%	25%
Porous Pavement - Sidewalks	50%	50%	50%
Rain Gardens	10%	10%	10%
Potential Conveyance SWM Measures in Non-Residential Areas	**Moderate Implementation**		
	Public	**Commercial**	**Industrial**
Street Narrowing and Infiltration Trenches	5%	5%	5%
Street Cleaning	Equals Existing Conditions		
Grass Swales	Equals Existing Conditions		



Communities / Neighbourhoods	Area (ha)	Land Use 2005			
		Commercial	Industrial	Educational	Institutional
Bel-Air Heights	65.9	0.32%	0.00%	1.75%	1.00%
Bel-Air Park	57.9	0.03%	0.00%	1.94%	1.48%
Britannia Village/Lincoln Heights	66.4	12.94%	0.00%	1.20%	1.47%
Carlingwood	29.9	0.02%	0.00%	0.00%	0.47%
Centrepointe	141.3	1.38%	0.00%	0.00%	0.73%
Copeland Park	81.9	0.92%	0.00%	0.00%	1.33%
Glabar Park	118.1	5.69%	0.01%	2.12%	6.58%
Highland Park	45.7	0.52%	0.00%	2.36%	0.00%
McKellar Park	71.7	0.22%	0.00%	0.02%	0.07%
Meadowlands/Crestview	167.5	1.88%	0.00%	3.70%	1.17%
Other	635.1	0.00%	0.01%	1.98%	1.81%
Q-way Terrace N/Britannia Heights	113.5	14.75%	0.03%	4.34%	1.37%
Ridgeview	154.1	0.34%	0.05%	0.00%	0.56%
St. Claire Gardens	76.9	0.87%	0.00%	0.00%	0.00%
Tanglewood	83.9	2.85%	0.00%	1.72%	0.87%
Westboro	63.9	0.02%	0.00%	0.00%	0.00%
Westboro Beach	1.5	1.38%	0.00%	3.38%	1.71%
Whitehaven	61.7	3.85%	0.00%	0.00%	0.32%
Wood Park	54.4	4.21%	0.00%	0.00%	3.40%
Woodroffe North	41.5	0.92%	0.00%	2.04%	1.54%
Woodvale/Manordale/Craig Henry	236.8	60.21%	0.00%	29.25%	0.00%
Total	**2369.6**	**113.31%**	**0.09%**	**56.32%**	**25.87%**

LEGEND:

- OttawaRiver
- Roads
- Communities
- Water
- TotalStudyArea

Commercial
- Regional Shopping Centre
- Community Shopping Centre
- Other Commercial
- Office

Industrial
- Industrial
- Industrial Condominium

Institutional
- Hospital, rehabilitation, nursing home
- Other institutions

Educational
- Elementary School
- Secondary School
- Post-Secondary School
- Post-Secondary Residence

Recreational
- Forest
- Open Space
- Active Recreation
- Active Recreation on Schools
- Passive Recreation
- Passive Recreation on Schools
- Vacant Lands

CLIENT: Ottawa

NOTES:
- The following data was provided by the City of Ottawa
- See Appendix A for the Land Use 2005 Glossary
- See Table 2 for a list of the Educational Buildings found within the study area

0 175 350 700 1,050 1,400 Meters

N

MAY 2011

REV. 1

BY: JFSA Water Resources and Environmental Consultants

PROJECT:
PINECREST CREEK / WESTBORO SWM RETROFIT STUDY

TITLE:
Potential Sites for Public Properties, Commercial, and Industrial SWM Measure Implementation

PROJECT No. 741-09

DESIGN	KM
GIS	KM
CHECK	JFS
REVIEW	JFS

FIGURE 2

MAP REF.: 741_09\Design\Maps\LotLevelPublic.mxd

4.2.1 End-of-Pipe Facilities

SWM measures on public property include end-of-pipe (EoP) facilities. The recommended EoP facilities are listed in Table 6 and locations are provided on Figure 3 - End of Pipe SWM Retrofit Locations.

Table 6: End-of-Pipe Implementation and Location

SWM Measures	Implementation over 50 Years	Location
End-of-Pipe	4 EoPs: 2 Wet Ponds 2 Oil & Grit Separators	EoP 16: Wet pond at outlet 4305, where Pinecrest Creek starts to daylight, north of Baseline Road. EoP 17a and b: Wet pond and O&Gs* at Wavell and Ardmore outfalls.
		EoP 1: O&Gs at outlet 04293, north of the QEW. EoP 3: O&Gs at outlet 10672 within Elmhurst Park (NW corner of Henley and Travistock).

*This O&Gs is not considered to be a stand-alone EoP, it would replace the traditional forebay, due to space limitations.

The following is recommended as a general approach to the implementation of the EoPs:

a) The wet pond facilities outletting to Pinecrest Creek will need to be designed to maximize water quality and flood control benefits while minimizing negative impacts to the fluvial geomorphic conditions of the Creek.

b) All the potential EoP sites are located on public lands. Three are located on land owned and managed by the National Capital Commission (NCC), a federal crown corporation. NCC approval and all environmental permits and processes required for use of federal lands will need to be obtained and completed in order for any of these three facilities to be implemented. Consultation with City Parks and Recreation will be required for the implementation of the EoP within Elmhurst Park.

c) Through the consultation process for this study, the NCC has provided detailed comments and requirements related to the proposed used of NCC lands within the Pinecrest Creek and Ottawa River Parkway corridors for the implementation of EoP retrofits. NCC correspondence to this effect dated January 19, 2010 is included in Appendix O. In particular, NCC has indicated:

- Prior to accepting any EoP solutions on NCC property, the City must be able to demonstrate a proactive commitment to ensure that programs to address improvements at the lot level and conveyance level will be developed, implemented and maintained to ensure their on-going performance. Education and outreach programs appear to be very important in this regard; and

- The net benefit to the health of Pinecrest Creek must be apparent in the concept as well as in the detailed design in order for the NCC to accept any proposed EoP facility on its land. NCC does not object in principle to accommodating SWM ponds on NCC lands for the purpose of achieving substantial improvements to the natural flow regime in Pinecrest Creek, especially ones that would allow for persistent fisheries to exist. However, since the overwhelming majority of flow comes from private and non-NCC public lands, these landowners must be seen to be actively and significantly participating in improving SWM quantity and quality over the long-term;

- Other requirements will include:
  - Landscape and naturalization design must be to a very high standard and context sensitive
  - A cultural landscape analysis of effects may be required
  - An application for Federal Land Use and Design Approval must be submitted
  - Demonstrated ability for the City (or any other public agency's) ability to maintain surface SWM ponds
  - Shoreline and stream enhancements will be necessary

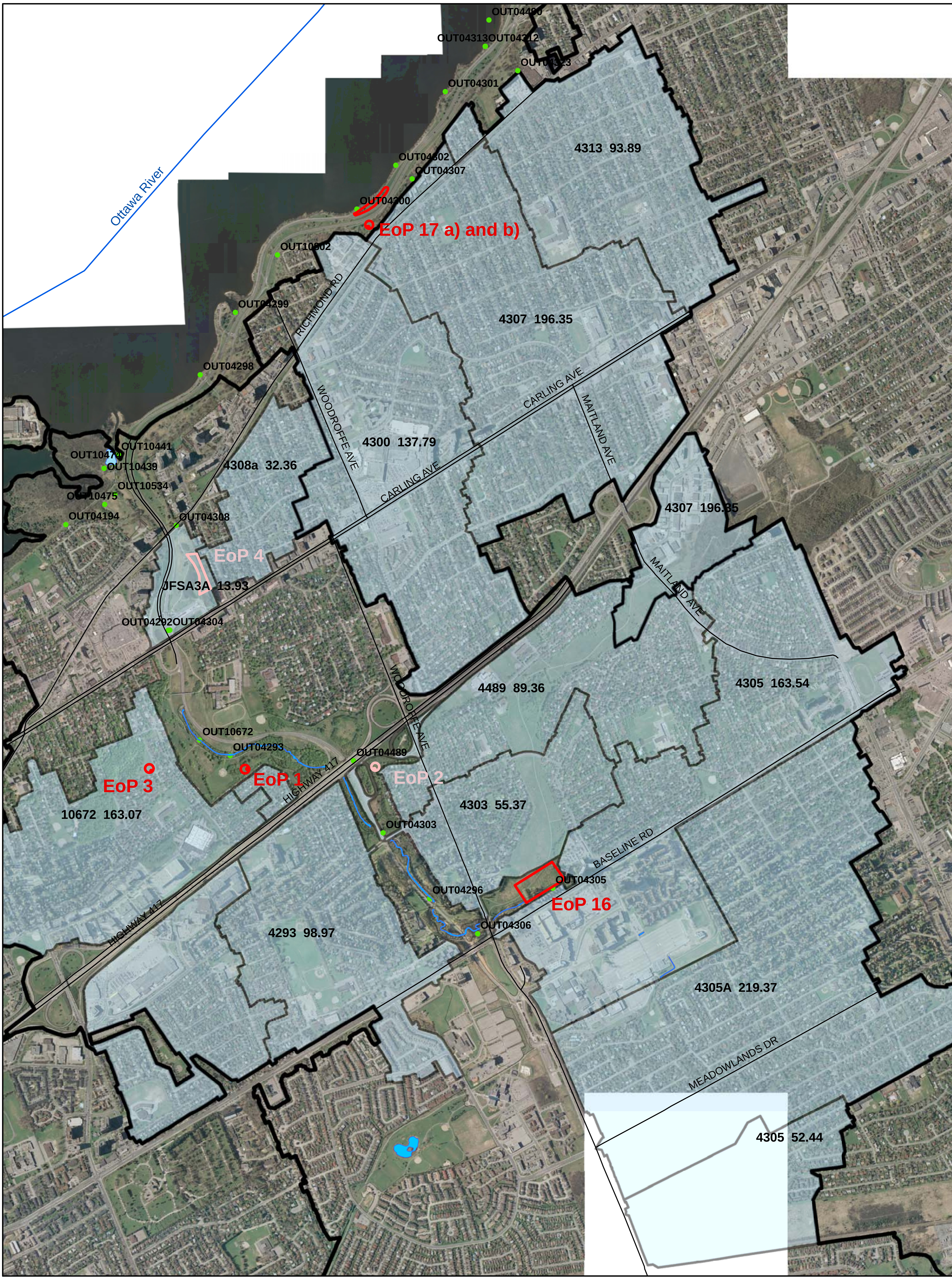
The two wet ponds noted in Table 6 would be surface installations and the Oil & Grit Separators, noted in Table 6, would be subsurface installations.

4.3 SWM Measures on Private Residential Properties

The SWM measures recommended for implementation on private residential properties are listed in Table 7.

Table 7: Private SWM Measure Implementation Percentage Over 50 Years

	SWM Measures	Implementation over 50 Years	Explanation of Implementation %
Lot Level Private	Downspout Disconnection / Redirection	70%	70% of the total roof area in residential neighbourhoods will drain to downspouts which are directed to pervious surfaces.
	Porous Pavement - Driveways	15%	15% of the driveway surfaces in residential neighbourhoods will be paved with either porous asphalt (or concrete) or permeable pavers.
	Rain Gardens	10%	10% of the residential neighbourhood lots will have rain gardens installed in depressions and planted with local native species.
	Rain Barrels	25%	25% of the properties found in residential neighbourhoods will have two rain barrels receiving runoff from roof downspouts on their lots.
	Side and Rear Yard Infiltration Trenches	5%	5% of the properties found in residential neighbourhoods will install either side or rear yard infiltration trenches/measures.



LEGEND:

- Ottawa Storm Sewer Outlets
- Roads
- Moderate SWM Implementation Ponds and OGS
- Other Potential Implementation Ponds and OGS
- EoP_DrainageArea
- BritanniaSWMpond
- Pinecrest Creek

CLIENT: Ottawa

BY: JFSA Water Resources and Environmental Consultants

NOTES:

- The background data was provided by the City of Ottawa

0 125 250 500 750 1,000 Meters

N

PROJECT:

PINECREST CREEK / WESTBORO SWM RETROFIT STUDY

TITLE:

End of Pipe SWM Retrofit Locations

PROJECT No. 741-09		FIGURE 3
DESIGN	KM	
GIS	KM	
CHECK	JFS	MAP REF.: 741_09\Design\Maps\EoPOpportunities_ModerateSWM.mxd
REVIEW	JFS	

NOV 2010

REV. 6

The implementation of SWM measures on private residential properties will require coordination with the steps outlined in Section 4.1.4 (Awareness and Engagement). Neighbourhoods within a sewershed area would be selected and then targeted for promotion of downspout disconnection/redirection as well as the suite of other lot level SWM measures. Pilot projects and information pieces can help to address some of the barriers to adoption of SWM measures by private residents. For example:

a) There may be typical site conditions which can discourage residents from disconnecting and redirecting downspouts. These could include concerns about outletting water into prized garden areas or across entrance walkways or patios. Therefore, to encourage downspout disconnection/reconnection, provide information on a set of possible solutions specifically tailored to the variety of typical site conditions associated with still connected downspouts. The information provided should be clear and user-friendly with accurate do's and don'ts for downspout disconnection/redirection. The typical site conditions that would be potential barriers would be determined from neighbourhood reconnaissance and surveys.

b) Protecting Existing Trees: Ensure that the health of mature trees in the study area is not compromised by the implementation of SWM measures that may require digging or excavation in their vicinity.

The full range of potential sites includes:

Residential Properties -

Low Density	Medium Density
Single-Detached	Row and Town Homes
Semi-Detached	

For the locations of these potential sites within the study area please refer to Figure 4: Potential Sites for Private Residential SWM Measure Implementation.

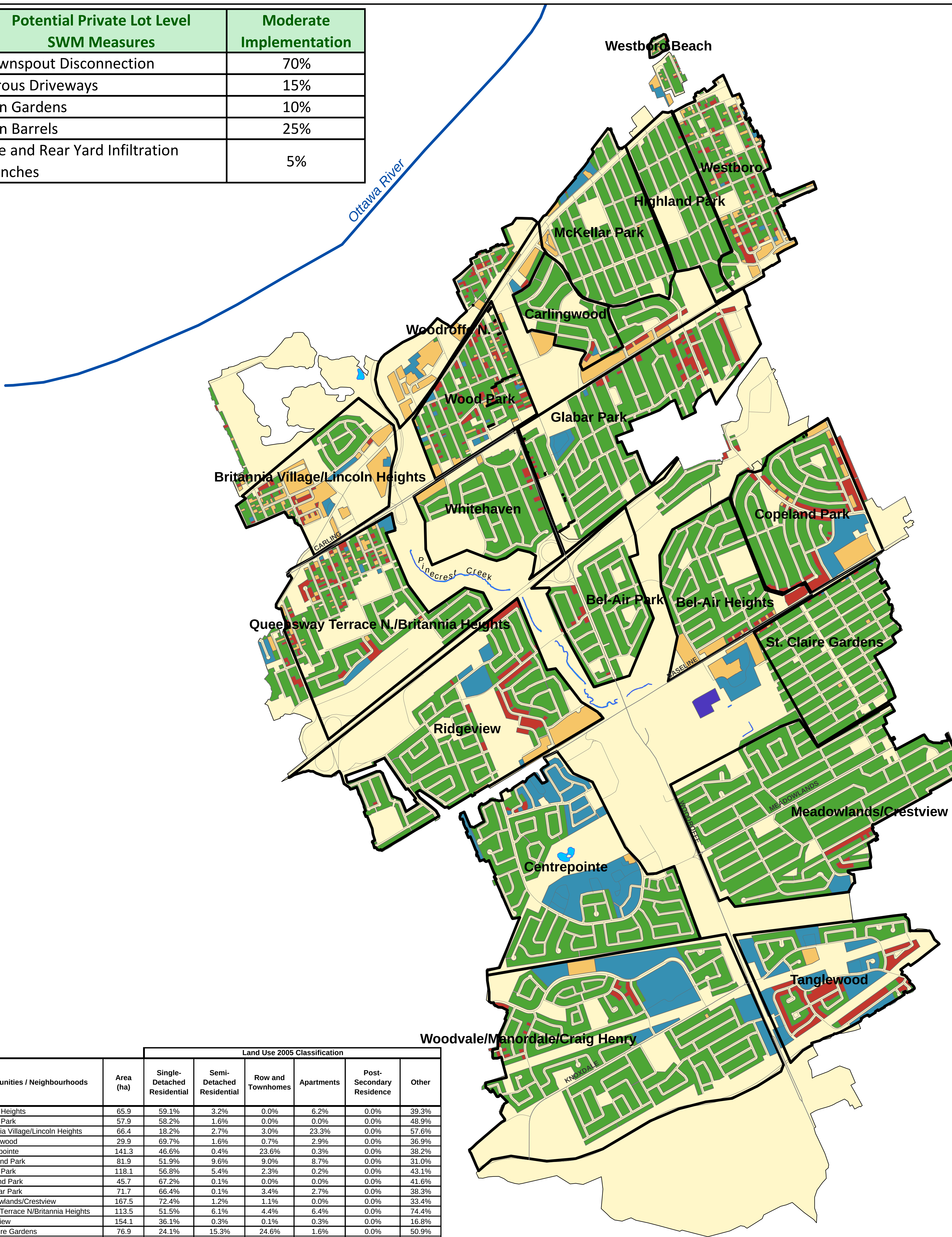
4.4 SWM Measures on Commercial and Industrial Properties

The SWM measures recommended for implementation on commercial and industrial properties are listed in Table 8 below.

Table 8: Commercial and Industrial SWM Measure Implementation Over 50 Years

	SWM Measures	Implementation over 50 Years	Explanation of Implementation %
Lot Level Private – Commercial and Industrial	Downspout Disconnection / Redirection	10%	10% of the total commercial and industrial roof area will drain to downspouts which are directed to pervious surfaces.
	Porous Pavement - Parking lots in Industrial Areas	25%	25% of industrial parking lots will be paved with either porous asphalt (or concrete) or permeable pavers.
	Porous Pavement - Parking lots in Commercial Areas	20%	20% of commercial parking lots will be paved with either porous asphalt (or concrete) or permeable pavers.

Potential Private Lot Level SWM Measures	Moderate Implementation
Downspout Disconnection	70%
Porous Driveways	15%
Rain Gardens	10%
Rain Barrels	25%
Side and Rear Yard Infiltration Trenches	5%



		Land Use 2005 Classification					
Communities / Neighbourhoods	Area (ha)	Single-Detached Residential	Semi-Detached Residential	Row and Townhomes	Apartments	Post-Secondary Residence	Other
Bel-Air Heights	65.9	59.1%	3.2%	0.0%	6.2%	0.0%	39.3%
Bel-Air Park	57.9	58.2%	1.6%	0.0%	0.0%	0.0%	48.9%
Britannia Village/Lincoln Heights	66.4	18.2%	2.7%	3.0%	23.3%	0.0%	57.6%
Carlingwood	29.9	69.7%	1.6%	0.7%	2.9%	0.0%	36.9%
Centrepointe	141.3	46.6%	0.4%	23.6%	0.3%	0.0%	38.2%
Copeland Park	81.9	51.9%	9.6%	9.0%	8.7%	0.0%	31.0%
Glabar Park	118.1	56.8%	5.4%	2.3%	0.2%	0.0%	43.1%
Highland Park	45.7	67.2%	0.1%	0.0%	0.0%	0.0%	41.6%
McKellar Park	71.7	66.4%	0.1%	3.4%	2.7%	0.0%	38.3%
Meadowlands/Crestview	167.5	72.4%	1.2%	1.1%	0.0%	0.0%	33.4%
Q-way Terrace N/Britannia Heights	113.5	51.5%	6.1%	4.4%	6.4%	0.0%	74.4%
Ridgeview	154.1	36.1%	0.3%	0.1%	0.3%	0.0%	16.8%
St. Claire Gardens	76.9	24.1%	15.3%	24.6%	1.6%	0.0%	50.9%
Tanglewood	83.9	34.8%	5.5%	0.7%	8.0%	0.0%	32.2%
Westboro	63.9	52.9%	1.3%	0.0%	3.1%	0.0%	48.0%
Westboro Beach	1.5	58.4%	0.0%	4.6%	11.1%	0.0%	39.4%
Whitehaven	61.7	47.2%	8.3%	2.4%	4.8%	0.0%	32.3%
Wood Park	54.4	10.6%	2.4%	2.5%	17.1%	0.0%	47.1%
Woodroffe North	41.5	231.9%	5.6%	68.6%	4.9%	0.0%	284.8%
Woodvale/Manordale/Craig Henry	236.8	15.7%	2.3%	4.5%	7.0%	1.0%	241.1%
Other	635.1	10.3%	1.5%	0.7%	0.8%	0.0%	10.3%
Total	**2369.6**	**45.2%**	**3.4%**	**6.1%**	**4.2%**	**0.1%**	**77.5%**

LEGEND:

- Roads
- OttawaRiver
- Communities
- Water
- Total Study Area

Residential

- Single-Detached
- Semi-Detached
- Row and Town Homes
- Apartments
- Post-Secondary Residence

CLIENT: Ottawa

NOTES:

- The following data was provided by the City of Ottawa
- Apartments not included in the Modest SWM Implementation Scenario
- Post-Secondary Residence was not included in the Residential Implementation; it was modelled with Institutional, see Figure 3.
- See Appendix A for the Land Use 2005 Glossary, Table 1 for Typical Residential Lots.

0 175 350 700 1,050 1,400 Meters

N

MAY 2011 REV. 1

BY: JFSA Water Resources and Environmental Consultants

PROJECT: PINECREST CREEK / WESTBORO SWM RETROFIT STUDY

TITLE: Potential Sites for Private Residential SWM Measure Implementation

PROJECT No. 741-09

DESIGN	KM
GIS	KM
CHECK	JFS
REVIEW	JFS

FIGURE 4

MAP REF.: 741_09\Design\Maps\LotLevelPrivate.mxd

Implementation on commercial and industrial properties will require coordination with the Awareness and Engagement component of the plan. See also Protecting Existing Trees under Leading by Example – SWM Measures on Public Properties. The commercial and industrial properties within the selected sewershed area can be targeted for promotion of downspout disconnection/redirection, infiltration trenches and porous paving.

Potential sites:

Commercial -
Regional Shopping Centre
Community Shopping Centre
Other Commercial

Industrial -
Industrial
Office
Industrial Condominium

For the locations of these potential sites within the study area please refer to Figure 2: Potential Sites for Public Property, Commercial and Industrial SWM Measure Implementation.

4.5 Planning and Implementation Schedule for a 50-year Time Frame

The priorities of the 50-year implementation plan are provided in Section 3. A summary the SWM measures to be implemented and the full extent of the implementation is also provided in Section 3 and the full lifecycle costing of the preferred Retrofit Plan (Moderate Scenario) is provided in Appendix L. Future studies and approval requirements anticipated for the implementation of the various measures are outlined in Section 4.6.

The proposed 50-year Implementation Schedule is shown in Figure 5 and Implementation Schedule Years 1 to 50 is outlined on Table 9. Percent uptake by land use, retrofit measures implemented and associated capital costs are also provided on Table 9. With the exception of the EoP facilities, the implementation of the retrofit measures can generally be carried out on a study area wide basis depending upon opportunity and the cost/ benefit conditions.

In terms of sheer numbers, the SWM measures to be implemented across the study area include:

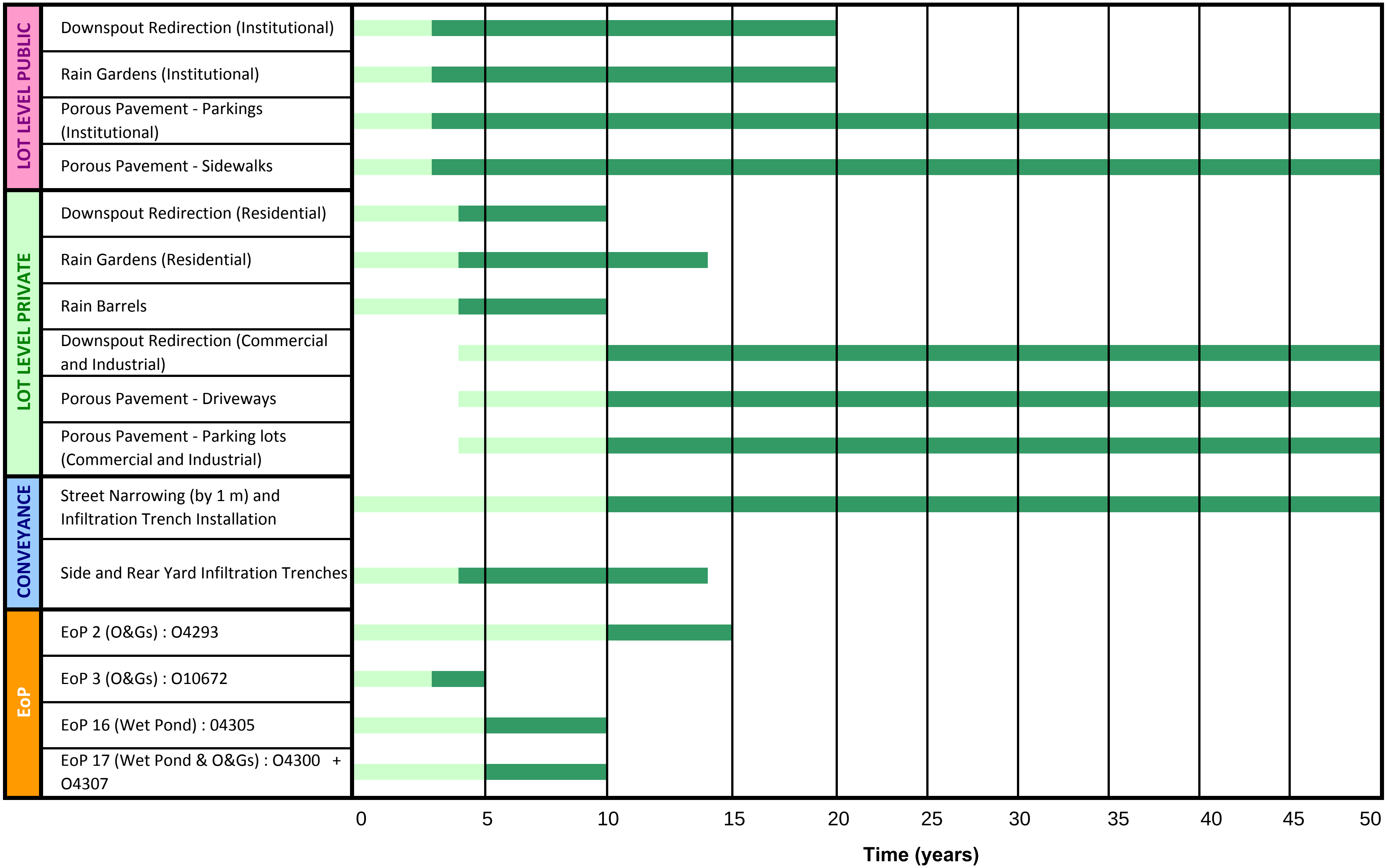
- 9,425 Rain Barrels (two per house; 25% of the households)
- 2,759 Downspout Redirections (two per house; nine % more households in the Pinecrest Creek subwatershed)
- 1,915 Infiltration Trenches (equivalent to 20 km of infiltration trenches 0.5 m wide, 0.6 m deep)
- 1,908 Rain Gardens (10% of households and institutional properties)
- 16.16 ha of Porous Pavement Driveways (15% of households)
- 19.16 ha of Porous Pavement Parking Lots (20% of commercial properties; 25% of institutional and industrial)
- 12.16 ha of Porous Pavement Sidewalks (equivalent to 81 km; 50% of all City sidewalks in study area)
- 0.89 ha of Street Narrowing (equivalent to 8.9 km; 5% of City streets in study area)

Four End-of-Pipe Facilities:

- An O&Gs treating a 98.97 ha catchment (EoP 1)
- An O&Gs treating a 163.07 ha catchment (EoP 3)
- A Wet Pond treating a 435.35 ha catchment (EoP 16)
- An O&Gs combined with a Wet Pond Treating a 335.00 ha catchment (EoP 17a and b)

Additional elements of the Implementation Plan include an Awareness and Engagement Program (Section 4.1.4) and a comprehensive Monitoring Program (Section 5).

Figure 5: Planning and Implementation Schedule for 50 Year Implementation



J.F. Sabourin and Associates Inc.
Water Resources and
Environmental Consultants

JFSAinc. Ref: 741-09
3/25/2011

Table 9: Implementation Schedule Years 1 to 50

	SWM MEASURES	Percent Uptake by Land Use[1]												Description of Implementation	SWM Measure Units			Capital Cost[2]			
		Residential Area			Institutional Area			Commercial Area			Industrial Area										
		1 - 5 yrs	6 - 10 yrs	11 - 50 yrs	1 - 5 yrs	6 - 10 yrs	11 - 50 yrs	1 - 5 yrs	6 - 10 yrs	11 - 50 yrs	1 - 5 yrs	6 - 10 yrs	11 - 50 yrs		1 - 5 yrs	6 - 10 yrs	11 - 50 yrs	1 - 5 yrs	6 - 10 yrs	11 - 50 yrs	Total
LOT LEVEL PUBLIC	Downspout Redirection				2%	3%	5%							**1 - 5 yr:** Awareness and Engagement Program Setup - Institutional Implementation on City property only for first 5 years. **6 - 10 yr:** Begin roll-out to non-City buildings based on lessons learned during pilot project. **11 - 50 yr:** Complete roll-out by year 20.	9	14	23	$11,700	$18,200	$29,900	$59,800
	Rain Gardens				2%	3%	5%							**1 - 5 yr:** Awareness and Engagement Program Setup - Implementation on City property only for first 5 years. **6 - 10 yr:** Begin roll-out to non-City buildings based on lessons learned during pilot project. **11 - 50 yr:** Complete roll-out by year 20.	5	7	11	$2,500	$3,500	$5,500	$11,500
	Porous Pavement (Parking Lots)				2.5%	2.5%	20.0%							**1 - 50 yr:** Opportunity Driven, Goal = 0.5 % / year for 50 years.	0.67 ha	0.67 ha	5.46 ha	$160,800	$160,800	$1,310,400	$1,632,000
	Porous Pavement (Sidewalks)	5%	5%	40%	5%	5%	40%	5%	5%	40%	5%	5%	40%	**1 - 50 yr:** Opportunity Driven, Goal = 1.0 % / year for 50 years.	1.21 ha	1.21 ha	9.74 ha	$290,400	$290,400	$2,337,600	$2,918,400
LOT LEVEL PRIVATE	Downspout Redirection (Residential)	1.5%	7.5%	N/A										**1 - 5 yr:** 1.5 % per year starting in year 5. **6 - 10 yr:** 1.5 % per year (completes year 10).	440	2199	0	$66,000	$329,850	$0	$395,850
	Rain Gardens	1%	5%	4%										**1 - 5 yr:** 1.0 % per year starting in year 5. **6 - 10 yr:** 1.0 % per year. **11 - 50 yr:** 1.0 % per year (completes year 14).	189	943	753	$94,500	$471,500	$376,500	$942,500
	Rain Barrels	4%	21%	N/A										**1 - 5 yr:** 4.0 % in the first year starting at year 5. **6 - 10 yr:** 4.2 % per year (completes year 10).	1508	7917	0	$324,220	$1,702,155	$0	$2,026,375
	Downspout Redirection (Non-Residential)							0%	0%	10%	0%	0%	10%	**1 - 10 yr:** Planning Phase. **11 - 50 yr:** Implementation begins in year 11, steady roll-out to private businesses over 40 years based on experience gained on City Buildings, completes by year 50.	0	0	74	$0	$0	$96,200	$96,200
	Porous Pavement (Driveways)	0%	0%	15%										**1 - 10 yr:** Planning Phase. **11 - 50 yr:** Implementation begins in year 11, steady roll-out over 40 years, completes by year 50.	0 ha	0 ha	16.16 ha	$0	$0	$3,878,581	$3,878,581
	Porous Pavement (Parking lots)							0%	0%	20%	0%	0%	25%	**1 - 10 yr:** Planning Phase. **11 - 50 yr:** Implementation begins in year 11, steady roll-out over 40 years, completes by year 50.	0 ha	0 ha	12.37 ha	$0	$0	$2,968,320	$2,968,320
	Side and Rear Yard Infiltration Trenches	0.5%	2.5%	2%										**1 - 5 yr:** 0.5 % per year starting in year 5. **6 - 10 yr:** 0.5 % per year. **11 - 50 yr:** 0.5 % per year (completes year 14).	92	471	379	$46,000	$235,500	$189,500	$471,000
CONVEYANCE	Street Narrowing (by 1 m) and Infiltration Trench Installation	0%	0%	5%	0%	0%	5%	0%	0%	5%	0%	0%	5%	**1 - 10 yr:** Planning Phase. **11 - 50 yr:** Implementation begins in year 11, steady roll-out over 40 years, completes by year 50.	0	0	0.89 ha and 973	$0	$0	$1,200,820	$1,200,820
EoP	EoP 1 (O&Gs) : O4293				0%	0%	100%							**1 - 10 yr:** Planning Phase. **11 - 50 yr:** Implementation begins in year 11.	0	0	1	$0	$0	$650,000	$650,000
	EoP 3 (O&Gs) : O10672				100%	N/A	N/A							**1 - 5 yr:** Planning phase (years 1-3), Implementation (years 4-5).	1	0	0	$1,300,000	$0	$0	$1,300,000
	EoP 16 (Wet Pond) : 04305				0%	100%	N/A							**1 - 5 yr:** Planning Phase. **6 - 10 yr:** Implementation begins in year 6, ends no later than year 10.	0	1	0	$0	$6,000,000	$0	$6,000,000
	EoP 17 a) and b) (Wet Pond & O&Gs) : O4300 + O4307				0%	100%	N/A							**1 - 5 yr:** Planning Phase. **6 - 10 yr:** Implementation begins in year 6, ends no later than year 10.	0	1	0	$0	$4,475,000	$0	$4,475,000
																	Total:	**$2,296,120**	**$13,686,905**	**$13,043,320**	**$29,026,345**

[1]Pecent uptake is by household, building or area based on the SWM Measure being described

[2]The Capital Cost is the total cost in 2010 dollars to construct the proposed measures, it does not include maintenance or replacement costs

Costs for any porous pavement installation and street narrowing only reflect the "premium" costs (i.e. the SWM measure would be implemented during required rehabilitation work and the cost shown is the difference between a typical installation and the proposed SWM measure). For the complete cost analysis, see Table L3 in Appendix L.

N/A denotes years for which, the measure had previously been fully implemented.

4.6 Moving Forward: Future Study

4.6.1 Future Studies and Pilot Projects

This Study and final report represent only the first step in a long-term plan to retrofit the study area to achieve the identified objectives of improved water quality, reduced flood risk, a healthier Creek and River and reduced Westboro Beach closures. The Study has confirmed the range, extent, general location and total cost of the various measures that comprise the proposed Retrofit Plan. However, moving forward with implementation will require various additional efforts and studies, including the following:

1) **Calibration of Hydrologic Model:**
It is recommended that the hydrologic model developed to support this Study be further refined through calibration and validation. This will ensure that the model reasonably reflects the actual watershed response to rainfall. Calibration should be undertaken as soon as possible, subject to the collection of sufficient rainfall and streamflow monitoring data (see Section 5.1.4). This calibration effort would prove particularly useful for flood risk confirmation, the detailed design of end-of-pipe facilities to ensure that downstream erosion concerns are not exacerbated, and confirmation of the threshold beyond which runoff occurs (i.e., how much rainfall is now being retained by the watershed and not immediately running off).

2) **Feasibility Study of Conveyance Measures:**
The Retrofit Plan recommends a total of 9 km of streets within the study area be retrofitted to provide water quality benefits, however, identification of the specific rights-of-way was beyond the scope of this initial effort. This future study would examine more closely existing rights-of-way within the study area, develop criteria for feasibility, consult internally and with the public, identify specific locations, and develop design standards for future applications.

3) **Pilot Lot Level/Conveyance Measure Installations:**
Given the limited opportunities for retrofit end-of-pipe facilities in the study area, water quality improvement over the longer-term will also depend on the implementation of lot level and conveyance measures. There is, however, limited experience with some of these measures. Pilot installations on public property will allow experience to be gained prior to broader application of these measures.

> i) Lot level measures on City property: Identify appropriate candidate facility/facilities (building/parking lot, etc.) and implement various lot level measures as appropriate, e.g., rainwater cistern, rain garden, pervious paving, biofilter, etc.
>
> ii) Pilot “Green Street:” Identify a length of street in the study area that could feasibly be retrofit as a "green street." This could include street narrowing (to increase pervious area), other infiltration measures, pervious sidewalks, tree-planting (e.g., Silva cell application), etc. This would require selection of an appropriate candidate site(s), public consultation, and would ideally be implemented in conjunction with a scheduled rehabilitation project.

4) Preparation of City design standards is required for the various lot level and conveyance SWM measures recommended. This would include revisions to existing City guideline documents as required.

5) Provision of training to City staff, the public and the development industry in the implementation of lot level measures specified is recommended.

6) Development of programs and identification of funding required to promote and provide incentives for the implementation of lot level measures on private property.

7) Preparation of a background study on the implementation of an area-specific SWM retrofit development charge to be applied to infill/redevelopment within the study area. The future collection of this charge would contribute proportionally to the construction of the recommended centralized end-of-pipe facilities.

Site specific surveys and studies will be required for the final design of the retrofit projects. The type of surveys and studies required will depend on the SWM measure(s) involved and could range from lot level surveys to verify that there is adequate space away from building foundation and pervious surfaces to soil infiltration testing, geotechnical investigations and parking demand studies for road narrowing and infiltration trenches.

4.6.2 Approval Requirements

As noted, this study has been undertaken as a Master Plan under the Municipal Class Environmental Assessment (October 2000, as amended in 2007). The following sections outline the approvals that may be required for certain of the proposed retrofit projects under the MCEA and other applicable federal, provincial and municipal legislation.[2]

Municipal Class Environmental Assessment Requirements
The Municipal Class EA (MCEA) process provides a means of addressing a group of related projects distributed over a broad geographical area, as is the case with the Pinecrest Creek/Westboro SWM Retrofit Plan. Projects undertaken by municipalities can vary in their environmental impact and therefore the MCEA classifies projects according to four different schedules: A, A+, B and C. Projects undertaken by private interests are not subject to the MCEA unless they fall under Schedule C.

Further MCEA work will be required for all end-of-pipe facilities (Schedule B or C) and some conveyance measures may also be subject to the MCEA. It is anticipated that lot level measures on public property would, for the most part, fall under Schedule A or A+. Notwithstanding this preliminary categorization, prior to the implementation of any City-led projects on public property, the appropriate MCEA schedule is to be confirmed.

Conservation Authority Requirements
Pinecrest Creek subwatershed and the Westboro area are within the jurisdiction of the Rideau Valley Conservation Authority (RVCA). The RVCA has participated in this study's consultation process and has had representatives on the project's Technical Advisory Committee. Retrofit projects affecting the Creek channel or shoreline of the Ottawa River (e.g. new EoP facility outfalls, stream rehabilitation works, etc.) will require permit as per RVCA's regulations under the Conservation Authorities Act.

Provincial Ministry Requirements
The Ministry of the Environment (MOE) has been consulted during this study and was represented on the project's Technical Advisory Committee. Certificates of Approval as per the Ontario Water Resources Act will be required for all proposed end-of-pipe facilities and may be required for conveyance retrofit projects involving infiltration measures.

Federal Agency Requirements
Federal lands (owned and managed by the NCC) will be required for the implementation of the 3 of the 4 end-of-pipe facilities. The Canadian Environmental Assessment Act (CEAA) applies to projects affecting federal lands or waters. The CEAA requires an assessment of the environmental effects of the project and alternatives, as well as consultation with the public and affected government agencies. The documentation and results of this study may be used in the federal EAs that will be required.

The NCC has participated in this study's consultation process and had representatives on the project's Technical Advisory Committee. Further consultation with the NCC will be essential to the implementation of several key parts of the SWM retrofit.

Other federal legislation that may apply and may require approvals and/or permits are:

- Fisheries Act (administered by Department of Fisheries (DFO) and by RVCA under agreement with DFO)

4.7 First 5 Years of Implementation

The first 5 years of implementation will be focussed on "mobilization" and putting in place those elements required for successful SWM retrofit over the long term. The priorities of the first five years are as follows:

a) Initiation of the *Awareness and Engagement* and *Leading By Example* components including lot level and conveyance SWM measure pilot projects to be initiated in year 1. Pilot projects on City owned properties are to be considered for implementation in years 1 through 5, ideally at sites (to be confirmed) where retrofits can be coordinated with life-cycle replacements (e.g., sidewalks, parking lots, rights-of-way, etc.).

b) Awareness and Engagement - To prepare for the implementation of lot level SWM measures on private properties, conduct Steps 1, 2 and 3 (Section 4.1.4) in the first year, Steps 4 and 5 in the second and third years, and Step 6 in the fourth year and onward. Advance downspout disconnection/redirection and look for opportunities for rain barrels, rain gardens, etc. [Promotion of SWM Measures on Private Residential Properties component]. Site specific surveys and studies will be required for the final design of some of these retrofit projects. Site specifics may be needed to verify site conditions, e.g. space from building foundation and pervious surfaces, soil infiltration rates, etc.

c) Initiation of land use approvals process, Class Environmental Assessments, design, development of contract specifications, project approval process and tender development for conveyance control measures and end-of-pipe facilities in year 1 through 3. Advance EoP3 (sited on City of Ottawa lands) for construction in year 4 – 5. Advance planning for EoP16 and EoP17 a) and b). If possible, advance implementation of EoP16 to realize benefits early on.

d) Initiate training of City staff in the implementation of lot level and conveyance measures and development of City design standards and revision of City guidelines as required to facilitate implementation for the various SWM lot level and conveyance measures in year 1.

e) Initiate outreach to industry/commercial property owners and look for opportunities for implementation of SWM measures on these properties [Promotion of SWM Measures on Commercial and Industrial Properties component, by year 4]. See site specific studies comment under b) above.

f) Monitoring to start by year 3 with the acquisition of baseline data followed by the condition-stress-response monitoring program (as described in Section 5).

g) Calibration of hydrologic model to be completed in year 3 subject to the availability of sufficient streamflow data.

h) Feasibility Study of Conveyance Measures: Described above in Section 4.6.1; complete this study in year 4.

The proposed Implementation Schedule for Years 1 to 5 inclusive is outlined on Table 9.

4.8 Implementation in Years 6 to 10

It is anticipated that the next 5 years of implementation will be focussed on the realization of further implementation of SWM measures on private residential properties as well as on institutional, commercial and industrial properties. The priorities for this five year period are as follows:

a) Continuation of the Awareness and Engagement component (Section 4.1.4: Step 6) and the development of programs and funding to promote and provide incentives for the implementation of lot level measures on private property using the information acquired by studies / surveys identified in Section 4.6.

b) Advancement of EoP 16 and EoP 17 a) and b) (sited on NCC lands) for construction. (EoP 2 scheduled for post year 10)

c) Monitoring on-going potentially with some sewershed and facility monitoring. (as described in Section 5).

The proposed Implementation Schedule for Years 6 to 10 is outlined on Table 9.

5. MONITORING AND ADAPTIVE MANAGEMENT

The monitoring requirements are twofold: one, to gather information about the state of the study area to assess how effectively the SWM retrofit is meeting the objectives and targets it was designed to achieve; and two, to track the progress of the implementation. Through this monitoring, knowledge and experience can be gained about the effectiveness of the Retrofit Plan. It may determine which components of the Plan perform well and which may require adjustment. Careful monitoring of the outcomes and progress is essential for the application of an effective adaptive management approach to implementation. The following sections prescribe a general level of monitoring to be carried out over the longer term as the Retrofit Plan is implemented. There are also recommendations for a shorter term performance type monitoring directed at the assessment of the effectiveness of lot level, conveyance and end-of-pipe facilities.

The proposed monitoring is based on a Condition-Stress-Response (C-S-R) framework[3]. It uses specific indicators to assess watershed health, watershed stressors and management response. This includes using the SWM retrofit objectives, targets and indicators (described in Part B: Section 2 and also included in Appendix N). The indicators fall into three main types depending on whether they measure the condition of, the stress acting on, or the response taken to mitigate impacts to watershed health:

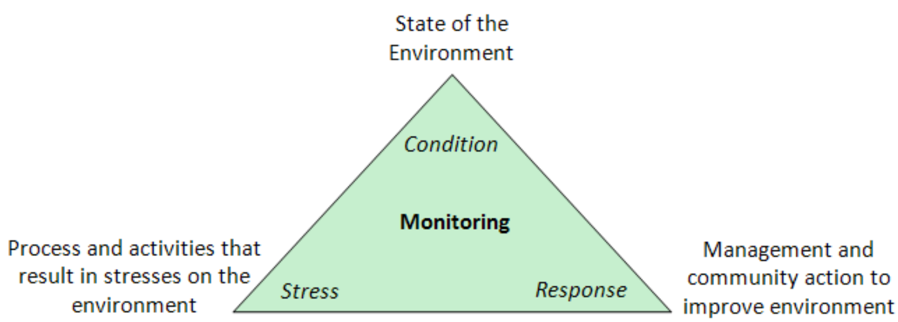
Condition indicators – are used to assess the state of environmental health and are chosen by considering biological, chemical and physical variables and ecological functions. Measures of water quality, channel stability and aquatic habitat are examples of condition indicators.

Stress indicators - reflect natural processes and human activities that impact, stress or pose a threat to environmental quality and include:

- Direct pressure or stresses that act immediately upon environmental quality, e.g., pollutant loadings
- Indirect pressure are human activities that lead to direct pressures, e.g., storm runoff
- Underlying pressure - societal, economic or cultural conditions that drive human activities, e.g., population growth

Response indicators - track individual and collective actions to reduce, remove or mitigate stress and damage to the environment. Education, regulation, technology changes and creation of protected areas are examples of response indicators.

Implementing this Retrofit Plan is a management ***response*** to the ***stresses*** created by uncontrolled runoff that are impacting the ***condition*** (overall health) of Pinecrest Creek and the Ottawa River. The monitoring programs and recommendations outlined here involve all three types of indicators.



Condition-Stress-Response Framework

5.1 Pinecrest Creek/Westboro Monitoring Program

The proposed monitoring program is described in detail in the following sections and summarised in Section 5.1.9.

5.1.1 Flood Risk on Pinecrest Creek

This component of the monitoring program tracks flood risk conditions. The indicators used are *flood elevations, flood flows* and *floodplain storage* [condition indicators].

With potential infill and redevelopment or any major works proposed within the creek corridor, there is a need to ensure flood risk to public health and safety and to property is not increased. The reduction of this flood risk and/or ensuring it does not increase above current conditions is one of the seven SWM retrofit objectives for the study area (refer to Appendix N). *Floodplain storage* attenuates peak flows as the flood wave moves downstream through the system and therefore, maintaining this feature of the floodplain is important to avoid peak flow increases from future potential works within the Creek corridor.

The confirmation of existing condition *flood elevations*, *flood flows* and *floodplain storage* will be accomplished through calibration of the hydrologic and hydraulic modelling prepared for this study (refer to Section 4.6: Moving Forward and Table 13). This modeling work will provide the benchmarks against which future monitoring (See Table 10) will be compared.

Table 10: Monitoring Program for Flood Risk on Pinecrest Creek

Indicator	Monitoring Locations and Details	Recommended Frequency
• Flood elevations • Flood flows	Locations at which the 2010 flood levels were generated in Pinecrest Creek/Westboro SWM Retrofit Study.	Subsequent to model calibration, in conjunction with any major works within the corridor and/or any major redevelopment in the subwatershed.
• Floodplain storage (riparian storage) volumes for 2 to 100 year events	Locations at which the storage volumes were determined from 2010 hydraulic modelling for the Pinecrest Creek/Westboro SWM Retrofit Study.	Subsequent to model calibration, in conjunction with any major works within the corridor and/or any major redevelopment in the subwatershed.

It is recommended that any changes in the cross-section forms (see Section 5.1.2) be used to update the existing hydraulic model. Similarly, the flows used in the hydraulic modelling should be the most up-to-date output from the hydrologic modelling (see Section 5.1.4).

Related indicators:
Cross-Sectional Forms (Section 5.1.2)
Hydrologic Cycle on Pinecrest Creek (Section 5.1.4)
Development Intensification within the Study Area (Section 5.1.8)

5.1.2 Erosion and Deposition Impacts and Channel Stability in Pinecrest Creek Corridor

This section was provided by JTB Environmental Services Inc.

This component of the monitoring program tracks the geomorphologic condition and channel stability of the Pinecrest Creek corridor and addresses the potential impacts of SWM measures on creek function. Erosion impacts and channel stability are measured by *cross-sectional form* [a condition indicator] coupled with integration of hydrologic data and analysis of sediment transport and deposition.

Erosion and deposition within the Pinecrest Creek corridor can be detrimental to property, infrastructure and stream habitat. The reduction of these impacts in the corridor is one of the seven SWM retrofit objectives for the study area. Channel stability is a function of time series flows, sediment regime, and stabilizing bank features (e.g. woody vegetation, artificial hardening).

The evaluation of cross-sectional form is derived through direct measurement of cross-sections in the channel at reaches which are considered sensitive to change (primarily to erosion but also to deposition). There are on-going rehabilitation projects on Pinecrest Creek which are tied to other works. The intent of those projects is to restore sensitive reaches. Due to this on-going restoration work a number of these currently sensitive reaches may no longer be of concern by the time implementation of SWM retrofit measures commences (in particular, EoP16). Therefore, prior to implementation of EoP 16 a baseline geomorphic survey should be undertaken to identify the most sensitive reaches at that time.

Surveying should be done with either GPS base station/rover or Total Station to ensure accuracy and the survey should be undertaken from monumented stations along the Creek. Surveyed locations should contain a mixture of riffles/runs/pools if possible and should be comprised of ten (10) sections, closely spaced, per reach being assessed. The location and spacing of the sections will depend on the reach being assessed. Direct and repeated surveys will allow for calculation of change in cross-sectional area under various flow levels.

In addition, the cross-section measurements can be used to determine changes in longitudinal profile and, through integration of the hydrologic data collected (see Section 5.1.4), cross-section data can be used to analyze sediment transport/deposition risk. If this analysis indicates that certain change(s) to sediment transport or calibre may be occurring (see Appendix N: Objectives and Targets: Objective 2), then a bulk sediment sampling will need to be collected from the creek bed for a dry weight analysis of grain size distributions. The grain size distribution can be used to confirm the sediment regime changes, if any, and inform decisions as to whether interventions to address deleterious impacts may be necessary, e.g., monitoring results may indicate the need for in-stream rehabilitation measures.

In terms of the lot level and conveyance measures alone, it is expected that approximately 10% of the recommended implementation of these measures would need to be in place before a noticeable peak flow change (reduction) would be observed in the Creek. That 10 % implementation coincides with the beginning of year 6 of the proposed implementation schedule. Therefore, both 10 % implementation and/or year 6 could be used as triggers for this fluvial geomorphological monitoring (full survey). (The proposed first five years of implementation also includes the installation of EoP 3, however, EoP 3 is an oil and grit separator which will not affect peak flow.) If the first five year component of the implementation plan proceeds according to schedule then the baseline monitoring and post-implementation cross-sectional monitoring locations would be sited at connection nodes (e.g., points of discharge to the Creek from the implementation areas) for the lot level and conveyance implementation (as per Table 11 - Monitoring Locations and Details column). The baseline monitoring should start prior to, but as close in time to as possible, the installation of the retrofit measures. The proposed schedule for the installation of EoP 16 is in years 6 to 10. If any further baseline information is required for EoP 16 monitoring then this will need to be done prior to the EoP 16 installation and the baseline monitoring and post-implementation cross-sectional monitoring locations would be sited at connection nodes for EoP 16 (as per Table 13 - Monitoring Locations and Details column).

This component would involve the following monitoring activities listed in Table 11 below.

Table 11: Monitoring Program for Erosion and Deposition Impacts in the Pinecrest Creek Corridor

Indicator	Monitoring Locations and Details	Recommended Frequency
• Cross-sectional form and area from repeated survey data	Initiation of lot level/conveyance measures will require geomorphic monitoring from the connection node downstream to the next connection node. For example, if retrofit implementation was to occur in Copeland Park, monitoring for channel stability will occur at a sensitive reach (to be confirmed at that time) located between Outfall 04306 and Outfall 04296 (see Figure B1 in Appendix B). Implementation of EoP 16 will require monitoring from the connection node downstream to the ORP culvert (the limit of the exposed portion of Pinecrest Creek).	The frequency of cross-section monitoring should be as follows: Prior to implementation, reaches, sections and velocity/sediment sampling should occur to establish the pre-construction conditions (baseline conditions); surveying and analysis should then occur a minimum of 2 times per year for a period of three years.

Related indicators:
Aquatic Habitat of Pinecrest Creek – Average pool depth, bank stability (Section 5.1.3)
Hydrologic Cycle on Pinecrest Creek (Section 5.1.4)
Development Intensification within the Study Area (Section 5.1.8)

5.1.3 Aquatic Habitat of Pinecrest Creek

This component of the monitoring program keeps track of what is occurring to the physical attributes of the Pinecrest Creek's aquatic habitat. The health of aquatic habitat in Pinecrest Creek can be measured by *average pool depth*, *percent cover*, and *bank stability* [which are condition indicators]. This aquatic habitat component would involve the monitoring activities outlined in Table 12.

In order to improve the quality and quantity of in-stream aquatic habitat, the physical structure of the corridor will need to be improved. Improving the potential for a sustainable fishery is a longer term objective (See Appendix N: Objectives and Targets: Objective 2C). This stems from the need to focus initial efforts on improving water quality and tempering the existing "flashy" hydrology through SWM retrofit measures. The need for the aquatic habitat monitoring component will be revisited based upon the progress made during the first 5 and 10 years of retrofit implementation.

Ultimately, as progress is made, monitoring will be expanded to keep track of changes occurring to the physical attributes of the Creek's aquatic habitat. This aquatic habitat component will involve the monitoring activities outlined in Table 12.

Table 12: Monitoring Program for Channel Stability in the Pinecrest Creek Corridor

Indicator	Monitoring Locations and Details	Recommended Frequency
• Average pool depth • Bank stability	Pool depth and bank stability will be monitored at the sensitive reaches used in cross-section monitoring (Section 5.1.2). The monitoring will be composed of both visual assessment and analysis of cross-section and hydrology data.	The frequency at which the cross-section form monitoring is occurring.
• Percent cover	Overhead cover will be assessed visually at the locations used for the Cross-section monitoring (Section 5.1.2).	The frequency at which the cross-section form monitoring is occurring.

The *average pool depth* and *bank stability* can be determined from the data collected by *cross-sectional area* measurements (Section 5.1.2). Through direct survey of cross-sectional area it is possible to determine depth of pools and stability of banks through interpretation of the survey data. A cross-section that is either widening or becoming narrower is an indication of instability. Additionally, changes in average pool depth using pool cross-sections and data from the hydrologic assessment (Section 5.1.4) will clearly indicate whether there is an impact on this indicator.

Percent cover is a visual assessment of the presence/absence of overhead shading of the Creek by vegetation. This should also include presence/absence of fallen trees in the Creek as the fallen trees act as cover while they are in place.

Related indicators:
Cross-sectional form (Section 5.1.2)
Water quality on Pinecrest Creek (Section 5.1.5)
Tree canopy (Section 5.1.6)

5.1.4 Hydrologic Cycle of Pinecrest Creek

This component of the monitoring program (seen in Table 13) assesses the flow regime conditions in Pinecrest Creek which can be characterized by *peak flows, runoff volume* and *effective imperviousness* [stress indicators].

The preservation and/or re-establishment of a more natural hydrologic cycle for the Pinecrest Creek subwatershed is one of the seven SWM retrofit objectives for the study area. This includes reducing the rapidity with which *peak flows* occur in the Creek and the *volume of runoff* from the watershed. *Effective imperviousness* is a measurement of the proportion of a catchment covered by impervious surfaces directly connected to the receiving watercourse by storm sewers. The degree of *effective imperviousness* can greatly impact the timing and magnitude of flows and pollutants reaching the watercourse. The *peak flows* and *runoff volumes* from frequent events can be determined using flow, water level, and rainfall monitoring data.

Continuous monitoring of water levels and rainfall events within the subwatershed is required to more accurately determine the in-stream hydrographs for frequent events and to allow validation of the hydrologic model developed during this study.

Table 13: Monitoring Program for the Hydrologic Cycle of Pinecrest Creek

Indicator Parameters	Monitoring Locations and Details	Recommended Frequency
• Peak flows • Runoff volume	Existing City flow monitoring site at Iris to be supplemented with additional sites (number and location to be determined). Figure 6 illustrates six (6) sites that are appropriate for monitoring*. Rainfall data collected at local rain gauges (additional rain gauges beyond the City's existing network are recommended).	Continuous data collection (water level) with wet weather velocity measurements taken as needed to build rating curves. Continuous data collection (April to November).
• Effective imperviousness	Watershed wide: Data derived from the City's GIS data base, development plans or other available data sets.	In conjunction with periodic reviews (every 5 years) of the Retrofit Plan.

*Note that a limiting monitoring effort has already been undertaken at locations 3, 4 and 5. See Appendix Q.

The sites identified in Figure 6 are considered stable and appropriate for multi-year monitoring. The ADCP method for streamflow measurement, described in Appendix Q, could be used for the additional flow monitoring.

An analysis of the change in these in-stream hydrographs over time, particularly the runoff volume for 10 mm and smaller rainfall events, and the 'peakiness' of all frequent events, will indicate the impact of the lot level and conveyance measures on the Creek's hydrology.

As this is a pilot project, a more thorough monitoring program than usual should be considered. The acquisition of quantifiable data describing in detail the actual benefits of implementing SWM measures within a highly-urbanised Ottawa subwatershed would prove valuable in planning retrofit projects within the rest of the City.

Related indicators:
Flood Risk on Pinecrest Creek (Section 5.1.1)
Erosion and Deposition Impacts and Channel Stability (Section 5.1.2)
Development Intensification within the Study Area (Section 5.1.8)

Figure 6 – Potential Stream Flow and Water Level Monitoring Locations

5.1.5 Water Quality in Pinecrest Creek and at Westboro Beach

This component of the monitoring program assesses the water quality conditions and stresses within the study area. The water quality in the Creek and Ottawa River is assessed by measurements of in-stream *total suspended sediment (TSS), total phosphorus* and *E.coli* [condition indicators] and the pollutant loadings to the Creek and River can be tracked by measuring concentrations of *total suspended sediment (TSS), total phosphorus* and *E.coli* [stress indicators] at storm outfalls.

The improvement of water quality in Pinecrest Creek and the Ottawa River is one of the seven SWM retrofit objectives for the study area. *TSS* and *total phosphorus* concentrations in Pinecrest Creek and the Ottawa River are linked to achieving fish community targets, aesthetics and non-eutrophic conditions and avoiding the creation of in-situ contaminant concerns. The reduction of the deleterious impact of runoff on Westboro Beach, i.e., reducing the number of beach closures, is another SWM retrofit objective for the study area.

The proposed water quality monitoring activities are listed in Table 14.

Table 14: Monitoring Program for Water Quality in Pinecrest Creek and at Westboro Beach

Indicator Parameters	Monitoring Locations and Details	Recommended Frequency
• TSS • Total phosphorus • *E.coli*	<u>In-stream monitoring in Pinecrest Creek</u>: Wet weather sampling at City's water quality sampling station on Creek at Iris Street (City ID: CK9_III) and at mouth of Creek (City ID CK9_I) <u>Outfall monitoring in Pinecrest Creek</u> : Wet weather sampling at outfalls (listed by City ID) OUT13408, OUT12946, OUT04306, OUT10441, OUT04305, OUT04292 and OUT10672	To be determined: subject to progress of implementation.
• TSS • Total phosphorus • *E.coli*	<u>In-stream monitoring in Ottawa River</u>: Wet weather sampling at Westboro Beach <u>Outfall monitoring in Ottawa River</u>: Wet weather sampling at outfalls: Wavell (OUT04302), Ardmore (OUT04300), New Orchard (OUT04298) and Pooler (OUT04299)	To be determined: subject to progress of implementation.

The results of this water quality monitoring can be compared to the existing conditions and targets noted in this study's Objectives and Targets (Appendix N) and to the water quality data collected by the City to date.

Related indicators:
Hydrologic Cycle on Pinecrest Creek (Section 5.1.4)
SWM Retrofit Implementation (Section 5.1.7)
Development Intensification within the Study Area (Section 5.1.8)

5.1.6 Natural Features and Functions of Pinecrest Creek Corridor

This component of the monitoring program assesses the condition of naturalization and stresses on the natural features and functions of Pinecrest Creek and its corridor. The indicators used to track these conditions and stresses are *riparian vegetation* and *tree canopy* [condition indicators] and by *corridor encroachments* [stress indicator].

The protection, enhancement and rehabilitation of the natural features and functions along the Pinecrest Creek corridor is one of the seven SWM retrofit objectives for the study area. The Environment Canada Habitat Guideline recommends the natural vegetation within 30 m of a watercourse be retained or re-established on each side of a watercourse for 75% of its overall length. This is a watershed level guideline and though it may not be achievable within an urban subwatershed, the protection and restoration of the natural landscape within the existing Pinecrest Creek corridor is an essential element of the work to be done. The extent of *riparian vegetation* and *tree canopy* that exists along the Creek are the indicator parameters to be monitored. The area of *tree canopy* throughout the study area will also be monitored since an increased tree canopy in urban areas can reduce runoff volume by intercepting rainfall particularly for small events.

Monitoring of incidences of potential, planned and/or implemented c*orridor encroachments*, such as further transportation infrastructure, provides a measure of significant stresses acting on the corridor that could compromise its natural features and functions. Conversely, the rehabilitation of the corridor as part of the development projects, including, for example, the daylighting of the Creek, could provide mitigation of the impacts of corridor encroachments.

The proposed monitoring activities are listed in Table 15 below.

Table 15: Monitoring Program for the Natural Features and Functions of the Corridor

Indicator Parameters	Monitoring Locations and Details	Recommended Frequency
• Riparian vegetation	Throughout the Creek corridor using GIS, satellite images and/or other data sets available - measure the extent of stream sections that are in natural condition, altered and highly altered. Compare to baseline conditions.	At a minimum, in conjunction with periodic reviews (every 5 years) of the Retrofit Plan.
• Tree canopy	Throughout the study area using City's GIS tree canopy inventories – determine tree canopy area.	At a minimum, in conjunction with periodic reviews (every 5 years) of the Retrofit Plan.
• Corridor encroachments	Throughout the Creek corridor – map the areas earmarked for potential and/or planned development and affected by implemented encroachments. Determine percentages of land area involved and potential loss and/or gain of natural features and functions.	At a minimum, in conjunction with periodic reviews (every 5 years) of the Retrofit Plan.

Related indicators:
Hydrologic Cycle on Pinecrest Creek (Section 5.1.4)
Water quality on Pinecrest Creek (Section 5.1.5)
Development Intensification within the Study Area (Section 5.1.8)

5.1.7 SWM Retrofit Implementation

This component of the monitoring program tracks the extent of implementation of the Retrofit Plan in the study area. Indicators used to measure the progress of the physical implementation are: *areas with SWM retrofit* and *number of SWM measures* [response indicators]. The monitoring will need to be further developed to incorporate measures for: *increased public awareness* and *increased public involvement* [response indicators].

The proposed monitoring activities are listed in Table 16.

Table 16: Monitoring Program for SWM Retrofit Implementation

Indicator Parameters	Monitoring Locations and Details	Recommended Frequency
• Areas with SWM retrofit	Throughout the study area – using GIS software plot the areas where implementation has occurred and measure the total area affected as a percentage of the study area, including any infill and redevelopment areas that have used lot level and/or conveyance controls.	At a minimum, in conjunction with periodic reviews (every 5 years) of the Retrofit Plan.
• Number of SWM measures	Throughout the study area – tally of SWM measures as they are implemented, including any SWM measures used in infill and redevelopment areas.	At a minimum, in conjunction with periodic reviews (every 5 years) of the Retrofit Plan.

It is recommended that there also be continuous tracking of the progress being made on the Implementation Plan: keeping a record of what, when, where and how the measures have been implemented, i.e., were any deviations from what was originally anticipated required? It is recommended that the tracking be done using GIS software. A GIS database created for recording the areas of implementation could also be used to produce graphic displays and table outputs for the implementation and monitoring report(s).

The GIS database could include various layers depicting the implementation of the various strategies and their possible combinations within the larger Pinecrest Creek/Westboro study area, such as polygons demarcating the areas of implementation with attribute tables for "logging" the progress of the implementation and notes on overall impacts and the other various monitoring results. A compilation of the attribute tables and metadata can then be exported out of the GIS and used in the annual monitoring report for comparison to previous years and to the objectives and targets established by the study.

Related indicators:
Development Intensification within the Study Area (Section 5.1.8)

5.1.8 Development Intensification within the Study Area

This component of the monitoring program tracks the extent of infill and redevelopment within the study area and involves the measurement of: *total infill and redevelopment area* [stress indicator]. The proposed monitoring activities are listed in Table 17 below.

Table 17: Monitoring Program for Development Intensification with the Study Area

Indicator Parameters	Monitoring Locations and Details	Recommended Frequency
• Total infill and redevelopment area	Throughout the study area – using GIS software, plot the areas where infill and/or redevelopment has occurred and measure the total area affected.	At a minimum, in conjunction with periodic reviews (every 5 years) of the Retrofit Plan.

Related indicators:
Corridor Encroachments (Section 5.1.6)
SWM Retrofit Implementation (Section 5.1.7)

5.1.9 Summary of Proposed Monitoring Program

The proposed monitoring program, described in detail in the sections above, is summarised in Table 18.

Table 18: Pinecrest Creek/Westboro Monitoring Program in Summary

Component	Indicator	Recommended Frequency
Flood Risk	• Flood elevations • Flood flows • Floodplain storage (riparian storage) volumes for 2 to 100 year events	Subsequent to model calibration, in conjunction with any major works within the corridor and/or any major redevelopment in the subwatershed.
Erosion and Deposition Impacts and Channel Stability	• Cross-sectional form and area from repeated survey data	The frequency of cross-section monitoring should be as follows: Prior to implementation, reaches, sections and velocity/sediment sampling should occur to establish the pre-construction conditions (baseline conditions); surveying and analysis should then occur a minimum of 2 times per year for a period of three years.
Aquatic Habitat	• Average pool depth • Bank stability • Percent cover	The frequency at which the cross-section form monitoring is occurring.
Hydrologic Cycle	• Peak flows	Continuous data collection (water level) with wet weather velocity measurements taken as needed to build rating curves.
	• Runoff volume	Continuous data collection (April to November)
	• Effective imperviousness	In conjunction with periodic reviews (every 5 years) of the Retrofit Plan.
Water Quality	• TSS • Total phosphorus • *E.coli*	To be determined: subject to progress of implementation.
Natural Features	• Riparian vegetation • Tree canopy • Corridor encroachments	At a minimum, in conjunction with periodic reviews (every 5 years) of the Retrofit Plan.Annual determination
SWM Retrofits	• Areas with SWM retrofit • Number of SWM measures	At a minimum, in conjunction with periodic reviews (every 5 years) of the Retrofit Plan.
Development Intensification	• Total infill and redevelopment area	At a minimum, in conjunction with periodic reviews (every 5 years) of the Retrofit Plan.

5.2 Facility and Sewershed Monitoring

Facility and sewershed monitoring in key locations can be carried out to assess the effectiveness of lot level, conveyance, and end-of-pipe measures implemented. This performance monitoring would be undertaken for a limited period of time in specific locations upstream of which measures have been implemented in sufficient quantity.

5.2.1 Selection of Sites and Establishing Baseline Information

In the case of sewershed monitoring, it is recommended that the extent of retrofit implementation in terms of area, type and number of measures and expected uptake be sufficient to cause at least one (1) centimetre decrease in the water level in the storm sewer pipe for a ten (10) millimetre event. The size of the sewer pipe will also need to be taken into account when the implementation area is being selected. The maintenance hole location selected must also be suitable for the installation and use of an automated sampler.

In order to establish sufficient baseline data with which to compare the impacts of SWM retrofit measures, pre-implementation monitoring will need to be conducted. For water quantity and water quality, the baseline data on the indicator parameters (e.g. TSS, *E.coli* and total phosphorus for water quality) will need to be collected for the area(s) where the implementation is to occur (unless the City already has sufficient monitoring data for the site/outfall). For example, if the implementation is to occur in a particular sewershed then the baseline data on the discharge from the sewershed will be collected at the same point where the post-implementation monitoring will be done. Baseline data should be collected for two to three years prior to the implementation of the SWM measures.

5.2.2 Post-Implementation Monitoring

The proposed monitoring to be done following the implementation of a sufficient quantity of lot level and conveyance measures or end-of-pipe facilities is outlined in Table 19. The data from the flow and water level monitoring will be used to evaluate how well the retrofit is meeting objectives 1, 2 and 3 (Appendix N). The data from the water quality monitoring will be used to evaluate how well the retrofit is meeting objectives 4 and 5 (Appendix N).

Table 19: Proposed Facility and Sewershed Monitoring Program

Parameters	Monitoring Locations and Details	Recommended Frequency
• Flow and Water Levels	Pinecrest Creek flow and water level monitoring – Refer to Section 5.1.4: streamflow monitoring undertaken for the general monitoring program.	
	Outfall monitoring – monitoring EoP discharge	April to October Continuous for all events
	Sewershed flow monitoring – It is recommended that flow be monitored at an outflow point in the sewershed by installing continuous flow gauges within the sewer at a maintenance hole location.	April to October Continuous for all events
• Precipitation (input)	Precipitation monitoring collected at a local gauge which may be one of the gauges installed for the general monitoring program. Note: The establishment of rain gauge sites at schools can be used as part of the Awareness and Engagement component of the Implementation Plan.	April to October Continuous
• Water Quality Monitoring: TSS, Total phosphorus and *E.coli.*	Outfall monitoring – monitoring EoP discharge using automated sampler triggered by flow levels. Sewershed monitoring – at same location(s) used for the sewershed flow monitoring with an automated sampler that can be triggered by flow levels.	April to October 5 to 7 events
• Creek Corridor Stability Monitoring	Refer to Section 5.1.2: Erosion and Deposition Impacts and Channel Stability in Pinecrest Creek Corridor undertaken for the general monitoring program.	Refer to Section 5.1.2

5.3 Adaptive Management Feedback Loop

The monitoring results should be used to confirm and/or adjust future actions. Implementation of the Retrofit Plan and the anticipated watershed response will occur over an extended period of time, in the order of decades. Therefore it may be years before the effectiveness and performance of the SWM retrofit measures can be sufficiently demonstrated. The adaptive management feedback loop will need to accommodate different temporal (short to long term) and spatial scales as well as a wide range of monitoring parameters. This is particularly the case for work affecting the Pinecrest Creek corridor (as opposed to work in the Westboro area, related solely to water quality improvements).

ENDNOTES

[1] Murray, C. and D. R. Marmorek. 2004. Adaptive Management: A spoonful of rigour helps the uncertainty go down. 16th Int'l Conference, Society of Ecological Restoration , August 24-26, 2004, Victoria, Canada
And
Low Impact Development Stormwater Management Planning and Design Guide. Developed by the Credit Valley Conservation and Toronto Region Conservation Authority. Version 1.0. 2010. pp. 5.1 – 5.2.

[2] Potential approval requirements information acquired from numerous sources including Toronto Wet Weather Flow Management Master Plan (July 2003): Section 8 and Ontario government websites.

[3] Aquatic Habitat and Species Monitoring: A Discussion Paper in Support of the Development of a Regional Watershed Monitoring Network. Toronto Region Conservation Authority, September 2000. p. 2-3.
And
Rideau State of the River Report: A report on the environmental health of the Rideau River. Prepared by the Research & Monitoring Committee of the Rideau Roundtable, December 2001. http://www.rideauroundtable.ca/riverreport.html

REFERENCES

REFERENCES

Aquafor Beech Limited, in association with Center for Watershed Protection, Chesapeake Stormwater Network, Schollen & Company, Inc. 2008. Low Impact Development Stormwater Management Manual. Prepared for Credit Valley Conservation, Toronto and Region Conservation Authority, November 2008 Draft.

Aquafor Beech Limited and Robinson Consultants Inc. 2005. Lower Rideau Watershed Strategy Executive Summary. Report prepared for Rideau Valley Conservation Authority, September 2005.

Aquafor Beech Limited and Robinson Consultants Inc.. 2004. Performance Assessment of Two Types Of Oil & Grit Separator For Stormwater Management In Parking Lot Applications. Prepared by: Stormwater Assessment Monitoring and Performance (Swamp) Program. Report prepared for: Ontario Ministry of Environment, Toronto and Region (TRCA) and the Credit Valley (CVC) Conservation Authorities, Municipal Engineers Association of Ontario, City of Toronto. 135 p.

Aqualogic. 2008. North Oakville Pendent/Lower Fourth EIR/FSS Supplementary Erosion Analysis Methodology. North Oakville Agency Meeting. December 15, 2008.

Archaeological Assessment on Ontario Ministry of Tourism and Culture website: http://www.mtc.gov.on.ca/en/archaeology/archaeology assessments.shtml

Baird & Associates. 2009. Ottawa River Water Quality Model Study, Phase III - Assessment of River Inputs. October 2009.

Baird & Associates. 2008. Assessment of Bacterial Conditions at Westboro Beach. Report prepared Environmental Programs and Technical Support, Transportation, Utilities And Public Works Dept., City of Ottawa. September 2008. 82 p.

Baird & Associates. 2004. Assessment of Bacterial Conditions at Westboro Beach in 2003. Report prepared Environmental Programs and Technical Support, Transportation, Utilities And Public Works Dept., City of Ottawa. Final Report May 5, 2004. 43 p.

Baird & Associates. 2002. Assessment of Bacterial Conditions at Westboro Beach. Report prepared Environmental Programs and Technical Support, Transportation, Utilities And Public Works Dept., City of Ottawa. Final Report September 2002. 52 p.

Center for Watershed Protection. 2007. Urban Subwatershed Restoration Manual No. 3 – Urban Retrofit Practices (version 1.0). Prepared for Office of Wastewater Management U.S. Environmental Protection Agency, July 2007.

City of Ottawa, 2007. Stormwater Management Strategy – Stage 2: Final Policies. May 2007.

Credit Valley Conservation and Toronto and Region Conservation Authority. 2010. Low Impact Development Stormwater Management Planning and Design Guide. Version 1.0.

Cumming-Cockburn and Associates Ltd. 1980. Watershed Management Study – Pinecrest Creek – S.W. Transitway Corridor. Prepared for the Regional Municipality of Ottawa-Carleton, June 1980

D'Andrea, M.A. 2006. Wet Weather Flow Management. Prepared for the City of Toronto, November 2006.

Environment Canada. 2004. *How Much Habitat is Enough?: A* Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern. Prepared by the Canadian Wildlife Services. www.on.ec.gc.ca/wildlife

J.F. Sabourin and Associates Inc. 2000. An Evaluation of Roadside Ditches and Other Related Stormwater Management Practices- Addendum – Revised Cost Analysis and Selection Tool. Prepared for Toronto and Region Conservation Authority, February 2000.

J.F. Sabourin and Associates Inc. 1997. Keep the Rain Out of the Drain – Making it work in the City of Toronto. Prepared for the City of Toronto, December 1997.

J.F. Sabourin and Associates Inc. and JTB Environmental Systems Inc. 2010. Pinecrest/Centrepointe Stormwater Management Criteria Study. Prepared for the City of Ottawa, February 2010.

J.L. Richards & Associates Ltd. Consulting Engineers. 1997. Britannia Storm Sewer, Outlet and Sedimentation Facilities, Pond B - Design Rationale and Implementation, July 1997.

J.L. Richards & Associates Ltd. Consulting Engineers. 1968. Construction of Trunk Sewers on Woodroffe Avenue South of Baseline Road. Prepared for the Council of the Township of Nepean, September 1968.

JTB Environmental Systems Inc., J.F. Sabourin and Associates Inc. and LGL Environmental Research Associates. 2007. Pinecrest Creek Restoration Plan – Integrating Fluvial Geomorphology, Hydrology and Ecology. Report prepared for the National Capital Commission, March 2007.

Low Impact Development Stormwater Management Manual (Draft). Prepared for the Credit Valley Conservation and Toronto Region Conservation Authority by Aquafor Beech Limited in association with the Center for Watershed Protection, Chesapeake Stormwater Network and Schollen & Company Inc. November 2008. pp. 245-246.

Municipal Engineers Association (MEA). 2007. Municipal Class Environmental Assessment Manual. Executive Summary, Part A: Class EA Planning Process of the Municipal Engineers Class EA and Appendix 4: Approach #1. p. 4-2. http://www.municipalengineers.on.ca/classea/manual

Murray, C. and D. R. Marmorek. 2004. Adaptive Management: A spoonful of rigour helps the uncertainty go down. 16th Int'l Conference, Society of Ecological Restoration, August 24-26, 2004, Victoria, Canada

Nichol, G. 2006. City Stream Watch 2006 Annual Report. Prepared for the Rideau Valley Conservation Authority (RVCA), December 18, 2006.

Oliver, Mangione, McCalla and Associates Ltd. 1983. Design Report for Proposed Pinecrest Creek Improvements. Prepared for the City of Ottawa, April 1983.

Ontario Ministry of the Environment (MOE). 2003. Stormwater Management Planning and Design Manual. March 2003.

Ministry for the Environment; Government of New Zealand. 2010. Microbiological Water Quality Guidelines frequently asked questions (FAQs) website:
http://www.mfe.govt.nz/issues/water/water-quality-faqs.html#question4

Pitt, R. and J. Voorhees. 2000. The Source Loading and Management Model (SLAMM) – A Water Quality Management Planning Model for Urban Stormwater Runoff. Volume 1.

Rideau Roundtable. 2001. Rideau State of the River Report: A report on the environmental health of the Rideau River. Prepared by the Research & Monitoring Committee of the Rideau Roundtable, December 2001. http://www.rideauroundtable.ca/riverreport.html

Stantec. 2010. Westboro Beach Feasibility Study. Prepared for the City of Ottawa, February 2010.

Stormwater Assessment Monitoring and Performance (SWAMP) Program. 2003. Performance Assessment of an Open and Covered Stormwater Wetland System –Aurora, Ontario. Prepared for the Town of Aurora, May 2003.

Stormwater Assessment Monitoring and Performance (SWAMP) Program. 2002. Performance Assessment of a Pond-Wetland SWM Facility – Markham, Ontario. Prepared for the Town of Markham, June 2002.

Thurston, H.W, M.A. Taylor, W.D. Shuster, A.H. Roy and M.A. Morrison. 2010. Using a reverse auction to promote household level stormwater control. Environmental Science & Policy 13(2010): 405-414.

Toronto Region Conservation Authority (TRCA). 2000. Aquatic Habitat and Species Monitoring: A Discussion Paper in Support of the Development of a Regional Watershed Monitoring Network. September 2000. p. 2-3.

Toronto Region Conservation Authority (TRCA), Geomorphic Solutions, Sernas Group Inc. and LGL Limited, 2009. Evaluating the Effectiveness of 'Natural' Channel Design Projects: A Protocol for Monitoring New Sites. Report prepared for the Toronto Region Conservation Authority. 65 p.

Totten Sims Hubicki Associates. 2003. Toronto Wet Weather Flow Management Master Plan - Area 2: Etobicoke and Mimico Watersheds. Prepared for the City of Toronto, July 2003

U.S. Army Corps of Engineers. 2010. HEC-RAS River Analysis System: Hydraulic Reference Manual. Version 4.1. January 2010.

Woodward, D. E., R. H. Hawkins, R. J., A. T. Hjelmfelt, Jr., J. A. Van Mullem and Q. D. Quan, 2003. Runoff Curve Number Method: Examination of the Initial Abstraction Ratio. Proceedings of the World Water & Environmental Resources Congress 2003 and Related Symposia.