# THUNDER BAY

# STORMWATER MANAGEMENT PLAN

## FOR SUSTAINABLE SURFACE WATER MANAGEMENT

APRIL 2016

## VOLUME II:
## Plan Appendices

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Thunder Bay Stormwater Management Plan Prepared by Emmons & Olivier Resources, Inc. (EOR)

CITY OF Thunder Bay
Superior by Nature

EOR water ecology community
Emmons & Olivier Resources, Inc.

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## APPENDIX A Related Studies, Plans and Reports

**Approved Assessment Report for the Lakehead Source Protection Area** (2011) outlines the steps that the province, Municipalities, landowners, industries, farmers and others need to take to protect water quality and quantity in our streams, rivers, lakes and groundwater systems. These watershed-based plans will identify the threats to water quality and water quantity, identify vulnerable areas and then propose steps to reduce any risks to our water.

The **Bacterial Study of Chippewa Beach** (1989) was prepared to assess the periodic bacterial contamination rendering the bathing area unsuitable for swimming. Sampling analysis determined that the contamination was not caused by external sources in Lake Superior and the source of fecal coliform bacteria in the bathing area was from waterfowl and wildlife in the park.

The **Boulevard Lake (Current River) Water Management Plan** (2006) is the plan for waterpower for the dam and generating station at the south end of Boulevard Lake. This water management plan (WMP) sets out legally enforceable provisions for the management of flows and levels on this river within the values and conditions identified in the WMP. This plan does not authorize any other activity, work or undertaking in water or for the use of water, or imply that existing dams(s) meet with safe design, operation, maintenance, inspection, monitoring and emergency preparedness to provide for the protection of persons and property under the Lakes and Rivers Improvement Act.

The **Current River Flood Plain & Fill Line Mapping Study** (1979) was conducted to develop flood risk and fill line mapping for the study area as well as to investigate the feasibility and cost of methods of alleviating flooding associated with the Regional Design Storm (Timmins or 1 in 100 year flood flow). The study area covers approximately 700 metres of the Current River from the Boulevard Lake Dam to Lake Superior.

The **Current River Greenway Master Plan** (2000) outlines key legacy projects along the Current River corridor, in addition to defining management zones with different criteria, to link a series of open spaces into a major new ecotourism attraction.

The **Current River Spill Investigation** (1985) was conducted to assess the Current River spill area near Cumberland Street and develop remedial measures. The study updated past hydrologic assessments of the watershed to establish calibrated flows for the 5-, 10-, 25-, 50-, and 100-year and Regional storms. The streamflow gauge near Stepstone was used to perform a frequency analysis of regional flood flows. The study also updated the HEC-2 model used to develop flood plain maps in the 1979 report and recommended measures to mitigate future spill damage.

The **Detailed Discussion on Storm Drainage Facilities for the City of Fort William** (1965) investigated existing drainage issues and recommended a system of storm drainage facilities. A rainfall intensity duration curve was developed as part of the study and the 20-year return period was used in the design of the relief system. The impacts of high water levels in the Neebing River on the stormwater conveyance system were assessed.

The report on **Drainage Improvements for the Rosslyn Road and Neebing Avenue Areas** (1987) provides a review of drainage options for improving local drainage problem within the Rosslyn Road and Neebing Avenue areas.

The **Drainage Study of Fort William Indian Reserve No. 52** (1979) was conducted to address ongoing surface and subsurface drainage issues in Fort William Village. The study identified drainage improvements for the CNR, FWFN, and City lands along City Road between Quarry Road and northwest of Whisky Jack Creek. The alternatives were evaluated based on surface water interception, surface water removal, ability to lower pond levels, ability to control groundwater, and cost.

The **EarthWise Community Environmental Action Plan** (2008) provides an overview of the current thinking around sustainability and climate change. The plan also defines the objectives and recommended actions from each working group within EarthWise (now EarthCare, including the Water Working Group (WWG). The plan also provides an implementation framework and overall governance structure to guide the plan into a sustainable future.

The **Fisheries Management plan for Fisheries Management Zone 6** (2009) provides direction for the management of the fisheries resources within Fisheries Management Zone 6 (FMZ6). Management objectives and actions are presented to address specific fisheries management issues and challenges identified during the preparation of the background information document for FMZ6 (MNRF 2007).

The **Flood Control Study on Thunder Bay District** (date unknown) was completed by Confederation College to investigate the control of flood waters in the vicinity of the City of Thunder Bay (City) in the Neebing River. The report considered alternatives such as the Floodway, reservoirs in the watersheds upstream of the City, and diversion of the Neebing River into the Kaministiquia River using open channels or underground tunnelling. After determining that the Floodway was the best option, the report assessed the proposal for the channel and recommended it be realigned to cross through the Chapples Golf Course.

The **Fort William Drainage Study** (1979) was prepared to assess the drainage and shallow groundwater issues in the residential area of the Fort William First Nation and recommend improvements to the system.

The **Kaministiquia River Study** (1987) assessed the fish community and aquatic habitat of the Kaministiquia River. The results indicated that the lower nine kilometres of the river was severely degraded as a result of low rainfall, minimal flow rates, warm temperatures, depressed dissolved oxygen levels, and concentrated effluents entering the river.

The **Kaministiquia River System Water Management Plan** (2004) was prepared to support sustainable development of water resources for waterpower and other uses, while protecting and enhancing the natural ecosystems. The plan identifies flow and level compliance requirements for waterpower facilities and control structures.

The **Kaministiquia River Watershed Management Study** (1990) contains a review of existing water resource use and water management of the watershed and identifies and assesses options for water quantity management. This study includes the development of an action plan which includes recommendations for potential policy changes and additional data collection and analysis.

The **Lake Superior Lakewide Action and Management Plan, Annual Report** (2013) provides an update on accomplishments, challenges, and next steps for improvement projects on Lake Superior as part of the program.

The **Master Drainage Strategy Study for the City of Thunder Bay** (1987) evaluates potential impacts of future development on existing developed areas of six watersheds, including the Mosquito Creek, McVicar Creek, Neebing River, Pennock Creek, McIntyre River, and Current River watersheds, through the development of hydrologic models to compare existing and future peak flows. In addition, the study recommends remedial works to alleviate flooding problems in the South Ward area.

The **McIntyre River Adult Steelhead Study** (2014) quantitatively describes the changes in the steelhead population following the 1999 harvest regulations and describes the effects of environmental variables on wild steelhead.

The **McIntyre River Flood and Fill Line Mapping Study** (1985) was conducted to evaluate the flood potential of the McIntyre River for the Timmins Storm and the 5-, 10-, 25-, 50-, and 100-year return period floods and to map the lands vulnerable to flooding.

The purpose of the **Flood Line Mapping Study of Vicar's Creek** (1978) was to determine the land inundated as a result of the Regional Storm within the study area using a HEC-2 model.

**McVicar Creek Floodplain Study** (1995) describes the hydrology and hydraulic calculations required to estimate the Flood Plain limits and the slope stability investigations needed for locating the Fill and Construction Limits. This study used the OTTHYMO model to predict a wide range of flows along the creek. Corresponding water levels were computed using HEC-2 modelling.

**McVicar Creek Protection & Rehabilitation Plan** (2014) was developed to address issues related to Thunder Bay having been identified as an Area of Concern (AOC). The outcomes of this Plan are intended to ensure that gains realized through Remedial Action Plan (RAP) implementation are maintained and progress towards restoration and ultimate delisting of Thunder Bay as an AOC continues.

The **McVicar Creek Stewardship Program Phase 2 Report** (2007) details the public meetings held as part of the stewardship program in addition to recommendations from the process, such as the development of a Watercourse Protocol and a contact list for regulatory agencies based on their jurisdiction or authority.

**A Meteorological Analysis of the Thunder Bay Heavy Rain Event: May 28, 2012** (2012) summarizes the precipitation events that led to the May 28, 2012 extreme event and documents the forecasting and warnings that were given at the time of the event.

The **Mosquito Creek Flood and Fill Line Mapping Study** (1984) was developed to evaluate the floodplains of Mosquito Creek. This study evaluated the hydrologic response of the watershed under both the Regional and Timmins Storm and defines flows for various recurrence intervals varying between 5 and 100-year storms.

The **Neebing McIntyre Floodway Confluence Study** (2011) was conducted to assess the condition of the lower reach of the Floodway from the CPR tracks downstream of Fort William Road to the outlet in Thunder Bay Harbour. Based on a topographic survey and updated hydrologic/hydraulic analysis, the study found significant sediment accumulation throughout the channel that will increase water levels and could cause flood damage in the area around Memorial Avenue. The study recommended dredging in the near future to restore the channel to its design capacity and maintain the flood protection it is intended to provide. In addition, establishment of a regular sediment accumulation monitoring program and consideration for the installation of upstream sediment traps were recommended.

The **Neebing McIntyre Floodway Diversion Channel Drainage Investigation** (2003) was conducted to investigate the cause of surface water ponding within the Neebing/McIntyre Floodway Diversion Channel (Diversion Channel). The subsurface investigation included the installation of 20 boreholes at the site equipped with groundwater monitoring wells and five monitoring standpipes. A numerical two-dimensional steady-state groundwater flow model was developed using Visual Modflow (version 2.8) to simulate flow across the Diversion Channel. In addition, cross-sectional and longitudinal profiles of the Diversion Channel were surveyed. The study recommended confirmation of irrigation rates to the adjacent golf course and installation of a dewatering system constructed simultaneously with the regarding/cleaning of the Diversion Channel.

The **Neebing River Flood and Fill Line Mapping Technical Report** (1985) was developed to evaluate the floodplains of the Neebing River. This study evaluated the hydrologic and hydraulic response of the watershed using the HYMO Computer Model and HEC-2 under both the Regional Storm and defines flows for various recurrence intervals varying between 5 and 100-year storms. The HYMO model was calibrated using observed hydrographs from two storm events at the WSC gauging station 02AB008. Peak flows calculated in the calibrated model were also consistent with a Flood Frequency analysis.

The **Neebing River Study from Simpson Street to the Expressway** (1985) was conducted to assess the erosion, bank stability, and potential flooding problems. Peak flows were estimated for the Timmins Storm and the 2-, 5-, 10-, 25-, 50-, and 100-year return period floods using a flood frequency analysis. Flood line maps were then developed based on water levels calculated in a HEC-2 model.

The **Neighbourhood Master Stormwater Drainage Study** (2014) was conducted to assess the May 2012 flood in four neighbourhoods that experienced basement flooding and recommend infrastructure improvements to minimize future flooding events. The neighbourhoods included Northwood (north of Redwood Avenue), Intercity, East End (East of Simpson Street), and East End (West of Simpson Street). The analysis did not include sanitary sewer systems, combined sewer systems, and overland stormwater flow. The City undertook a new rainfall and flow monitoring program in 2013 to provide the data required for model calibration. The model assesses the 2-, 5-, 10-, and 25-year design storms.

**North Harbour Sediment Remediation Project** (2014) is a collaborative study involving Environment Canada and MOECC resulting from many studies ongoing since 2002. The project intends to remediate the 350,000 - 400,000 cubic metres of enriched organic sediment (EOS) currently sitting within the northern most section of the breakwall in Thunder Bay Harbour. The Mercury contaminated EOS does not behave like typical sediment and some specialized field work and analysis are required before proceeding to the next stage of remediation.

The **Pennock Creek Watershed Assessment Update** (2010) includes water quality analysis, as well as documentation of the physical and biological attributes of six planning locations. Water quality analysis completed for the 2010 assessment indicated that the Pennock Creek Watershed was in good condition, with minimal exceedances of the Provincial Water Quality Objectives at the time of sampling. The 2010 laboratory results reported three parameters, aluminium, iron and phosphorous, which exceeded PWQO criteria. Comparison of the 1996 and 2010 water quality results indicated that between the two study periods there has been negligible change to the water quality within the Pennock Creek Watershed.

The **Pennock Creek Flood Plain and Fill Line Mapping Study** (1982) was developed to evaluate the floodplains of Pennock Creek. This study evaluated the hydrologic response of the watershed for the Regional or Timmins Storm and defines flows for various recurrence intervals varying between 5 and 100-year storms.

The **Phase 1 Scoping Study for the Stormwater Management Plan** (2011) was undertaken to provide a preliminary assessment of the status of the City’s SWM infrastructure and servicing based on consultation with EarthCare’s Water Working Group (WWG). The study identifies problem and opportunity statements concerning the City’s SWM and summarizes the priorities.

**Policy Review of Municipal Stormwater Management in the Light of Climate Change – Summary Report** (no date) summarizes the review by the Ministry of Environment and Climate Change (MOECC) of the need for a new policy, Act or regulation to deal with municipal stormwater management systems in Ontario municipalities in light of climate change.

The **Recreation and Parks Master Plan** (2008) provided an overall framework to guide the provision of leisure programs, facilities, parks, and open space until 2018. The plan included broad strategies to address the priority outcomes and detailed action plans to achieve these strategies.

**Remedial Action Plan – Stage 1: Environmental Conditions and Problem Definition** (1991) presents background information such as biogeography and land and water uses, defines environmental problems, identifies the sources, and documents information gaps.

**Remedial Action Plan – Stage 2: Remedial Strategies for Ecosystem Restoration** (2004) describes remedial strategies identified in Stage 1 that are completed or currently underway, and outlines monitoring actions to measure the effectiveness of the remediation projects in meeting their designated goals. In addition, the report contains recommended actions to identify and remediate any remaining point and non-point sources which may be contributing to fish and wildlife related impairments and to fill baseline information gaps wherever possible.

**Remedial Action Plan DRAFT Re-designation Recommendation – Degradation of Aesthetics Beneficial Use Impairment** (2013) provides rationale and supporting documentation of completed remedial actions that have met the delisting criteria for degraded aesthetics and recommends re-designating the degradation of aesthetics beneficial use impairment to “not impaired”.

The **Report of the South End Storm Sewer System and Pumping Station** (1990) was completed to design the storm sewer and pumping system near the current location of the Third Avenue Drainage Channel for a 2-year storm to replace the previous the previous design based on the 10-year storm. The design flows were calculated using the IMPRAM (Improved Rational Method) computer program.

The **Report on Kaministiquia River Floodline Mapping, Lake Superior to Rosslyn Village** (1979) prepared flood and fill line mapping based on 100-year peak flows calculated based on a flood frequency analysis and hydraulic modelling in HEC-2.

The **Report on Study of Surface Drainage Planning Area West of Expressway and North of Highway 17** (1975) provides recommendations for drainage improvements in the planning area.

The **Report and Technical Discussion on Drainage in the South End for the City of Port Arthur** (1969) assesses drainage issues and flood control measures. The south end area includes about 2000 acres of land bounded on the west and south by the McIntyre River, on the east by Lake Superior and on the north by Oliver Road. It also includes about 500 acres north of Oliver Road extending from Algonquin Avenue to High Street, and reaching Van Norman Street. The impacts of high water levels in the McIntyre River on the stormwater conveyance system were assessed and improvements to the ditch and storm sewer system were proposed using the 2-year design storm.

The **Slate River Watershed Assessment Report** (2008) includes water quality analysis, as well as documentation of the physical and biological attributes, of seven sampling locations. Water quality analysis indicated that the Slate River Watershed was in good condition, however there were exceedances of the PWQOs for E. coli, aluminum, iron, copper, and phosphorous.

The **Stormwater Executive Summary** (2011) from EarthCare’s Water Working Group was included in the Scoping Study to describe the City’s progress on SWM improvements to date and provide input on the scope and purpose of the Stormwater Management Plan.

The **Stormwater Impacts Assessment of McVicar Creek, South Neebing River, and Lyons/Third Avenue Drainage Channels** (2011) was completed to assess the severity of impacts of stormwater or other diffuse sources of pollution and identify stormwater hot spots in three regions within the Thunder Bay AOC. The methodology included unified stream assessment (USA) to assess the physical attributes of the study areas, water quality sampling, and benthic analysis of McVicar Creek and Lyons/Third Avenue Channel.

The **Stormwater Impacts Assessment of McVicar Creek** (2012) involved an Urban Subwatershed Site Reconnaissance (USSR) methodology to further investigate stormwater hotspots on McVicar Creek identified in the Phase I assessment. The hotspots were outfalls at Court Street, Castlegreen, and County Fair.

**Stormwater Management Planning and Design Manual** (2003) released by the MOECC provides practical guidance on environmental planning, environmental design criteria, the development of stormwater management plans, operation, maintenance and monitoring of stormwater management techniques as well as capital and operational costs of these techniques.

The **Terms of Reference for New Marina and Pool 6 Lands Project** was prepared through an **Individual Environmental Assessment** (2010) to identify the preferred land use concept for these lands which will connect the redevelopment at Prince Arthur's Landing and the downtown.
**Thunder Bay Area Aquifer Characterization Groundwater Management and Protection Study Final Report** (2005) was developed to obtain a better understanding of the groundwater resources within the study area, characterize the hydrogeology of the area, inventory and assess potential contaminant sources, asses water use and groundwater vulnerability and make recommendations for groundwater protection strategies. The study area includes the jurisdiction of the LRCA plus some additional area to the north and west.

**Thunder Bay Native Fisheries Rehabilitation – Chronology of Development on the Current River** (2012) was prepared by the Ministry of Natural Resources and Forestry (MNRF) to outline the history of anthropogenic impacts on the Current River, with focus on the AOC.

The **Thunder Bay Pollution Prevention and Control Plan Phase 1 Report** (1995) identifies direct discharge points to receiving waters from the City's urban service area, determines the quantity and quality of discharges under dry and wet weather conditions, and identifies environmental impacts on receiving waters.

The **Thunder Bay Pollution Prevention and Control Plan Phase 2 Report** (1999) evaluates pollution prevention and control strategies. This document includes and implementation plan addressing short and long term control objectives and servicing needs of the City. Development of the implementation plan (pollution prevention and control measures) included consideration of the following: community standards, regulatory requirements, collection system management, receiving water quality, and cost effectiveness.
The **Thunder Bay Waterfront Storm Sewer Discharge Survey Water and Sediment Study** (2000) to evaluate how drainage and runoff from the urban/industrial area of the City could potentially affect water and sediment quality along the waterfront.

The **Trowbridge Forest Stewardship Plan** (date unknown) developed goals, objectives and strategies to provide the long-term direction for maintaining the environmental and social benefits provided by the forest.

The **Wet Weather Flow Management in the Great Lakes Areas of Concern** (2005) describes the Municipal Wastewater Program of the Great Lakes Sustainability Fund and progress thus far towards addressing the Great Lakes Areas of Concern.

The **Whitefish River Fill Line Study** (1985) was conducted to delineate fill lines based on hydrologic and hydraulic analysis extending from the Whitefish River confluence with the Kaministiquia River to the Highway 588 bridge near Nolalu. Flows in the river were simulated using the OTTHYMO computer model for the Timmins storm, 100-year storm, and the 1977 storm. Although the 1977 storm resulted in greater peak flows, the study recommended the Timmins storm be used for generating flood and fill line maps. Hydraulics were modelled in HEC-2.

The results from the **Workshop on Stormwater Remediation Options along McVicar Creek** (2012) were prepared for the EarthCare WWG in partnership with Lakehead University and the North Shore RAP.

## APPENDIX B Land Use Determination

**Table 1. Simplification of Zoning Categories for Land Use Determination**

| Original Land Uses Designated by City Zoning | | Simplified Categories for Land Use Determination | |
|---|---|---|---|
| ZONE_ID | ZONE_DESC | LC_CODE | LC_DESC |
| AP | Airport Zone | 2 | Airport |
| C1 | Urban Village Zone | 4 | Commercial |
| C2 | Urban Centre Zone | 4 | Commercial |
| C3 | Highway Commercial Zone | 4 | Commercial |
| C4 | Arterial Commercial Zone | 4 | Commercial |
| C5 | Central Business District Zone | 4 | Commercial |
| C6 | Regional Centre Zone | 4 | Commercial |
| EP | Environmental Protection Zone | 6 | Environmental Protection |
| FD | Future Development Zone | 10 | Future Development |
| IN1 | Light Industrial Zone | 5 | Industrial & Utilities |
| IN2 | Medium Industrial Zone | 5 | Industrial & Utilities |
| IN3 | Heavy Industrial Zone | 5 | Industrial & Utilities |
| IN4 | Extractive Industrial Zone | 5 | Industrial & Utilities |
| IN5 | Utilities and Services Zone | 5 | Industrial & Utilities |
| IN6 | Prestige Industrial Zone | 5 | Industrial & Utilities |
| MI | Major Institutional Zone | 3 | Major Institutional |
| MU1 | Mixed Use Zone 1 | 8 | Residential |
| MU2 | Mixed Use Zone 2 | 8 | Residential |
| MU3 | Mixed Use Zone 3 | 8 | Residential |
| MU3 | Mixed Use Zone 3 | 8 | Residential |
| MU3 | Mixed Use Zone 3 | 8 | Residential |
| MU3 | Mixed Use Zone 3 | 8 | Residential |
| MU3 | Mixed Use Zone 3 | 8 | Residential |
| MU3 | Mixed Use Zone 3 | 8 | Residential |
| MU3 | Mixed Use Zone 3 | 8 | Residential |
| MU3 | Mixed Use Zone 3 | 8 | Residential |
| NC1 | Neighbourhood Centre One Zone | 8 | Residential |
| NC2 | Neighbourhood Centre Two Zone | 8 | Residential |
| NC2 | Neighbourhood Centre Two Zone | 8 | Residential |
| NC3 | Neighbourhood Centre Three Zone | 8 | Residential |
| OS | Open Space Zone | 7 | Open Space |
| R1 | Residential Zone 1 | 8 | Residential |
| R2 | Residential Zone 2 | 8 | Residential |
| R3 | Residential Zone 3 | 8 | Residential |
| R4 | Residential Prefabricated Dwelling Zone | 8 | Residential |
| R5 | Residential Future Zone | 8 | Residential Future |
| RU1 | Rural Area Zone | 1 | Rural |
| RU2 | Rural Residential Zone | 9 | Rural Residential |
| WD | Waterfront Zone | 4 | Commercial |

## APPENDIX C Public Participation & Consultation Plan

The Consultation Plan was used to engage a variety of stakeholders in the Stormwater Management Plan development process. The goal of this Consultation Plan is to develop a method (or series of methods) for educating the public about stormwater impacts and stormwater management, identifying public concerns and values, developing consensus among affected parties, and producing cost-effective solutions through an open, inclusive process. While the City of Thunder Bay (City) acknowledges its role in providing and maintaining the infrastructure required for successful stormwater management, it would like to see more community-based solutions being implemented in partnership with the City's efforts. To this end, the Consultation Plan included the following:

Although extensive community and stakeholder consultation was completed including regulatory agencies, special interest groups, Aboriginal communities and City staff as detailed in Appendix C, the SMP was not done in accordance with the formal Municipal Class Environmental Assessment (MCEA) process. However the document provides baseline data and some alternatives assessment that can be used to support MCEA approvals that will be required going forward. As individual projects recommended in the SMP are planned and implemented, the City will undertake formal environmental assessments as required under the MCEA.

All projects will be reviewed to identify the appropriate Class EA Schedule requirements prior to any planning or design work being undertaken. In general it is understood that the following project types and schedules will, at a minimum, be considered for implementation of the SMP:

- Schedule A Projects: are limited in scale, have minimal adverse environmental effects and include a number of municipal maintenance and operational activities. Projects are pre-approved and may proceed without following the Class EA. *Project example: establish new or replace or expand existing stormwater detention/retention ponds or tanks and appurtenances including outfall to receiving water body provided all such facilities are in either an existing utility corridor or an existing road allowance where no additional property is required.*
- Schedule A+ Projects: Projects are pre-approved and may proceed without following the Class EA however, the public is to be advised prior to project implementation. *Project example: modify, retrofit, or improve a retention/detention facility including outfall or infiltration system for the purpose of stormwater quality control. Biological treatment through the establishment of constructed wetlands is permitted.*

- Schedule B Projects: have the potential for some adverse environmental effects. The proponent is required to undertake a screening process involving mandatory contact with directly affected public and relevant review agencies, to ensure that they are aware of the project and that their concerns are addressed. If there are no outstanding concerns, then the proponent may proceed to implementation. Schedule B projects generally include improvements and minor expansions to existing facilities. *Project examples: Construct a stormwater control demonstration or pilot facility for the purpose of assessing new technology or procedures, establish stormwater infiltration system for groundwater recharge, and establish new stormwater retention/detention ponds and appurtenances or infiltration systems including outfall to receiving water body where additional property is required.*
- Schedule C Projects: projects have the potential for significant environmental effects and must proceed under the full planning and documentation procedures specified in the Class EA. Schedule C projects require that an Environmental Study Report be prepared and filed for review by the public and review agencies. Schedule C projects generally include the construction of new facilities and major expansions to existing facilities. *Project example: Construct new or modify, retrofit or improve existing retention/detention facility or infiltration system for the purpose of stormwater quality control where chemical or biological treatment or disinfection is included, including outfall to receiving water body.*

The schedule of meetings that took place over the course of the Consultation Plan is illustrated in Table 2.

## 1 Steering Committee

The Steering Committee held 20 meetings with the consultant over the course of the project. The Committee was composed of the following representatives of City Divisions with roles and responsibilities related to stormwater management:

- Dave Dutchak, Infrastructure and Operations-Environment – Project Manager
- Aaron Ward, Engineering & Operations – Project Engineer
- Brad Adams, Engineering & Operations – Roads Manager
- Darrell Matson, Infrastructure & Operations – General Manager
- Kathy Walkinshaw, Central Support Supervisor, Customer Services
- Kayla Dixon, Engineering & Operations – Engineering Director
- Kerri Marshall, Infrastructure & Operations – Environment Director / General Manager
- Kris Ketonen, Central Support Communications Officer
- Leslie McEachern, Development and Emergency Services – Planning Services Division Director
- Pat Mauro, Infrastructure & Operations – Director - Engineering
- Sarah Kerton, Infrastructure & Operations – Sustainability Coordinator
- Wendy O’Connor, Central Support – Website Communications Coordinator
- Werner Schwar, Infrastructure & Operations-Parks and Open Spaces – Supervisor
- Numerous additional staff also participated in multiple Division Staff meetings

**Table 2. Consultation Meeting Schedule**

| | 2014 | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | April | | | | | May | | | | | June | | | | | July | | | | |
| | 1-4 | 7-11 | 14-18 | 21-25 | 28-30 | 1-2 | 5-9 | 12-16 | 19-23 | 26-30 | 2-6 | 9-13 | 16-20 | 23-27 | 30 | 1-4 | 7-11 | 14-18 | 21-25 | 28-31 |
| Steering Committee | | ● | | | | | | | | | | ● | | | | | | | | |
| Public Input | | | | | | | | | | | | | | | | | | | | |
| On-going Team Meetings | | | | | | | | | | | | | | | | | | | | |
| Special Interest Group | | | | | | | | | | | | | | | | | | | | |
| Division(s) Staff [(1)] | | | | | | | | | | | | 2/3 ● | | | | | | | | |
| Aboriginal Communities | | | | | | | | | | | | | | | | | | | | |

| | 2014 | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | August | | | | | September | | | | | October | | | | | November | | | | December | | | | |
| | 1 | 4-8 | 11-15 | 18-22 | 25-29 | 1-5 | 8-12 | 15-19 | 22-26 | 29-30 | 1-3 | 6-10 | 13-17 | 20-24 | 27-31 | 3-7 | 10-14 | 17-21 | 24-28 | 1-5 | 8-12 | 15-19 | 22-26 | 29-31 |
| Steering Committee | | | ● | | | | | ● | | | | | | | | | | | | | | | | |
| Public Input | | | | | | | | ● | | | | | | | | | | | | | | | | |
| On-going Team Meetings | | | | | | | | | | | | | | | | | | | | | | | | |
| Special Interest Group | | | | | | | | ● | | | | | | | | | | | | | | | | |
| Division(s) Staff [(1)] | | | | | | | | (4) ● | | (4) ●●● | | | | | | | | | | | | | | |
| Aboriginal Communities | | | | | | | | | | (5) ● | | | | (5) | (5) ●● | | | | | | | | | |

| | 2015 | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | January | | | | | February | | | | March | | | | | April | | | | |
| | 1-2 | 5-9 | 12-16 | 19-23 | 26-30 | 2-6 | 9-13 | 16-20 | 23-27 | 2-6 | 9-13 | 16-20 | 23-27 | 30-31 | 1-3 | 6-10 | 13-17 | 20-24 | 27-30 |
| Steering Committee | | | | | | ● | | | | | ● | | | | | | | | |
| Public Input | | | | | | | | | | | ● | | | | | | | | |
| City Council Non-business | | | | | | | | | | | ● | | | | | | | | |
| Special Interest Group | | | | | | (6) ●●● | | | | | ● | | | | | | | | |
| Division(s) Staff [(1), (3)] | | | | | | ●●●●● | | | | | | | | | | | | | |
| Aboriginal Communities | | | | | | ● | | | | | | | | | | | | | |

| | 2015 | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | May | | | | | June | | | | | July | | | | | August | | | | | September | | | | |
| | 1 | 4-8 | 11-15 | 18-22 | 25-29 | 1-5 | 8-12 | 15-19 | 22-26 | 29-30 | 1-3 | 6-10 | 13-17 | 20-24 | 27-31 | 3-7 | 10-14 | 17-21 | 24-28 | 31 | 1-4 | 7-11 | 14-18 | 21-25 | 28-30 |
| Steering Committee | | | | | | | | | | | | | | | | | | | | | | | | | |
| Public Input | | | | | | | | | | | | | | | | | | | | | | | | | |
| City Council Non-business | | | | | | | | | | | | | | | | | | | | | | | | | |
| Special Interest Group | | | | | | | | | | | | | | | | | | | | | | | | | |
| Division(s) Staff [(1), (3)] | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aboriginal Communities | | | | | | | | | | | | | | | | | | | | | | | | | |

| | 2015 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | October | | | | | November | | | | | December | | | | |
| | 1-2 | 5-9 | 12-16 | 19-23 | 26-30 | 2-6 | 9-13 | 16-20 | 23-27 | 30 | 1-4 | 7-11 | 14-18 | 21-25 | 28-31 |
| City Council Presentations | | | | | | | | | | | | | | | |
| Aboriginal Communities | | | | | | | | | | | | | | | |

| | 2016 | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | January | | | | | February | | | | | March | | | | | April | | | | | May | | | | | June | |
| | 1 | 4-8 | 11-15 | 18-22 | 25-29 | 1-5 | 8-13 | 15-19 | 22-26 | 29 | 1-4 | 7-11 | 14-18 | 21-25 | 28-31 | 1 | 4-8 | 11-15 | 18-22 | 25-29 | 2-6 | 9-13 | 16-20 | 23-27 | 30-31 | 1-3 | 6-10 |
| City Council Presentations | | | | | | | | | | | | | | | | | | | | | ● | | | | | | ● |
| Aboriginal Communities | | | | | | | | (7) ● | (8) ● | | | | | | | | | | | | | | | | | | |

● = Meetings at Thunder Bay

**(1):** Key Divisions: Engineering, Environmental, Roads, Planning and Parks
**(2):** All Divisions at once
**(3):** Small Groups Meetings
**(4):** Additional Meetings with Division Staff: Planning (9/15-19), Environment, Parks & Roads (9/29-30)
**(5):** Northern Ontario First Nations Env. Conference, Conference call w/ Ann Magiskan, 2 mtgs with FWFN
**(6):** Developers Breakfast + EarthCare Advisory Committee meeting + Climate Change Adaptation
**(7):** FWFN (Band Office) – City Representatives, Ian Banning and Michael Pelletier (2/19)
**(8):** Red Sky (Metis Independent Nation) – City Representatives, Dean Whellan and Donelda Laronde (2/22)

## 2 City Council

Development of the Stormwater Management Plan involved engaging City Council via one non-business meeting as well as two regularly scheduled meetings. The non-business meeting was held with the City Council on March 9th, 2015 to inform Council Members about the project and the public input process. The role of the City Council was to:

- Provide input on public presentations so changes could be made in advance of public meetings;
- Share their stormwater management issues and priorities for implementation and the Capital Improvement Program; and
- Approve both the draft and final version of the Stormwater Management Plan.

## 3 City Division Staff Meetings

Three sets of meetings were held with the City Divisions to obtain more technical input regarding City policies and programs (see Table 1). The first meeting was held with all Division heads and supervisors. The second and third sets of meetings were held with key Division staff in a small group discussion format, totalling approximately ten meetings.

## 4 Public Meetings

Anyone with an interest in stormwater, surface water, groundwater and/or watershed management were welcome to participate in the plan development process. To reach as many members of the public as possible, the City used a number of techniques to engage the public centred around two Public Open Houses and two Special Interest Group Meetings. In addition, the City utilized resources developed in previously implemented Consultation Plans. For example, the City developed a list during the development of the Comprehensive Solid Waste Management Strategy which includes the email addresses of individuals interested in being contacted by the City for future planning efforts. These individuals were asked to participate in the Stormwater Management Plan development process.

### 4.1 Special Interest Group

A series of two meetings were held with the Special Interest Group. As Table 2 illustrates these meetings took place in September of 2014 and March of 2015. The topics for these meetings generally followed the topics of the Public Open House but the level of discussion was more technical in nature.

The following agencies, organizations and individuals were identified by the Project Steering Committee and EarthCare to participate in the Special Interest Group. The role of this group was to share technical information, provide technical review, and let the Project Steering Committee and Project Consultant know of any opportunities to further engage the public via stormwater management related activities in the community.

| | |
|---|---|
| - EarthCare Water Working Group | Brad Doff, EarthCare Coordinator |

| | |
|---|---|
| | Curniss McGoldrick, Climate Adaptation Coordinator<br>Gail Willis, Chair |
| - EcoSuperior | Ellen Mortfield, Manager<br>Jamie Sauders, Program Coordinator<br>Lucie Lavoie, Program Coordinator |
| - Environment Canada | Sara Varty |
| - First Nation Members | Ann Magiskan, City's Aboriginal Liaison |
| - LRCA | Tammy Cook, Watershed Manager |
| - Lakehead University | Rob Stewart, Professor of Geography |
| - Ministry of Environment and Climate Change | Michelle McChristie<br>Steven Hunsberger |
| - Ministry of Natural Resources and Forestry | Jeff Black |
| - Ministry of Transportation | Cindy Brown, Head of Transportation |
| - Northshore Remedial Action Plan | Jim Bailey, Remedial Action Plan Coordinator |
| - Northshore Steelhead Association | Frank Edgson |
| - Thunder Bay District Health Unit | Lee Sieswerda, Epidemiologist |

Three additional meetings were held with other Special Interest Groups in February, including representatives from the Thunder Bay development community, the EarthCare Advisory Committee, and the Climate Change Adaptation consultants and City project manager.

## 4.2 Public Open House and Engagement

Two Public Open House Meetings were held over the course of this project. As Table 2 illustrates, these meetings took place in September of 2014 and March of 2015. Each meeting was held from 3:00 p.m. to 8:00 p.m. to facilitate greater participation from the public. A 20 minute presentation was given twice during the 5-hour meeting time: once at 3:30 p.m. and again at 6:30 p.m. For the remainder of the time, participants reviewed storyboards and GIS files explaining the project, issues and potential solutions and engaged with the Project Consultants and City Staff.

### *Thunder Bay Website and Feeds to Social Media*

The goal of the Municipal website was multifaceted:

- to reinforce the project brand which establishes, maintains and communicates to stakeholders a clear, consistent and compelling vision of project purpose, goals and benefits;
- to provide information on the plan development process as well as individual components of the plan;
- to solicit feedback on stormwater management issues, potential implementation activities (i.e. Low Impact Development/Green Infrastructure techniques), and plan content;
- to advertise opportunities for stakeholder engagement; and
- to post comments, queries or recommendations received to date.

The municipal website was refreshed on a regular basis and had a dedicated email address. Social media (Twitter and Facebook) were used for regular dissemination of information.

### *Articles in Citizen Newsletter – MYTBAY*

A total of six articles for inclusion in MYTBAY were developed by the City to educate the public about stormwater management, the plan development process, and let people know how they can participate in the process.

### *Pamphlet*

The City developed a pamphlet that described the project, how individuals can get involved and contact information for the City. This pamphlet was distributed at the Public Open Houses, in the City's newsletter (MYTBAY) and at public facilities such as libraries, community centres, local coffee shops, etc.

### *Surveys*

Two surveys were developed during the plan development process: each to coincide with the Public Open House meetings. The first survey was available at the Public Open House meeting and on the City's website. The purpose of the first survey was to gage the public's knowledge of stormwater, its impacts to downstream resources and the built environment and to identify people's top stormwater management concerns. The purpose of the second survey collected on the Story Boards at the second Public Open House was to gage the public's preferences for the types of stormwater management solutions they want to be implemented in their neighbourhood.

Eighty-five responses were received from the first survey, of which 95% of participants said they lived in Thunder Bay. Thunder Bay residents care strongly about protecting water quality (67%) and improving flood management (70%). These priorities align with the community's primary concerns of surface water quality (61%) and ecological function (48%). When asked to list their top three educational topics from a list of 13, participants expressed the most interest in Low Impact Development (LID) (52%), storm drains (45%), and groundwater impacts of surface water management (36%). Other popular LID topics included rainwater harvesting and integrating native plants into stormwater management. Thunder Bay residents are more concerned with flooding and drainage control than impacts of runoff to Lake Superior or erosion caused by construction. The majority of residents surveyed feel the City should improve stormwater quality by fixing existing stormwater structures and increasing maintenance of the overall stormwater system.

### 4.3 Aboriginal Communities

Over the course of the plan development process, the City made numerous efforts to engage the Aboriginal communities including executive members and the urban population. The Stormwater Survey was distributed by the City's Aboriginal Liaison Office to their local First Nation, Métis, and Aboriginal Community contact list. The City and/or consulting team attended the Northern Ontario First Nations Environment Conference and met one on one with the Fort William First Nation and Red Sky Metis Nation on at least one occasion to discuss the SMP and consultation processes going forward as projects are implemented. Metis Nation of Ontario was also contacted by letter and phone to discuss the SWP and will be included in consultation for individual project implementation going forward that impact their members.

### 4.4 Development Community

The City hosts an annual breakfast to gather the local development community, including land developers/owners, planners, architects and other members of the Design/Build community for the purpose of receiving their general concerns on development in Thunder Bay. In recent years, the City has taken the opportunity to present new changes, requirements, etc. to the development community as it related to existing or proposed development activity. On February 5, 2015 the Project Consultant made a presentation on the Stormwater Management Plan to the development community at the Developer's Breakfast. Following the presentation, there was active discussion with meeting participants about the City's approach to stormwater management and recommendations for updates to the Engineering and Development Standards.

# APPENDIX D Model Development

## 1 Introduction

Hydrologic and hydraulic models were developed as part of the City's Stormwater Management Plan (SMP) to provide insight into stormwater management challenges at the watershed and local scale. Base Models were developed for seven watersheds within the City, including the watersheds of the Current River, McVicar Creek, McIntyre River, Neebing River, Pennock Creek, Kaministiquia River, and Mosquito Creek shown in Figure 1. A Feasibility-Level Model was also developed for the Northwest Arterial Golf Links neighbourhood shown in Figure 2 (hereafter referred to as the Golf Links Study Area) identified by the SMP Steering Committee as an area where impacts of stormwater are expected due to future development. This technical memorandum describes the background, model development, results, and recommendations of each model.

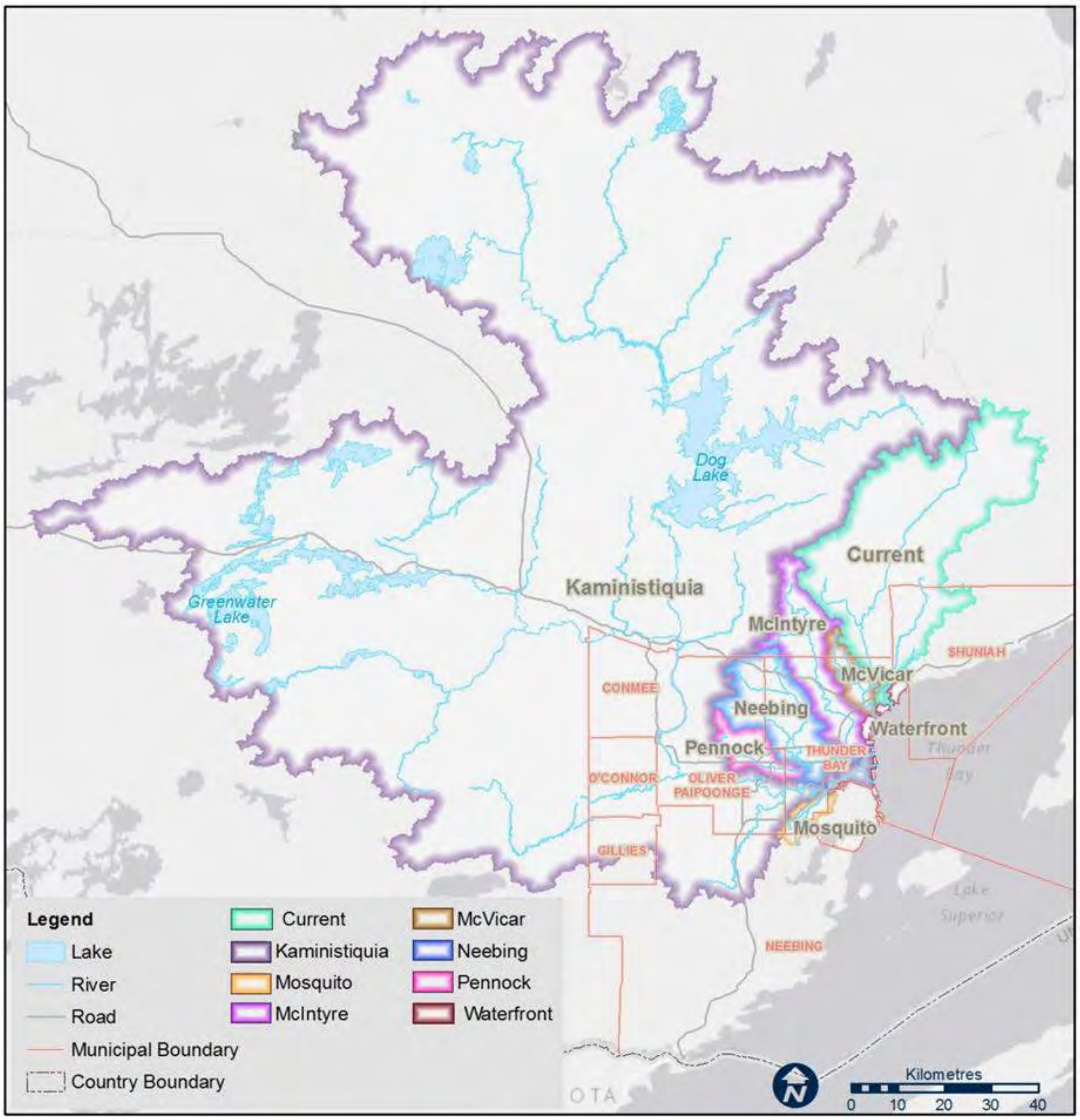


**Figure 1. Watershed Location Map**

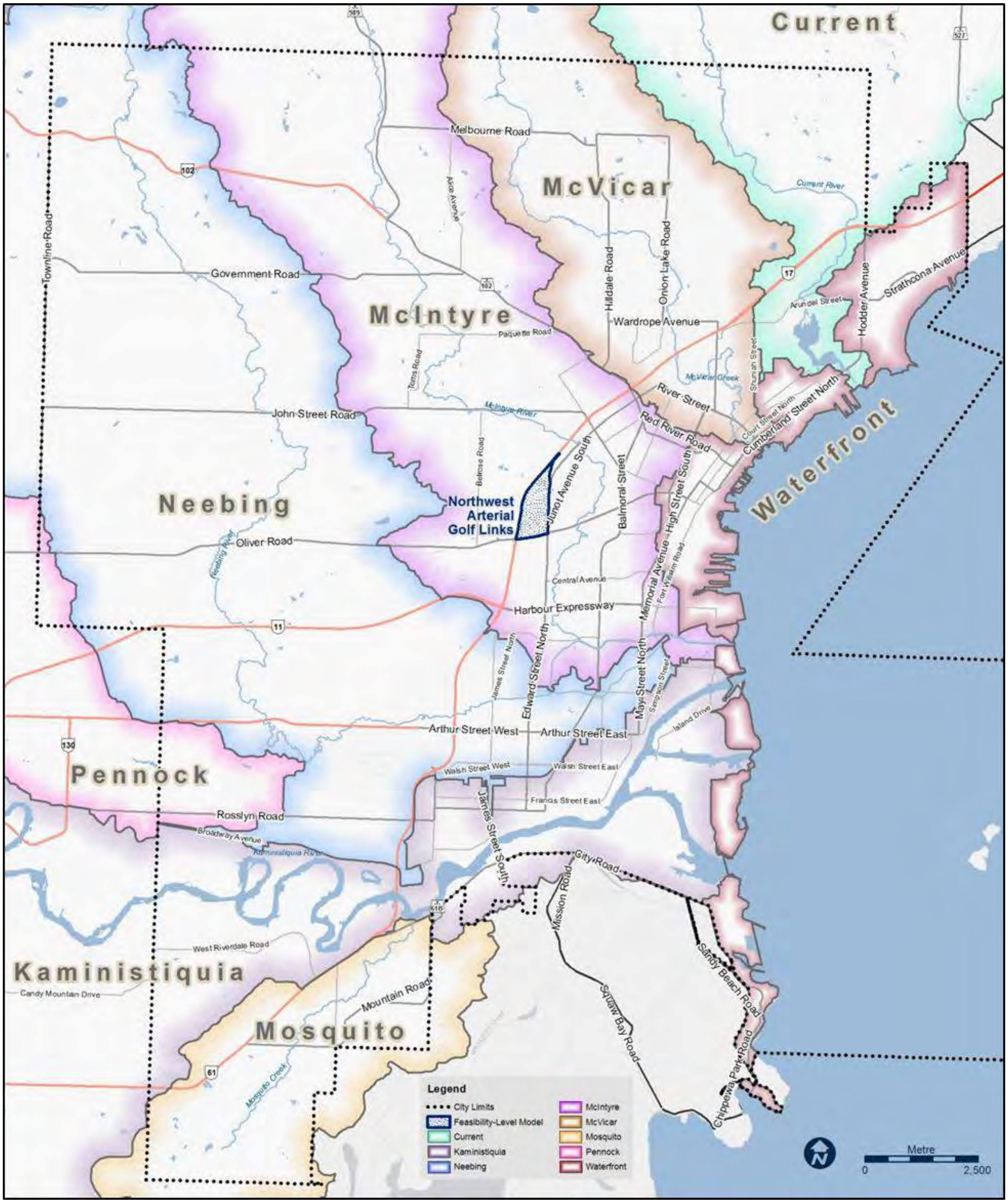


**Figure 2. Watershed and Feasibility-Level Model Study Area Location Map**

Detailed maps of the watersheds are provided in Volume 3 of the SMP, including subwatershed maps (Maps 55 to 61) existing land use maps (Maps 62 to 68) and future land use maps (Maps 69 to 75).

## 1.1 Objectives

The objective of the model development was to update the City's existing models to better describe and evaluate all watersheds in the City, identify problem areas where environmental impacts from stormwater are known or expected and develop recommendations to address these problem areas. The models were also developed to lead to recommendations regarding standards, policies, and priorities for future infrastructure investments, and new stormwater measures in the SMP.

## 1.2 Scope

This project included the evaluation of seven watersheds in the City using Base Models. An eighth watershed in the City, the Waterfront Watershed, encompasses all other areas within the City that drain directly to Lake Superior and was included in the scope of this plan. In addition, the expected future stormwater management challenges faced by future development in the Northwest Arterial Golf Links neighbourhood were evaluated in more detail using a Feasibility-Level Model. The effectiveness of the City's existing stormwater management infrastructure at reducing the negative impacts of stormwater on the environment was evaluated, including reduction of peak flows, flooding, erosion, and contaminant loadings.

### 1.2.1 Base Models

The seven watershed Base Models were developed in a new modelling platform, PCSWMM, to expand the usefulness of the City's current models. The Base Models include updated model input data since the past modelling efforts completed in the 1970's and 80's as part of the LRCA flood and fill line mapping studies (using HEC-2 and flood frequency analyses) and the Master Drainage Study (using HEC-RAS and OTTHYMO).

The Base Models were developed to evaluate the following features in each of the seven major watersheds:

- Major natural conveyance facilities (e.g. creeks, ravines and channels)
- Major culverts and bridges (major water crossings)
- Significant elements of minor tributaries to major natural conveyance facilities.
- Regional man-made stormwater storage facilities (e.g. ponds, dams, etc.)
- Major natural stormwater storage facilities (wetlands, lakes, etc.)

### 1.2.2 Northwest Arterial Golf Links Feasibility-Level Model

The more detailed Feasibility-Level Model of the Golf Links Study Area was developed to compare the impacts of stormwater management facilities designed with different development approaches to the urban expansion planned in the neighbourhood. The results of the Feasibility-Level Model were used to complete an analysis of the costs and benefits of different development scenarios, including the following aspects:

- Peak flow and runoff volume
- Pollutant loadings, including total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN)
- Capital and operation and maintenance costs of infrastructure

# 2 Base Models

A Base Model was developed for seven watersheds in the City, including those of the Current River, McVicar Creek, McIntyre River, Neebing River, Pennock Creek, Kaministiquia River, and Mosquito Creek. The Base Models are a step towards building a detailed understanding of the watershed systems in Thunder Bay. The models were developed in the current modelling platform of PCSWMM using the available information, including GIS data and past technical studies, to represent existing and future conditions scenarios. Each model includes a coarse division of subwatersheds, the major watercourse and tributaries, and the major watercourse crossings. Due to significant limitations in the available structural and monitoring information, the models cannot be immediately used to assess the specific hydraulics of infrastructure, such as culverts and bridges. Nevertheless, the models do provide useful hydrological information that can be used as an initial baseline for evaluation. It is recommended that, in the future, the City incorporates additional details and monitoring results in the Base Models to ultimately develop Comprehensive Watershed Management Models. This section details the Base Model development and a framework for continued model upgrades into Comprehensive Watershed Management Models, including the recommendations for additional data collection and calibration.

## 2.1 Model Development

The model development process included the following tasks:

1. Collection of Geographic Information System (GIS) files, bridge and culvert data, and the latest hydrologic and hydraulic models of the watersheds.
2. Delineation of the subcatchments using ArcSWAT and verification.
3. Importation of GIS into PCSWMM.
4. Revision of subcatchment delineation in PCSWMM.
5. Parameterization of data inputs.
6. Basic verification of the model results using observed flows.

### 2.1.1 Data Collection

Input data for the model construction included GIS data, monitoring data, and information from past technical reports and models. GIS data was provided in shapefile and raster dataset formats from a variety of sources as summarized in Table 3. The data provided by the City was within the municipal boundary therefore additional data was gathered from provincial sources.

Monitoring data was collected from provincial, federal, and conservation authority monitoring programs, including flow, water level, precipitation, and temperature. Water Survey of Canada monitoring stations are operated in collaboration with the Lakehead Region Conservation Authority (LRCA) to record flows on an hourly basis and monitor rainfall in a tipping bucket rain gauge with 15 minute intervals. Precipitation data at the three Thunder Bay Airport stations were obtained in varying time intervals and were processed into hourly intervals for consistency. Lake level measurements were provided in 1 hour intervals from the Department of Fisheries and Oceans. Ontario Power Generation also provided daily and hourly flow and level records for the three dams and two hydroelectric generating stations in the Kaministiquia Watershed. A summary of the monitoring data is provided in Table 4.

**Table 3. GIS Data**

| Data Category | Source | Notes |
|---|---|---|
| **Watershed** | Land Information Ontario | Quaternary and tertiary watersheds |
| **Watercourses and Waterbodies** | City | |
| | National Hydro Network | |
| **Wetlands** | MNRF | |
| **Bridges and culverts** | City | No information on invert or size |
| **Ditch** | City | |
| **Soils** | Land Information Ontario | Provincial soils mapping with gaps in the upper Current River and Kaministiquia River watersheds |
| **Land Use** | City | Proposed land use from City's official plan |
| | Provincial | Provincial Land Cover |
| **Roads** | City | |
| | National Roads Network | |
| **Railway** | National Railway Network | |
| **Contours** | City | 1 m contours |
| | Land Information Ontario | 10 m contours within ECO Regions 7 and 11 |
| **Digital Elevation Model (DEM)** | City | 15 m grid |
| | Canadian Digital Elevation Data | 10 m grid |
| **Air Photo** | City | 2012 |

**Table 4. Precipitation, Flow, and Water Level Monitoring Stations**

| Watershed | Station Name | Number *(LRCA ID)* | Data* | Drainage Area ($km^2$) |
|---|---|---|---|---|
| **Current River** | Current River at Stepstone | 02AB021 *(32)* | P/F/L | 392 |
| | North Current River | 02AB014 *(33)* | P/F/L | 111 |
| **McVicar Creek** | McVicar Creek at Thunder Bay | 02AB019 *(30)* | P/F/L | 46 |
| **McIntyre River** | McIntyre River above Thunder Bay | 02AB020 *(45)* | P/F/L | 90 |
| **Neebing River** | Neebing River near Intola | 02AB024 *(58)* | P/F/L | 40 |
| | Neebing River near Thunder Bay | 02AB008 *(29)* | P/F/L | 187 |
| | Thunder Bay CS | 6048268 | P/C | n/a |
| | Thunder Bay A | 6048262 | P/C | n/a |
| | Thunder Bay | 6048260 | P | n/a |
| **Pennock Creek** | None | n/a | n/a | n/a |
| **Kaministiquia River** | Kaministiquia River at West Fort William | 02AB025 | L | 8111 |
| | Kaministiquia River above West Fort William | 02AB026 | L | 8101 |
| | Slate River near Thunder Bay | 02AB023 *(57)* | P/F/L | 180 |
| | Corbett Creek near Murillo | 02AB022 *(34)* | P/F/L | 43 |
| | Kaministiquia River at Kaministiquia | 02AB006 | P/F/L | 6475 |
| | Whitefish River at Nolalu | 02AB017 *(31)* | P/F/L | 210 |
| | Kakabeka Falls Generating Station | n/a | F/L | 6759 |
| | Silver Falls Generating Station / Dog Lake Dam | n/a | F/L | 3406 |
| | Kashabowie Lake Dam | n/a | F/L | 526 |
| | Greenwater Lake Dam | n/a | F/L | 174 |
| | Shebandowan Lake Dam | n/a | F/L | 1172 |
| **Mosquito Creek** | None | n/a | n/a | n/a |
| **All** | Lake Superior at Thunder Bay | 100050 | L | n/a |
| | Welcome Island (AUT) | 6049443 | P | n/a |

* P = Precipitation, F = Flow, L = Water Level, C = Climate

The City also provided Municipal Structure Inspection Forms (2010) which included dimensions and photographs of bridges and culverts larger than 3 m. Copies of these reports and photos are included in the documentation of the models.

Where appropriate, information from technical reports and hydrologic and hydraulic models was incorporated into the Base Models. Some studies provided by the City and LRCA had incomplete information regarding the models and copies of the models could not be located or accessed due to outdated platforms. The following reports were reviewed for information applicable to the Base Models:

- Master Drainage Study (1987)
- Neighbourhood Master Stormwater Drainage Study (2014)
- Flood Plain and Fill Line Mapping of Current River (1979)
- Current River Spill Investigation (1985)
- Boulevard Lake (Current River) Water Management Plan (2006)
- Flood Line Mapping Study: McVicar Creek (1978)
- McVicar Creek Floodplain Study (1995)
- McIntyre River Flood and Fill Line Mapping Study (1985)
- Neebing McIntyre Floodway Diversion Channel Drainage Investigation (2003)
- Neebing McIntyre Floodway Confluence Study (2011)
- Neebing River Flood and Fill Line Mapping Technical Report (1985)
- Pennock Creek Watershed Update (2010)
- Pennock Creek Flood Plain and Fill Line Mapping Study (1982)
- Slate River Watershed Assessment Report (2008)
- Whitefish River Fill Line Study (1985)
- Kaministiquia River Watershed Management Study (1990)
- Kaministiquia River System Water Management Plan (2004)
- Report on Kaministiquia River Floodline Mapping: Lake Superior to Rosslyn Village (1979)
- Mosquito Creek Flood and Fill Line Mapping Study (1984)

#### *2.1.1.1 Data Gaps*

Data gaps were identified in the information used in the development of all the models, in addition to gaps identified for specific watersheds. Overall the gaps analysis demonstrates that an insufficient extent and quality of information is available to quantitatively assess infrastructure and the impacts climate change is having locally in the Base Models. As a result, Section 2.4includes recommendations for collecting data, and developing the tools that will provide the City with the information needed to better manage its infrastructure and resources. To compensate for quantity and quality of baseline information, assumptions were made regarding the hydrologic and hydraulic system which limits the ability of the assessments to define the needs in the watershed systems and actions required to address these needs.

The following gaps in topographic, infrastructure, monitoring, and past modelling information were identified in all watersheds in addition to watershed-specific data gaps:

***Topography***

The DEMs provided by the City and Canadian Digital Elevation Data have low horizontal resolutions (15 m and 10 m grids respectively), and low vertical resolution of 1 m intervals. Both appear to have been created using City and Ontario Base Mapping contours. The City’s 1 m contours do not include all hydraulic structures.

***Land Use and Land Cover***

No GIS shapefiles identify the existing land use in the City and the future land use separately with the same level of detail. Both the zoning and Official Plan land use shapefiles provided by the City include both existing and future conditions. The provincial land cover does not reflect forestry and mining practices.

***Stormwater Infrastructure***

In some areas, the GIS shapefiles of the storm sewer mains, laterals, and structures have incomplete information on size, material, age, and elevations. The bridge and culvert inventory is missing structures and elevations. Information on other structures in the watershed systems is incomplete. Ditches have not been comprehensively digitized in useable format. The line work currently available from the City is broken and incomplete.

***Hydrologic and Hydraulic Modelling***

The majority of past models could not be used in the Base Models because they were developed in model platforms no longer in use, more recent information was available than the model inputs, and/or the final and official version of models could not be confirmed.

***Monitoring Data***

No metadata is available to assist in the processing of the LRCA data, making it challenging to perform QA/QC on the data. Additional monitoring data gaps were identified in specific watersheds and discussed in the following subsections.

***Current River Data Gaps***

Several data gaps in the Current River Watershed were found in the hydraulics and operation of the Boulevard Lake and Dam, including:

1. The dependency of the dam operation on weather and personnel. There are normal settings for the Boulevard Lake Dam spillways during the summer and winter months. The procedures for operating the spillways are outlined in the City Environment Division's Standard Operating Procedure (SOP). The procedures define target water levels, normal operating water levels, and the criteria for how much the generating station can lower with lake water level. However, the operating procedures for when stop logs are inserted or removed and the diversion rate of the generating station are highly dependent on weather and personnel.
2. There is no survey of the Lake's storage volume above and below the normal water level.
3. Historical water level records for Boulevard Lake are not kept after 60 days of being recorded via a SCADA System at the Bare Point Water Treatment Plant.
4. There is no other flow monitoring within urban limits of the Current River Watershed at points of interest such as in/outflow from Boulevard Lake and at the mouth of the Current River.
5. The topographic information was very limited downstream of the Dam where the City's 1 m contours did not extend across bridges. No soils information in the watershed headwaters.
6. No details available for Hazelwood Lake Dam.
7. The most recently developed hydrologic model of the Current River Watershed was developed as part of the Current River Flood and Fill Line Mapping (1979) when the Onion Lake Dam was still operational (since has been removed) and only considered the Regional Storm.

#### *Kaministiquia River Data Gaps*

Operation of the Kakabeka Falls Generating Station and spillway is dependent on multiple requirements documented in the Kaministiquia River Watershed Management Study (1990) and Kaministiquia River System Water Management Plan (2004). Translating the operating procedures into control rules or rating curves was not possible within the scope of this study due to the dependency on power demand and other non-hydrologic or hydraulic factors. In comparison, operation of other control points farther upstream, such as the Greenwater Lake Dam, was more predictable and information provided by Ontario Power Generation could be used to develop a rating curve.

Data gaps in the Kaministiquia River Watershed included:

1. No soils information in the headwaters of the watershed
2. No river bottom elevation to convert the depth measurements at the West Fort William gauge (02AB025) into water elevations.

### McIntyre River Data Gaps

Information gaps in the McIntyre River Watershed included:

1. Multiple bridges were not included in the past hydraulic model developed for the Neebing-McIntyre Floodway, including the CNR, Memorial Avenue, Fort William Road / Simpson Street, and CPR bridges over the Floodway.
2. The model did not include the Chapples Drive bridge and one pedestrian bridge over the Neebing-McIntyre Floodway diversion channel. Some of these structures are included in the City's Municipal Structure Inspection Forms (2010).
3. The most recent information available for Lake Tamblyn on the Lakehead University campus is from the McIntyre Flood and Fill Line Mapping Technical Report prepared in 1985 and provides information on the dam and weir controlling outflow from the lake. No information on the storage in Lake Tamblyn is available.

### McVicar Creek Data Gaps

No gaps were identified specific to the McVicar Creek Watershed.

### Mosquito Creek Data Gaps

Information gaps specific to the Mosquito Creek Watershed included:

1. No monitoring information was available for flow, level, or precipitation in the Mosquito Creek Watershed.
2. Only one crossing in the watershed is greater than 3 m and, as such, included in the City's Municipal Structure Inspection Forms (2010).

### Neebing River Data Gaps

The following data gaps were identified specific to the Neebing River Watershed:

1. Multiple bridges were not included in recently developed hydraulic models of the Neebing-McIntyre Floodway, including the Edward Street, Waterloo Street, CNR, Cameron Street, Vickers Street, May Street, Simpson Street, and six pedestrian bridges over the Neebing River. Some of these structures are included in the City's Municipal Structure Inspection Forms (2010).
2. The LRCA precipitation gauge 58 at the same location as flow gauge 02AB024 has missing data in 2011 and 2012.

### Pennock Creek Data Gaps

The following data gaps were identified specific to the Pennock Creek Watershed:

1. No monitoring information was available for flow, level, or precipitation in the Pennock Creek Watershed.
2. None of the bridges and culverts in the watershed are included in the current City's Municipal Structure Inspection Forms (2010).

### 2.1.2 Model Platform

PCSWMM was selected as the platform for Base Model development because its applicability to the needs of the City's analysis and the ease of model construction and revision. First released in 1984, PCSWMM is a spatial decision-support tool for the United States Environmental Protection Agency Storm Water Management Model (USEPA SWMM). SWMM is a dynamic hydrology-hydraulics-water quality simulation model, which can be used for both single event and long-term (continuous) simulations. The USEPA has released SWMM5 with a graphical user interface (GUI) commonly referred to as EPA SWMM, but several third-party GUIs have also been developed to augment SWMM's functionalities in a myriad of ways. PSCWMM was built upon a GIS engine, making it a powerful interface for developing models using GIS-based input data. PCSWMM provides all the hydrologic, hydraulic, and water quality computational capabilities of SWMM5 while offering a large number of additional tools for easier model development, parameterization, calibration, results inference and scenario analysis.

### 2.1.3 Data Processing

The soils mapping from Land Information Ontario was processed to determine infiltration parameters corresponding to soil textures. Some soil types were removed from the dataset because they were not applicable to infiltration parameters. For example, areas identified as open water or bedrock were copied to the land use layer as water body and impervious areas respectively. Areas categorized as unclassified, gravel pit and quarry were also omitted from the mapping. The soils were then categorized using the soil textures in Table 32 (Attachment 1 on Page 86).

The provincial land cover layer was modified to reflect updated wetland and water body mapping, bedrock coverage, and more specific land uses within the developed area of the City. This was done by importing the wetlands GIS data from the Ministry of Natural Resources and Forestry, water body outlines from provincial sources and the City, bedrock areas from the soils GIS data, and the land use specified in the City's zoning shapefile. The areas in the zoning shapefile identified for future development or rural land use were represented using provincial land cover or inspection of aerial imagery to reflect current conditions.

Three of the four currently operating Environment Canada precipitation monitoring stations are located at the Thunder Bay Airport. Data from Station 6048268 was used while the others were not due to redundancy. The fourth station is located on Welcome Island and was not used because it has only been operating since 2014. The Environment Canada Thunder Bay Airport Station records were used to develop updated Intensity-Duration-Frequency (IDF) curves for the SMP. In addition to the Regional Timmins Storm, design storms were generated using the updated IDF curves and the 24 hour SCS Type II distribution. The rainfall depth of each return period is summarized in Table 6. The precipitation data from the Water Survey of Canada/LRCA stations were used for the continuous simulations of the Base Models.

**Table 5. Depth-Frequency for Thunder Bay Airport Station (6048261), 24-hour Duration**

| Return Period (years) | Rainfall Depth (mm) |
|---|---|
| 2 | 48.7 |
| 5 | 67.0 |
| 10 | 79.0 |
| 25 | 94.2 |
| 50 | 105 |
| 100 | 117 |

Minimal processing was performed for the flow data, which only required eliminating missing records.

### 2.1.4 Parameterization

The Base Models were developed in PCSWMM using several external parameterization methods. The subcatchment parameters were determined based on area-weighted averages and analysis of the DEM. The subcatchment properties for each Base Model and the lookup tables used in the area weighting calculations are provided in Attachment 1 (Page 86). Subcatchment length and slope were calculated using the ArcMap Spatial Analyst Tool.

A DEM of surface slope was created and then ArcMap Zonal Statistics was used to calculate the average slope of each subcatchment. The same zonal statistics tool was also used to calculate the maximum and minimum elevations in each subcatchment. The results were then used to calculate the subcatchment length.

Volume 3 of the SMP provides maps of the subcatchment delineation (Maps 54 to 60), soils mapping (Maps 19 to 25), and existing and future land use mapping (Maps 61 to 74).

Green-Ampt infiltration parameters (hydraulic conductivity, suction head, and initial moisture deficit) were calculated based on soil types as derived from the work of Rawls et al. (1982). Some of the watersheds have a significant amount of bedrock identified in the soils mapping to the extent that the Current River northern subwatersheds consist entirely of bedrock. After some iteration, bedrock areas were represented by 100% pervious areas with infiltration properties similar to clay soils and depression storage similar to woodlands. The bedrock coverage allows minimal infiltration through fractures of the bedrock and, in some areas, the thin layer of soil above shallow bedrock.

Percent impervious was determined using typical impervious percentages of each land use. Manning’s roughness of pervious surfaces was determined for each land use using values from the U.S. Army Corps of Engineers (USACE 1998) and the Soil Conservation Service (Soil Conservation Service 1986).

Depression storage has a linear correlation with surface roughness (Onstad 1984). Therefore, Manning’s Roughness for overland flow was used as a surrogate for depression storage. Limiting values for depression storage were then chosen as the lowest and highest values cited in the SWMM 5 User Manual (see Table 6). The values were used in conjunction with corresponding land uses in the table of Manning’s Roughness values provided (see Table 7). If a range of values was provided instead of a single value for Manning’s Roughness, the median value of that range was used. The resulting depression storage values are summarized in Table 8.

**Table 6: Depression Storage Values (Rossman 2010)**

| Surface | Depression Storage (mm) |
|---|---|
| Impervious surfaces | 1.27 – 2.54 |
| Lawns | 2.54 – 5.08 |
| Pasture | 5.08 |
| Forest litter | 7.62 |

Source: ASCE, (1992). *Design & Construction of Urban Stormwater Management Systems,* New York, NY.

**Table 7: Manning's Roughness (n) for Overland Flow (Rossman 2010)**

| Surface | N |
|---|---|
| Smooth asphalt | 0.011 |
| Smooth concrete | 0.012 |
| Ordinary concrete lining | 0.013 |
| Good wood | 0.014 |
| Brick with cement mortar | 0.014 |
| Vitrified clay | 0.015 |
| Cast iron | 0.015 |
| Corrugated metal pipes | 0.024 |
| Cement rubble surface | 0.024 |
| Fallow soils (no residue) | 0.05 |
| Cultivated soils<br>Residue cover < 20%<br>Residue cover > 20% | <br>0.06<br>0.017 |
| Range (natural) | 0.13 |
| Grass: Short, prairie<br>Dense<br>Bermuda grass | 0.15<br>0.24<br>0.41 |
| Woods: Light underbrush<br>Dense underbrush | 0.40<br>0.80 |

Source: McCuen, R. et al. (1996), *Hydrology,* FHWA-SA-96-067, Federal Highway Administration, Washington, DC.

**Table 8: Manning's N and Depression Storage Relationship**

| Example Land Use Categories | Manning s Roughness | | Depression Storage* (mm) |
|---|---|---|---|
| | Range | Median | |
| Avg. Grass Cover | 0.40 | 0.40 | 4.40 |
| Commercial/Industrial | 0.11 | 0.11 | 2.07 |
| Dense Forest | 0.80 | 0.80 | 7.62 |
| Dense Grass | 0.17 – 0.30 | 0.235 | 3.07 |
| Impervious | 0.011 | 0.011 | 1.27 |
| Road | 0.015 | 0.015 | 1.30 |
| Rural Residential | 0.40 | 0.40 | 4.40 |

*Blue represents the upper limit used, red denotes the lower limit used

Daily maximum and minimum temperatures from Environment Canada Station 6048268 were used in the climatology editor in PCSWMM to estimate evapotranspiration.

Average cross sections of each reach of the watercourses were calculated using the DEM and the Transect Creator tool in PCSWMM. Invert elevations along the watercourses were also estimated based on the DEM and then refined with contours and/or information from technical reports, where available.

Bridges and culverts along the watercourses were modelled when information on the crossings were available in the City's Municipal Structure Inspection Forms (2010) or in past technical reports. At each crossing, an overflow route was included to represent the road overtopping when the crossing capacity is exceeded. An inventory of the crossings included in each Base Model is included in the documentation window of the models and in Attachment 1 (Page 86).

The roughness of the river and creek cross sections, bridges, culverts, and road overtopping was set based on conduit's material and values obtained from the City's Engineering and Development Standards (2014), Chow (2009) and the American Society of Civil Engineers (Bizier 2007).

A time series of hourly recorded water levels by the Department of Fisheries and Oceans in Lake Superior was applied to the outfalls of each watercourse to the lake to represent the potential effects of backwater from rising water levels in the lake in the continuous simulation models. An average lake water level of 183.20 masl was used to represent the starting water elevation at the outfall and at any reaches or structures below this level at the beginning of the event simulations.

The potential for backwater impacts was also considered by modelling the tributary watersheds in the same model as the receiving watersheds (i.e. Pennock Creek, Neebing River, and McIntyre River Watersheds in one Base Model; Mosquito Creek and Kaministiquia River Watershed in another Base Model).

Watershed-specific assumptions considered during parameterization are discussed in the following subsections, although there are no notable assumptions specific to the McVicar Creek, Mosquito Creek, and Pennock Creek Watersheds.

#### *2.1.4.1 Current River*

Several assumptions were necessary to represent the Boulevard Lake and Dam to compensate for limited available information, as follows:

- Several plans were provided by the City depicting rehabilitation of the Dam. The details were not used because the repairs were not yet performed.
- The bottom elevation of Boulevard Lake was assumed based on the Boulevard Lake Southwest Corner Dredging Plan (Surveyed 2008).
- The insertion and removal of logs in the Dam was not represented due to limited information on the reasoning for such operation of the spillways.
- The diversion to the generating station was also not represented in the model due to the same limitation. Instead, the dam was represented using the typical summer settings shown in the Boulevard Lake Water Management Plan (2006) and high flows were conveyed by one overflow weir when the Lake's water level was above 211.80 m.

The areas in the upper Current River Watershed without soils information were assumed to have similar infiltration properties as the nearest areas with known soil types.

#### 2.1.4.2 Kaministiquia River

Development of the Kaministiquia River Watershed Base Model was limited by the regulation of flows at the Kakabeka Falls Generating Station, the last control point before the River enters the City limits. Upstream of Kakabeka Falls, there is one other Generating Station (Silver Falls) on Dog Lake and three Dams on the Greenwater, Kashabowie, and Shebandowan Lakes.

Control rules or discharge rating curves were needed to represent the performance of these structures in event simulation of the Kaministiquia River Watershed Base Model. The operator, Ontario Power Generation, provided the available flow and level records from 2006 to 2014 for each structure and additional information on the variables considered in operating procedures were documented in the Kaministiquia River Watershed Management Study (1990) and Kaministiquia River System Water Management Plan (2004).

Operation of the Kakabeka Falls spillway and generating station were found to be dependent on multiple variables such as aesthetic requirements of the falls, fish habitat, capacity of the generating station, and power demand. Although thresholds are set for each requirement, actual flows vary considerably and cannot be represented by event simulations as done for other watersheds in this study.

The Kaministiquia River Watershed Base model was simplified in light of these limitations by replacing simulation of the watershed upstream of Kakabeka Falls with the observed continuous time series provided by Ontario Power Generation for the spillway and generating station in the existing conditions continuous simulation. No event simulations were possible in the present state of model development for existing or future conditions. The implications of this limitation are discussed further in Section 2.3.

An average slope of 0.01% was assumed for some sections of the Kaministiquia River where no information was found regarding the bottom elevation of the River.

#### *2.1.4.3 McIntyre and Neebing Rivers*

The most recent model of the Neebing-McIntyre Floodway was a HEC-RAS model prepared as part of the draft Floodway Integrity Study provided by the LRCA. Although the model was not final, it was used in the Base Model development because it was the most recent and highest quality information representation of the Floodway and lower Neebing River. The lengths and locations of structures were adjusted as needed based on the GIS interface in PCSWMM and structures were added where information was available from the City's Municipal Structure Inspection Forms (2010) and the McIntyre River Flood and Fill Line Mapping Study (1985).

The storage capacity of Lake Tamblyn, an inline Lake on the McIntyre River within Lakehead University's campus, was estimated based on the City's 1 m contours. The dam and weir controlling the Lake's discharge could not be represented using physical parameters due to limited information available. The rating curves provided in the McIntyre River Flood and Fill Line Mapping Study (1985) were assumed to represent the existing structures.

The time period selected for the continuous simulation of all the Base Models was the spring and summer of 2012, however one precipitation station (LRCA Station 58 also referred to as the Upper Neebing Near Intola) had significant gaps in precipitation data throughout 2011 and 2012. Data from other stations were used for the Neebing River subwatersheds nearest to LRCA Station 58.

## 2.2 Model Results

The Base Model results of the existing and future conditions scenarios are summarized in this section.

First, the existing conditions continuous simulation of the spring and summer of 2012 are verified in comparison to observed flow data for all watersheds except for those without flow gauges (Pennock and Mosquito Creeks' Watersheds). The verification qualifies the ability of the model to reflect the conditions in the watersheds and, in doing so, helps identify additional information required to calibrate the models in the future, as summarized in Section 2.4 *Recommendations*.

Second, the Base Model event simulations under existing and future conditions are presented for the Regional Timmins Storm and the 2- to 100-year events. Under existing conditions, the event simulation results are compared to results of past technical studies. Most of the past studies were completed almost 30 years ago so future conditions scenarios from past studies were used where possible instead of existing conditions to reflect the conditions in 2012. The future conditions results of the Base Models reflect how peak flows may change in the next 15 to 20 years.

### 2.2.1 Current River

The existing conditions model results in the Current River watershed were compared to observed flows monitored at the North Current River gauge at Isku Park Drive (Station 02AB014) and the Current at Stepstone gauge at Onion Lake Dam Road (Station 02AB021).

The continuous hydrographs in Figure 3 and Figure 4 show a good match of peak lows during several events. The figures show missed events. The missing events are likely due to rainfall occurring in the headwaters of the watershed that was not captured by the rain gauges in the lower watershed.

The verification shows a poor fit with baseflows. The lack of fit may be due to groundwater contributions and snowpack accumulation not represented in the Base Model.

There is no monitoring data in the lower watershed below Boulevard Lake to evaluate the model's representation of the Boulevard Lake Dam beyond the limitations in operating rules previously discussed. Additional data required to consider snowpack accumulation, groundwater, and localized rainfall in the Comprehensive Watershed Management Models are outlined in Section 2.4.

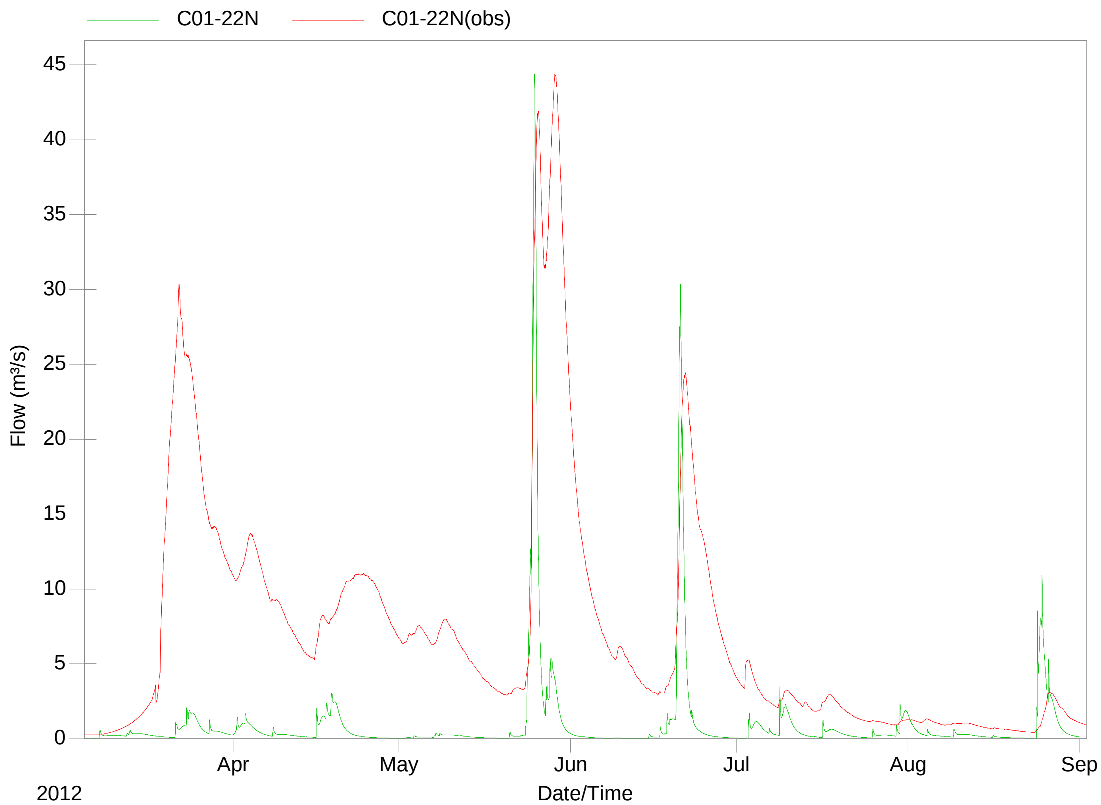


**Figure 3. Verification of Current River at Stepstone (Station 02AB021)**

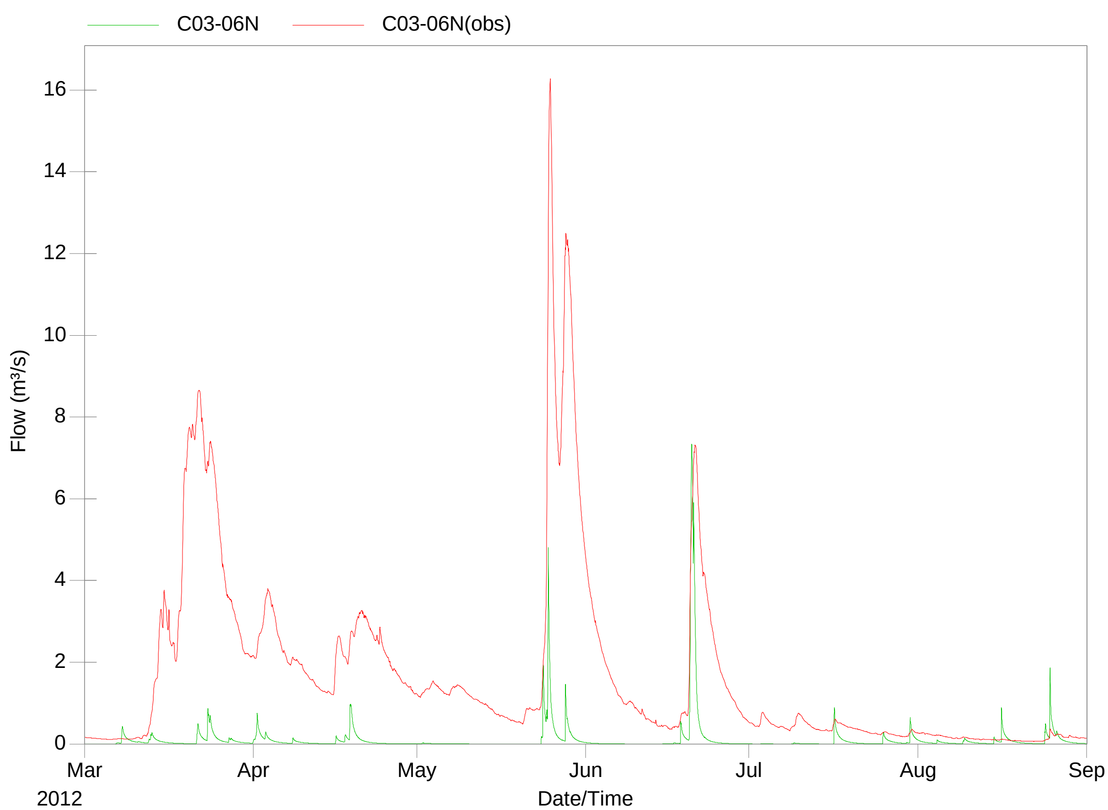


**Figure 4. Verification of North Current River (Station 02AB014)**

The peak flows estimated by the Base Model at locations throughout the Current River watershed under existing conditions are summarized in Table 9 and compared to the results of past technical studies.

The peak flow at the outlet of Current River to Lake Superior during the Regional event is slightly less than the peak flow estimated in the Current River Flood and Fill Line Mapping Study (1979). The difference may be due to maintaining the typical summer settings of the Boulevard Lake Dam in the Base Model.

**Table 9: Existing Conditions Peak Flows in Current River Watershed ($m^3/s$)**

| Location | Peak Flow from Base Model ($m^3/s$) *(Peak Flow from Past Study)* | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr | Regional |
| Current River at Stepstone (Station 02AB021) | 31 | 48 | 59 | 96 | 127 | 166 | 312 |
| North Current River (Station 02AB014) | 20 | 31 | 39 | 49 | 57 | 66 | 96 |
| Highway 11-17 | 19 | 44 | 71 | 120 | 163 | 220 | 421 |
| Arundel Street | 19 | 44 | 71 | 120 | 164 | 220 | 421 |
| Boulevard Lake Dam | 10 | 39 | 71 | 120 | 164 | 220 | 421 |
| Cumberland Street | 11 | 39 | 71 | 120 | 164 | 220 | 421 |
| Outlet to Lake Superior | 11 | 39 | 71 | 120 | 164 | 220 | 423 *(433)* |

Source of Past Technical Study Results: Current River Flood and Fill Line Mapping (1979)

Under future conditions, the Base Model shows peak flows increasing by approximately 10% during the 2-year event below Boulevard Lake and remaining the same at all other locations and during all other return periods, as summarized in Table 10. The increase in peak flows downstream of Boulevard Lake is likely due to new development expected in the lower watershed in the next 15 – 20 years.

**Table 10: Future Conditions Peak Flows in Current River Watershed ($m^3/s$)**

| Location | Peak Flow from Base Model ($m^3/s$) *Change from Existing to Future Conditions* (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr | Regional |
| Current River at Stepstone (Station 02AB021) | 31 | 48 | 59 | 96 | 127 | 166 | 312 |
| North Current River (Station 02AB014) | 20 | 31 | 39 | 49 | 57 | 66 | 96 |
| Highway 11-17 | 19 | 44 | 71 | 120 | 163 | 220 | 421 |
| Arundel Street | 19 | 44 | 71 | 120 | 164 | 220 | 421 |
| Boulevard Lake Dam | 11 *+10%* | 39 | 71 | 120 | 164 | 220 | 421 |
| Cumberland Street | 12 *+9%* | 39 | 71 | 120 | 164 | 220 | 421 |
| Outlet to Lake Superior | 12 *+9%* | 39 | 71 | 120 | 164 | 220 | 423 |

### 2.2.2 Kaministiquia River

The existing conditions, continuous simulation results of the Kaministiquia River Base Model were compared to the observed flow and depth monitored at the following four gauges:

- Whitefish River flow gauge at Highway 588 and Old Mill Road (Station 02AB017)
- Corbett Creek flow gauge at McNally Drive (Station 02AB022)
- Slate River flow gauge at Candy Mountain Drive (Station 02AB023)
- Kaministiquia River at West Fort William water elevation gauge (Station 02AB025)

The continuous hydrographs at the three flow gauge locations during the summer of 2012 are shown in Figure 5 to Figure 7 and the depth at West Fort William is shown in Figure 8.

The verification at the three flow gauges shows an underestimate of base flows in the tributaries to the Kaministiquia River (Whitefish River, Corbett Creek, and Slate River) and an overestimate of peak flows in Whitefish River. The discrepancy in flows may be due to limited discretization in the subwatersheds draining to the tributaries, no representation of snowpack accumulation, and no representation of groundwater.

The water elevation gauge at West Fort William is the only active monitoring station on the Kaministiquia River (downstream of Kakabeka Falls). Figure 8 shows the relative changes in depth in 2012 is represented in the model, although the absolute calculated values are less than observed. The flow and level regime in the Kaministiquia River was expected to have a good fit in the Base Model because an observed time series at Kakabeka Falls was used to represent the flows from upstream of this point, which includes approximately 90% of the watershed. The difference in absolute values is partly due to the unknown invert elevation of the river that was assumed in order to compare observed water depth to calculated water elevation. Additional data required to consider snowpack accumulation, groundwater, and correlation of observed water levels in the Comprehensive Watershed Management Models are outlined in Section 2.4.

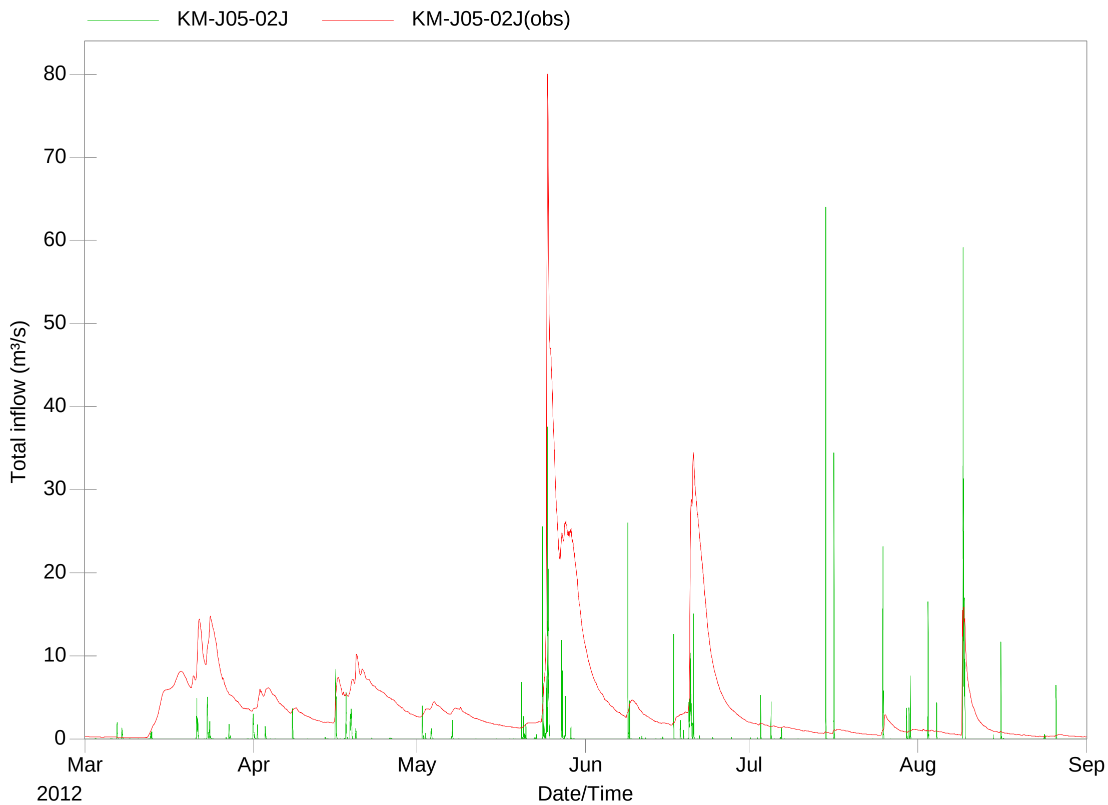


**Figure 5. Verification of the Kaministiquia River Base Model at Whitefish River (Station 02AB017)**

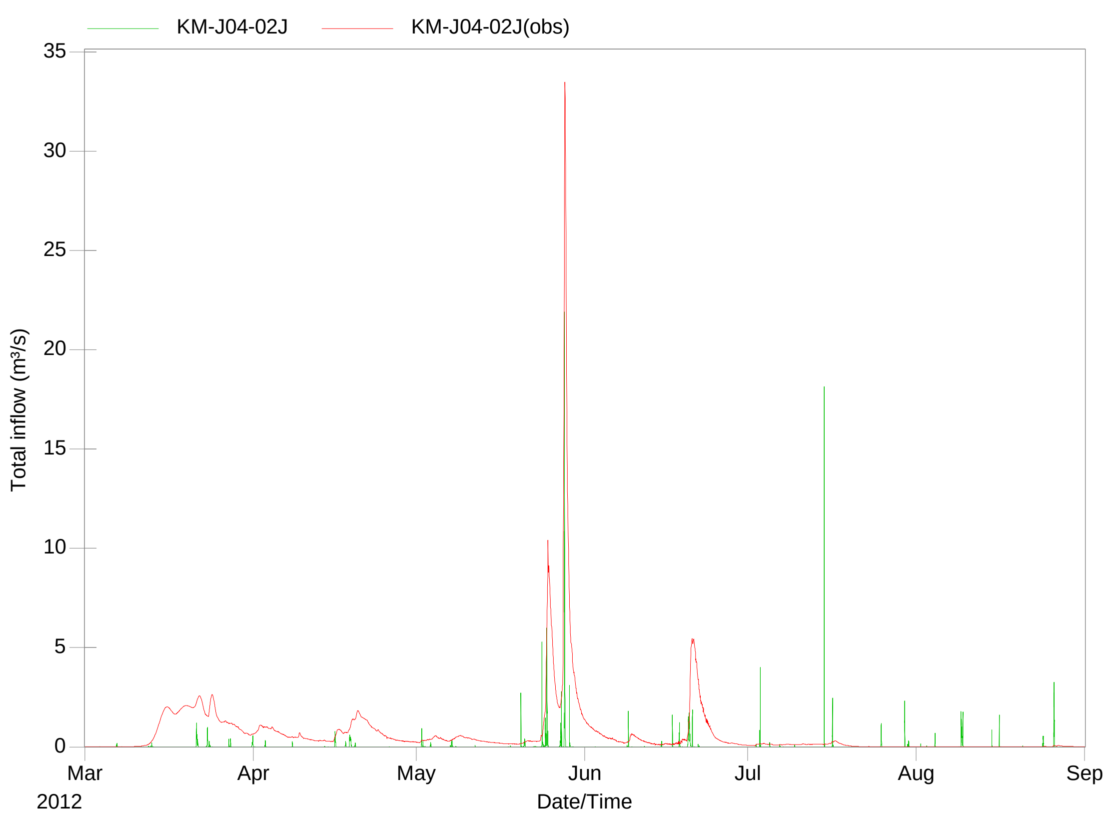


**Figure 6. Verification of the Kaministiquia River Base Model at Corbett Creek (Station 02AB022)**

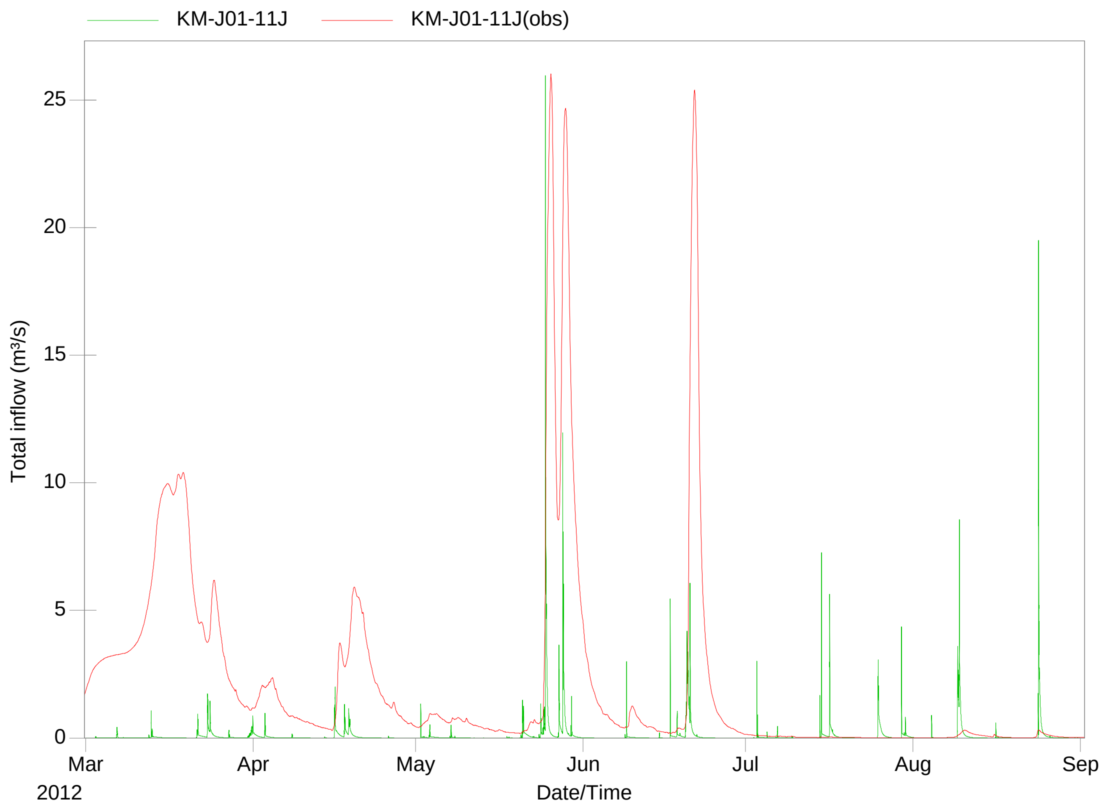


**Figure 7. Verification of the Kaministiquia River Base Model at Slate River (Station 02AB023)**

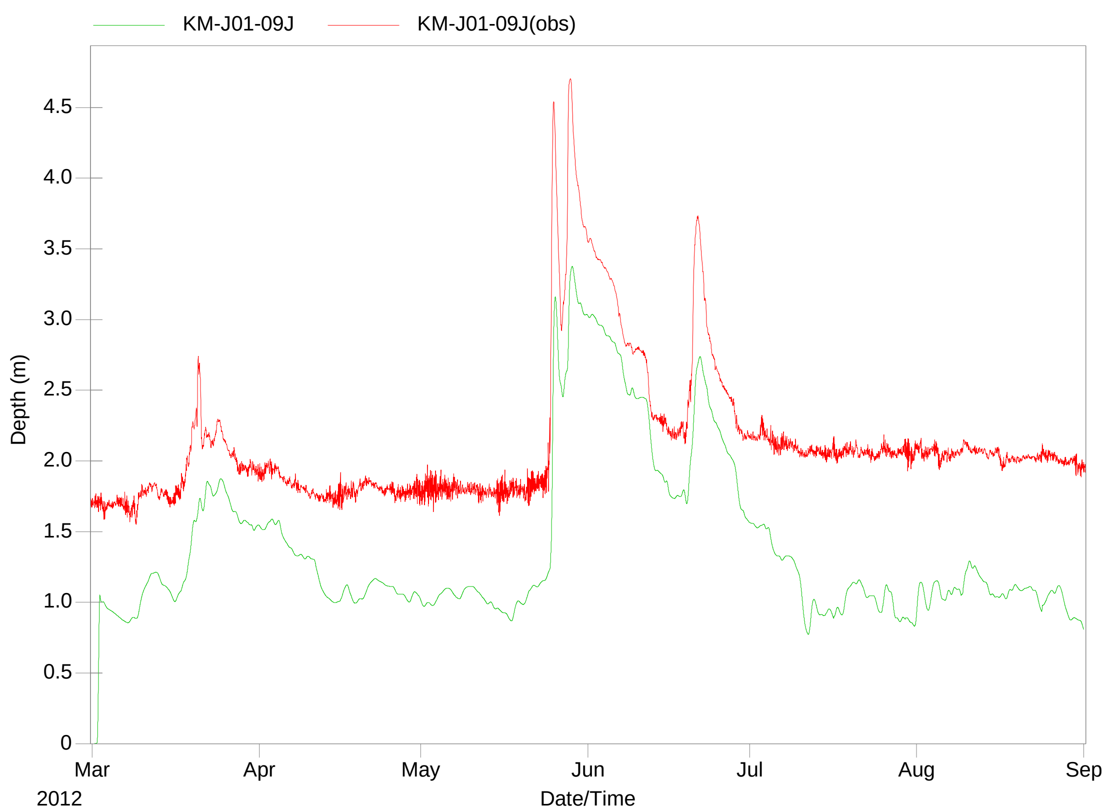


**Figure 8. Kaministiquia River at West Fort William (Station 02AB025)**

Event simulations of the Kaministiquia River Watershed were not included in this study due to previously discussed limitations in representing regulated flows from the Kakabeka Falls spillway and Generating Station during rainfall events. Recommendations for future work in the Kaministiquia River Watershed are further discussed in Section 2.4. Event simulations of Mosquito Creek Watershed, a tributary of the Kaministiquia River, are discussed in Section 2.2.5.

Peak flows calculated in past technical studies of the Kaministiquia River are summarized in Table 11.

**Table 11: Peak Flows in Kaministiquia River Watershed**

| Location | 100 yr Peak Flow ($m^3/s$) |
|---|---|
| Upstream of Confluence with Slate River | 732 |
| Outlet to Lake Superior | 746 |

Source: Report on Kaministiquia River Floodline Mapping Lake Superior to Rosslyn Village (1979)

### 2.2.3 McIntyre River

The existing conditions results of the McIntyre River Base Model are compared to the observed continuous hydrograph at McIntyre River gauge (Station 02AB020) at the intersection of Dawson Road and Dog Lake Road in Figure 9.

The verification shows that the model is underestimating baseflow in the spring and summer which is likely due to groundwater and snowpack accumulation not included in the model. The second peak in back-to-back storms in late May is underestimated which is likely due to rainfall occurring in the headwaters of the watershed not captured by the rain gauges in the lower watershed. The peak flows during events in August and September are overestimated in the model whereas peaks in the spring and early summer are underestimated. Additional data required to consider snowpack accumulation, groundwater, and localized rainfall in the Comprehensive Watershed Management Models are outlined in Section 2.4.

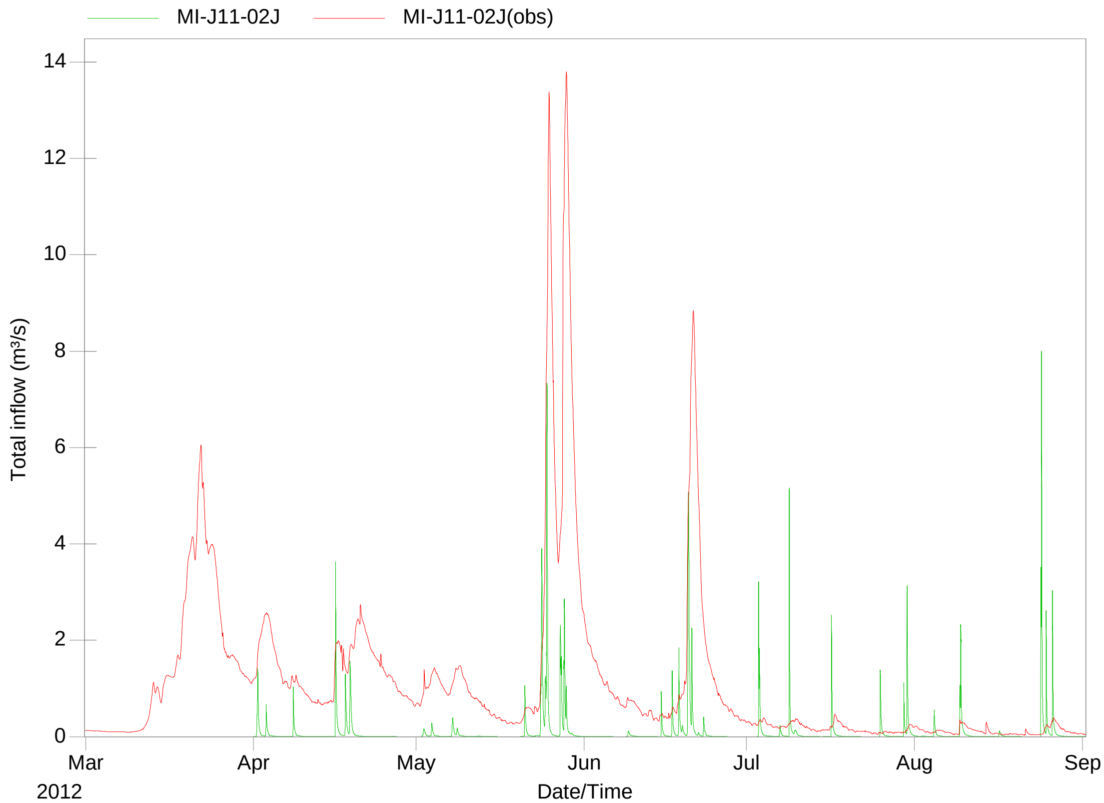


**Figure 9. Verification of McIntyre River at Station 02AB020**

The resulting peak flows at locations throughout the McIntyre River Watershed under existing conditions are summarized in Table 12 in comparison with peak flows calculated in past technical studies.

Overall, the Base Model peak flows are lower than those from past technical studies. Reasons for the differences in peak flows may include the assumptions made in past models, data gaps in model inputs of Base Models (i.e. Lake Tamblyn), and the need to calibrate the Base Model. It is not possible to conclude the reasons for these differences at this stage in the Watershed Model Development. The event simulation results can be further assessed following the development of Comprehensive Watershed Management Models as outlined in Section 2.4.

**Table 12: Existing Conditions Peak Flows in McIntyre River Watershed ($m^3/s$)**

| Location | Peak Flow from Base Model ($m^3/s$) *(Peak Flow from Past Study)* | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr | Regional |
| At City limits | 37 | 54 | 66 | 81 | 92 | 105 | 38 |
| | *(-)* | *(13)* | *(19)* | *(27)* | *(33)* | *(40)* | *(38)* |
| Dawson Road / HWY 102 (Station 02AB020) | 10 | 14 | 17 | 22 | 25 | 29 | 30 |
| Near John Street Road | 8 | 11 | 13 | 16 | 19 | 24 | 31 |
| | *(10)* | *(24)* | *(33)* | *(47)* | *(58)* | *(70)* | *(106)* |
| Highway 11-17 | 23 | 35 | 43 | 53 | 61 | 69 | 30 |
| Lakehead University (Inactive Station 02AB016) | 11 | 16 | 20 | 25 | 30 | 36 | 33 |
| | *(14)* | *(35)* | *(48)* | *(67)* | *(82)* | *(96)* | *(141)* |
| | *(-)* | *(38)* | *(57)* | *(83)* | *(103)* | *(124)* | *(129)* |
| Upstream of Floodway | 20 | 31 | 38 | 46 | 54 | 62 | 57 |
| | *(18)* | *(41)* | *(57)* | *(81)* | *(98)* | *(116)* | *(161)* |
| Above CNR Crossing | 33 | 46 | 55 | 64 | 71 | 80 | 76 |
| | *(-)* | *(47)* | *(70)* | *(101)* | *(125)* | *(150)* | *(152)* |
| Outlet to Lake Superior | 49 | 68 | 80 | 95 | 105 | 117 | 113 |

Source of Past Technical Study Results:
Grey rows are from HYMO model results in McIntyre Flood and Fill Line Mapping Technical Report (1985).
Other rows are from the developed conditions scenario Master Drainage Study (1987).

The resulting future conditions peak flows at locations throughout the McIntyre River Watershed are summarized in Table 13. The increase in peak flows from existing to future conditions is summarized in Table 13 and indicates that peak flows may increase up to 19% upstream of Highway 11/17 and up to 24% at Lakehead University. There is a lesser increase indicated in the lower watershed due to minor differences in the land uses identified in these areas under existing and future conditions.

**Table 13: Future Conditions Peak Flows in McIntyre River Watershed ($m^3/s$)**

| Location | Peak Flow from Base Model ($m^3/s$) *Change from Existing to Future Conditions* (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr | Regional |
| At City limits | 37 | 54 | 66 | 81 | 92 | 105 | 38 |
| Dawson Road / HWY 102 (Station 02AB020) | 10 | 14 | 17 | 21 | 25 | 29 | 30 |
| | | | | *-5%* | | | |
| Near John Street Road | 9 | 12 | 15 | 19 | 21 | 24 | 30 |
| | *+13%* | *+9%* | *+15%* | *+19%* | *+11%* | | *-3%* |
| Highway 11-17 | 25 | 40 | 49 | 61 | 71 | 80 | 31 |
| | *+9%* | *+14%* | *+14%* | *+15%* | *+16%* | *+16%* | *+3%* |
| Lakehead University (Inactive Station 02AB016) | 12 | 19 | 24 | 31 | 37 | 43 | 37 |
| | *+9%* | *+19%* | *+20%* | *+24%* | *+23%* | *+19%* | *+12%* |
| Upstream of Floodway | 21 | 33 | 40 | 50 | 58 | 66 | 64 |
| | *+5%* | *+6%* | *+5%* | *+9%* | *+7%* | *+6%* | *+12%* |
| Above CNR Crossing | 34 | 47 | 56 | 66 | 75 | 82 | 84 |
| | *+3%* | *+2%* | *+2%* | *+3%* | *+6%* | *+3%* | *+11%* |
| Outlet to Lake Superior | 49 | 68 | 80 | 95 | 109 | 118 | 120 |
| | | | | | *+4%* | *+1%* | *+6%* |

### 2.2.4 McVicar Creek

The existing conditions model results of the McVicar Creek Base Model are compared to the observed continuous hydrograph at McVicar Creek gauge (Station 02AB019) at Briarwood Drive in Figure 10.

The model verification process shows that the model underestimates baseflow in the spring and early summer, appears to miss the second of back-to-back storms in May, and overestimates peak flows in the late summer. Additional data required to consider snowpack accumulation, groundwater, and localized rainfall in the Comprehensive Watershed Management Models are outlined in Section 2.4.

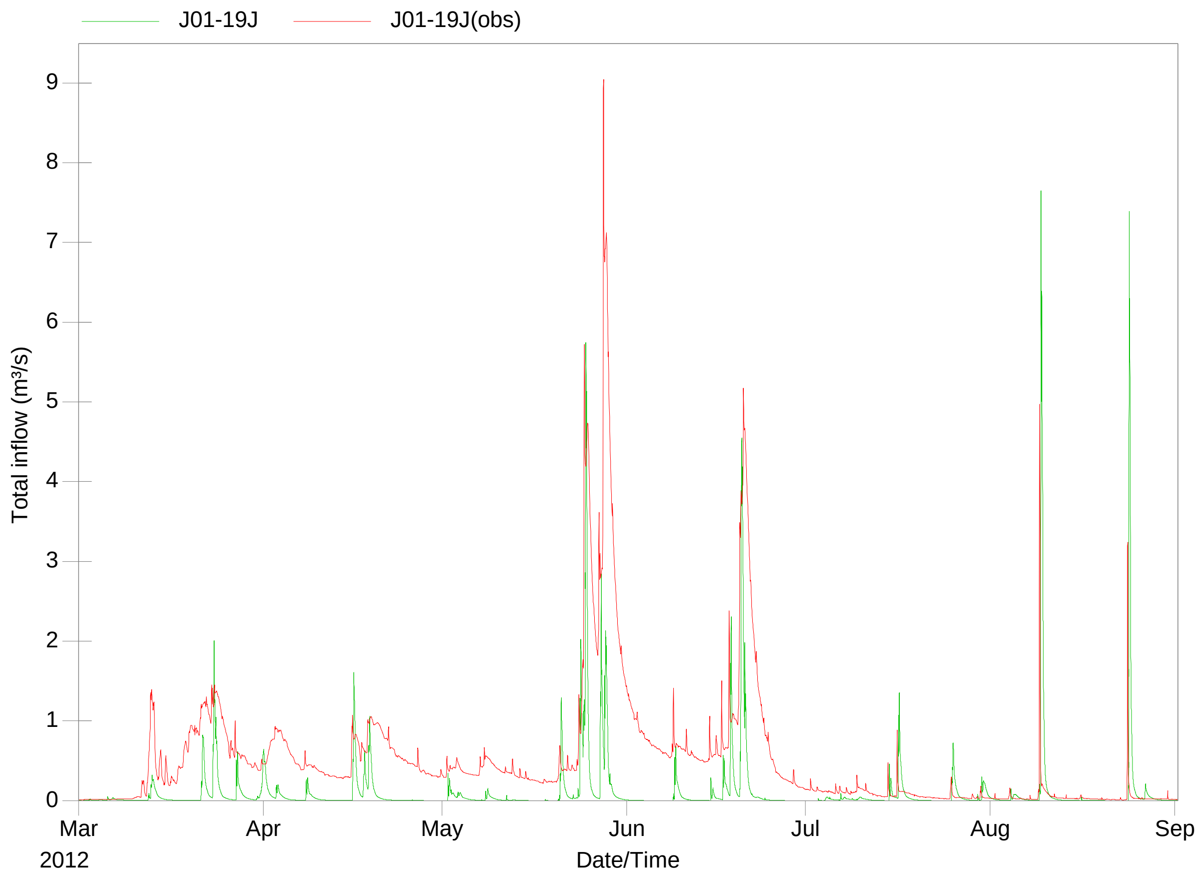


**Figure 10. Verification of McVicar Creek Base Model at Station 02AB019**

The existing conditions instantaneous peak flows estimated in the Base Model at locations throughout the McVicar Creek Watershed are summarized in Table 14.

The Base Model results are close to those from past technical studies for most locations during frequent events and are lower than the results of past technical studies for infrequent, large events. One exception is the historical flow frequency analysis included in the McVicar Creek Floodplain Study (1995) at Briarwood Drive, which provided flows similar to those estimated by the Base Model, although the study highlighted limitations to using the statistical analysis for return periods longer than 20 years due to the limited input data. The event simulation results can be further assessed following the development of Comprehensive Watershed Management Models as outlined in Section 2.4.

**Table 14: Existing Conditions Peak Flows in McVicar Creek Watershed ($m^3/s$)**

| Location | Peak Flow from Base Model ($m^3/s$) *(Peak Flow from Past Study)* | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr | Regional |
| Near Belton Street | **4** | **5** | **7** | **8** | **9** | **10** | **12** |
| | *(4)* | *(8)* | *(12)* | *(17)* | *(22)* | *(26)* | *(58)* |
| | *(4)* | *(16)* | *(27)* | *(43)* | *(56)* | *(70)* | *(124)* |
| Highway 11-17 | **12** | **14** | **16** | **18** | **19** | **21** | **18** |
| | *(5)* | *(12)* | *(19)* | *(27)* | *(33)* | *(39)* | *(62)* |
| | *(5)* | *(19)* | *(31)* | *(49)* | *(65)* | *(82)* | *(146)* |
| Briarwood Drive (Station 02AB019) | **7** | **11** | **14** | **17** | **20** | **22** | **20** |
| | *(5)* | *(7)* | *(9)* | *(12)* | *(15)* | *(18)* | - |
| | *(6)* | *(15)* | *(22)* | *(29)* | *(34)* | *(39)* | *(65)* |
| Outlet to Lake Superior | **9** | **14** | **18** | **23** | **27** | **31** | **24** |
| | *(8)* | *(17)* | *(25)* | *(33)* | *(41)* | *(48)* | *(66)* |
| | *(7)* | *(19)* | *(31)* | *(49)* | *(65)* | *(82)* | *(158)* |

Sources of Past Technical Study Results:
Dark grey rows are from the Future Conditions scenario of the McVicar Creek Floodplain Study (1995).
Light Grey rows are from the statistical analysis of recorded flows at the Briarwood Drive gauge station 02AB019 published in the McVicar Creek Floodplain Study (1995). It is important to note that due to the short span of data the predicted flows should not be extrapolated beyond a 20-year return period.
Other rows are from the developed conditions scenario in the Master Drainage Study (1987).

The future conditions instantaneous peak flows at locations throughout the McVicar Creek Watershed are summarized in Table 15 in addition to the percentage of change from existing conditions. The results indicate peak flows may decrease in the upper and lower watershed for certain but not all return periods while all return periods at the Highway 11/17 location show an increase in peak flows. The minor changes between existing and future land uses may have caused the inconsistent decreases in the upper and lower watersheds. The consistent increases at Highway 11-17 may be due to the future urban expansion proposed northwest of the Highway.

**Table 15: Future Conditions Peak Flows in McVicar Creek Watershed ($m^3/s$)**

| Location | Peak Flow from Base Model ($m^3/s$) *Change from Existing to Future Conditions* (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr | Regional |
| Near Belton Street | **4** | **5** | **7** | **7** | **9** | **10** | **12** |
| | | | | *-13%* | | | |
| Highway 11-17 | **13** | **15** | **17** | **19** | **21** | **22** | **20** |
| | *+8%* | *+7%* | *+6%* | *+6%* | *+11%* | *+5%* | *+11%* |
| Briarwood Drive (Station 02AB019) | **7** | **11** | **14** | **17** | **19** | **22** | **20** |
| | | | | | *-5%* | | |
| Outlet to Lake Superior | **9** | **14** | **17** | **23** | **26** | **30** | **23** |
| | | | *-6%* | | *-4%* | *-3%* | *-4%* |

### 2.2.5 Mosquito Creek

The event simulation of the Mosquito Creek Base Model under existing conditions resulted in the instantaneous peak flows summarized in Table 16 and compared to results of a past technical study in parentheses. The Base Model Results are close to those of the Master Drainage Study for frequent storms and in the upper watershed, however the Base Model results are increasingly lower than the Master Drainage Study as the storms become less frequent and locations are farther downstream.

**Table 16: Existing Conditions Peak Flows in Mosquito Creek Watershed ($m^3/s$)**

| Location | Peak Flow from Base Model ($m^3/s$) *(Peak Flow from Past Study)* | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr | Regional |
| Confluence of tributaries in upper watershed (immediately north of Mountain Road) | 13 *(5)* | 20 *(13)* | 24 *(19)* | 31 *(15)* | 36 *(33)* | 41 *(40)* | 28 *(63)* |
| Tributary running north between 15th Side Road and Mountain Road | 7 *(1)* | 11 *(2)* | 13 *(3)* | 16 *(5)* | 18 *(6)* | 21 *(8)* | 9 *(9)* |
| Confluence east of 15th Side Road | 10 *(6)* | 16 *(16)* | 20 *(24)* | 24 *(34)* | 28 *(43)* | 32 *(52)* | 37 *(82)* |
| Confluence of eastern tributaries (north of Fort William Country Club and Mountain Road) | 7 *(5)* | 12 *(11)* | 16 *(14)* | 21 *(19)* | 26 *(23)* | 32 *(26)* | 24 *(30)* |
| Confluence north of Foxborough Place and east of Norwester Drive | 7 *(10)* | 14 *(25)* | 20 *(35)* | 27 *(50)* | 34 *(63)* | 42 *(76)* | 55 *(114)* |
| Downstream limits of watershed | 7 *(11)* | 14 *(27)* | 19 *(39)* | 26 *(57)* | 32 *(74)* | 39 *(91)* | 56 *(125)* |

Source of Past Technical Study Results: Developed conditions scenario of the Master Drainage Study (1987)

The future conditions peak flows throughout the Mosquito Creek Watershed are summarized in Table 17 in addition to the percentage increase in peak flow compared to the Base Model under existing conditions. The results indicate a minor increase in peak flows under future conditions as expected because there will be minimal changes to development in those areas. Peak flows from the lower and eastern areas of the watershed are shown as decreasing under future conditions because the sources used to find future land uses (Official Plan Schedule A) show areas will be un-developed that are currently developed in the existing land use (Zoning Shapefile). Recommendations for information needed to improve the models are outlined in Section 2.4.

**Table 17: Future Conditions Peak Flows in Mosquito Creek Watershed ($m^3/s$)**

| Point of Interest | Peak Flow from Base Model ($m^3/s$) *Change from Existing to Future Conditions* (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr | Regional |
| Confluence of tributaries in upper watershed (immediately north of Mountain Road) | 13 | 20 | 24 | 31 | 36 | 42 *+2%* | 28 |
| Tributary running north between 15th Side Road and Mountain Road | 7 | 11 | 14 *+8%* | 17 *+6%* | 19 *+6%* | 22 *+5%* | 9 |
| Confluence east of 15th Side Road | 11 *+10%* | 17 *+6%* | 21 *+5%* | 25 *+4%* | 29 *+4%* | 33 *+3%* | 38 *+3%* |
| Confluence of eastern tributaries (north of Fort William Country Club and Mountain Road) | 5 *-29%* | 10 *-17%* | 14 *-13%* | 19 *-10%* | 23 *-12%* | 28 *-13%* | 23 *-4%* |
| Confluence north of Foxborough Place and east of Norwester Drive | 7 | 13 *-7%* | 19 *-5%* | 27 | 33 *-3%* | 41 *-2%* | 55 |
| Downstream limits of watershed | 6 *-14%* | 13 *-7%* | 19 | 25 *-4%* | 31 *-3%* | 39 | 56 |

### 2.2.6 Neebing River

The existing conditions model results are compared to the observed continuous hydrographs at Neebing River gauge 02AB024 (upper Neebing at John Street) in Figure 11 and Neebing River gauge 02AB008 (lower Neebing above Highway 11/17) in Figure 12.

The verification shows that the model is underestimating baseflow and peak flows in the spring and early summer whereas peak flows are overestimated in the late summer. One exception is the second peak following back-to-back storms in late May is overestimated at the Upper Neebing station. This is likely due to local rainfall not being captured by the rainfall gauge, especially since a station in the lower watershed was used instead of LRCA Precipitation Station 58 which is at the same location as the Upper Neebing flow gauge but was missing rainfall data for this time period. Additional data required to consider snowpack accumulation, groundwater, and localized rainfall in the Comprehensive Watershed Management Models are outlined in Section 2.4.

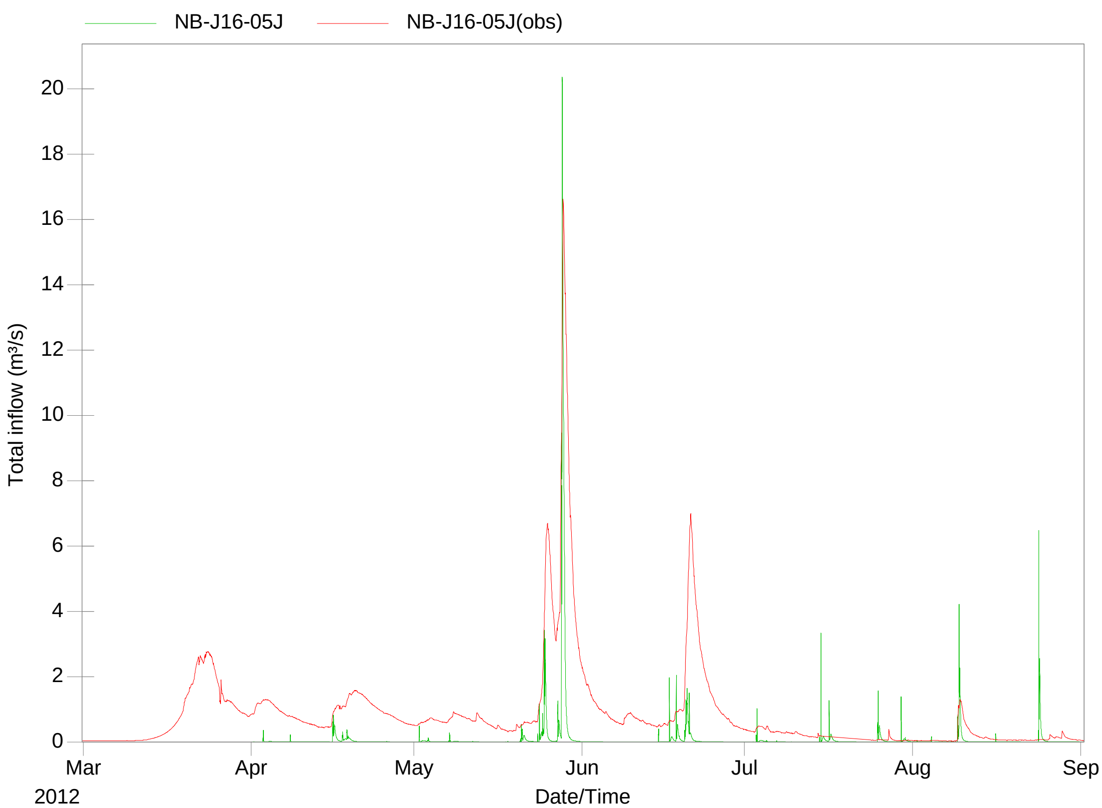


**Figure 11. Verification of Neebing River Base Model at Station 02AB024 (Upper Neebing)**

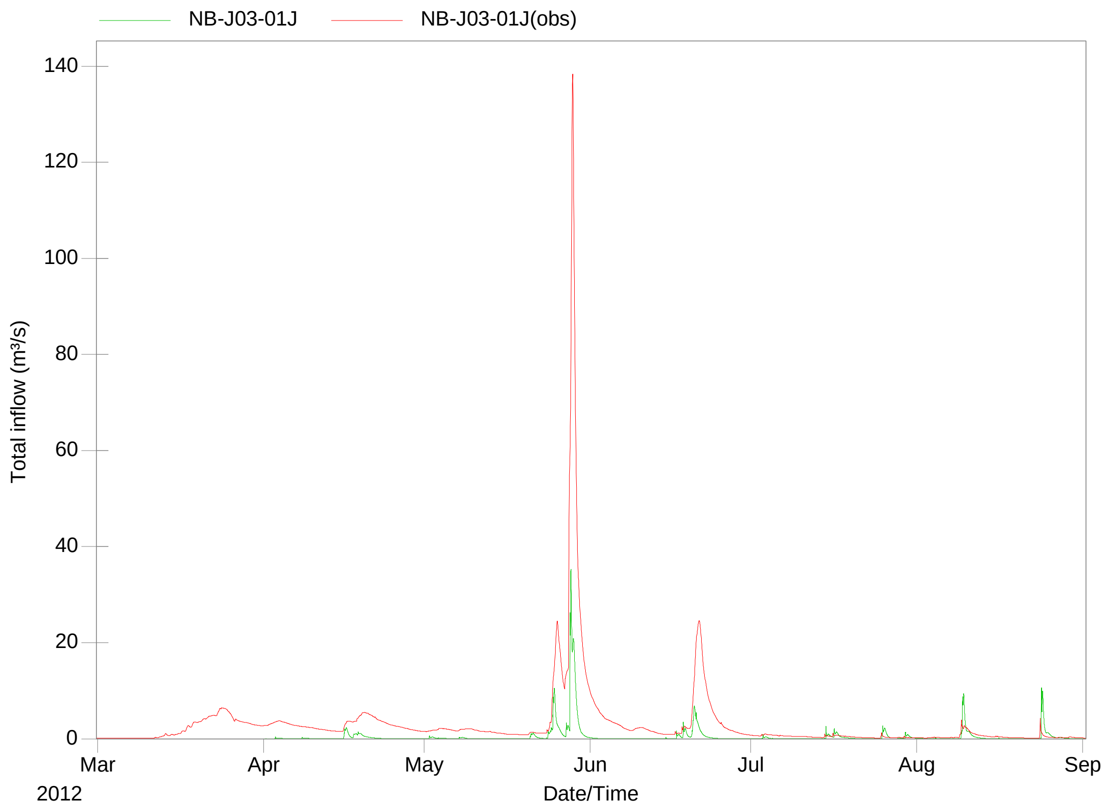


**Figure 12. Verification of Neebing River Base Model at Station 02AB008 (Lower Neebing)**

The existing conditions instantaneous peak flows throughout the Neebing River Watershed estimated in the Base Model are compared to results of a past technical study in Table 18. The Base Model results are close to those of the past technical study during the 2-year event but become increasingly less than the past study as the event return periods become less frequent. Exceptions from this trend include the location at Highway 11/17 where the 2-year to 100-year peak flows are very close and the locations Downstream of the Diversion within Neebing River and downstream limit of the Neebing River where peak flows in the Base Model are greater than or close to those of past studies.

**Table 18: Existing Conditions Peak Flows in Neebing River Watershed ($m^3/s$)**

| Location | Peak Flow from Base Model ($m^3/s$) *(Peak Flow from Past Study)* | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr | Regional |
| John Street Road (Station 02AB024) | 6 | 9 | 11 | 14 | 16 | 18 | 16 |
| Confluence of Pennock Creek / Neebing River | 11 *(10)* | 18 *(27)* | 25 *(39)* | 34 *(57)* | 41 *(71)* | 49 *(85)* | 52 *(113)* |
| Above Highway 11-17 (Station 02AB008) | 10 *(10)* | 16 *(27)* | 21 *(40)* | 29 *(58)* | 35 *(72)* | 41 *(86)* | 55 *(115)* |
| Highway 11-17 | 27 *(17)* | 43 *(34)* | 55 *(47)* | 71 *(66)* | 83 *(82)* | 97 *(99)* | 65 *(123)* |
| Upstream of Diversion | 8 *(12)* | 12 *(27)* | 17 *(40)* | 22 *(58)* | 27 *(72)* | 32 *(86)* | 48 *(115)* |
| Downstream of Diversion within Neebing River | 9 *(8)* | 14 *(16)* | 16 *(18)* | 22 *(21)* | 25 *(22)* | 27 *(24)* | 32 *(27)* |
| Floodway Upstream of McIntyre River | 3 *(4)* | 4 *(11)* | 5 *(22)* | 7 *(37)* | 8 *(50)* | 9 *(62)* | 17 *(88)* |
| Downstream Limit of Neebing River | 10 *(6)* | 15 *(11)* | 19 *(15)* | 25 *(21)* | 28 *(25)* | 33 *(30)* | 33 *(19)* |

Source of Past Technical Study Results: Developed conditions scenario of the Master Drainage Study (1987)

The future conditions Base Model summarized in Table 19 indicate that flows may increase in the mid-watershed area around Highway 11/17 up to 26% and minor decreases may occur in the lower reaches.

**Table 19: Future Conditions Peak Flows in Neebing River Watershed ($m^3/s$)**

| Location | Peak Flow from Base Model ($m^3/s$) *Change from Existing to Future Conditions* (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr | Regional |
| John Street Road (Station 02AB024) | 6 | 9 | 11 | 14 | 16 | 18 | 15 *-6%* |
| Confluence of Pennock Creek / Neebing River | 12 *+9%* | 20 *+11%* | 27 *+8%* | 36 *+6%* | 43 *+5%* | 52 *+6%* | 53 *+2%* |
| Above Highway 11-17 (Station 02AB008) | 10 | 17 *+6%* | 22 *+5%* | 30 *+3%* | 36 *+3%* | 42 *+2%* | 56 *+2%* |
| Highway 11-17 | 34 *+26%* | 54 *+26%* | 68 *+24%* | 87 *+23%* | 102 *+23%* | 119 *+23%* | 68 *+5%* |
| Upstream of Diversion | 8 | 14 *+17%* | 18 *+6%* | 24 *+9%* | 29 *+7%* | 34 *+6%* | 51 *+6%* |
| Downstream of Diversion within Neebing River | 10 *+11%* | 15 *+7%* | 17 *+6%* | 21 *-5%* | 24 *-4%* | 28 *+4%* | 33 *+3%* |
| Floodway Upstream of McIntyre River | 3 | 4 | 5 | 6 *-14%* | 8 | 8 *-11%* | 19 *+12%* |
| Downstream Limit of Neebing River | 10 | 15 | 19 | 24 *-4%* | 28 | 32 *-3%* | 35 *+6%* |

### 2.2.7 Pennock Creek

The peak flows estimated in the Base Model at the downstream limit of Pennock Creek under existing and future conditions are summarized in Table 20.

The existing conditions results are compared to those of a past study, indicating that the Base Model estimates peak flows greater than the past study. Table 20 also illustrates the percentage of change from existing to future conditions and indicates that peak flows may increase up to 20% at the downstream limits of Pennock Creek in the next 15-20 years.

**Table 20: Peak Flows at Downstream Limit of Pennock Creek Watershed**

| Development Condition | Peak Flow from Base Model ($m^3/s$) *(Peak Flow from Past Study)* *Change from Existing to Future Conditions* (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr | Regional |
| **Existing Conditions** | **5** *(2)* | **9** *(5)* | **12** *(8)* | **17** *(11)* | **21** *(14)* | **26** *(17)* | **32** *(22)* |
| **Future Conditions** | **6** *+20%* | **9** *0%* | **13** *+8%* | **18** *+6%* | **22** *+5%* | **27** *+4%* | **32** *0%* |

Source of Past Technical Study Results: Developed conditions scenario of the Master Drainage Study (1987)

## 2.3 Discussion

Overall, the Base Models have been developed with available information to represent the existing and future expected conditions in the watersheds. The general difference between the model and observed data (except for the May-June events for which modelled and observed peak flows are reasonably close) can be reduced by collecting and developing new and more data over the 20-year implementation period of the SMP. Additional information required to further develop and calibrate the Comprehensive Watershed Management Models are outlined in Section 2.4.

Although the absolute results of the event simulations are subject to change following further model development, the relative changes from existing to future conditions reflects the impact of land use changes in the watersheds. Without stormwater management controls, the Base Models indicate that future development expected in the McIntyre River, McVicar Creek, Neebing River, and Pennock Creek Watersheds may increase peak flows up to 26%. The future conditions events simulation did not consider potential changes in future rainfall depths and frequency due to climate change, which may exacerbate or degrade the increases in peak flows.

Watershed Management Models and the Base Models developed as part of the SMP represent just one tool available for watershed management decision makers. Numerous other watershed assessments have already been completed in Thunder Bay or are recommended for future implementation in the SMP to help improve the health of the watersheds. Through the development of the Kaministiquia River Watershed Base Model and the SMP, the apparent need for a Comprehensive Watershed Management Model developed solely by the City diminished in the face of other improvements and assessments that could be implemented immediately to provide deeper insight into the needs in the Watershed both within and outside of the City Limits. For example, a fluvial geomorphological assessment of the River within the City limits would help identify management objectives from the City's perspective to share with other municipalities, unorganized townships, and OPG farther upstream. Any implementation of further hydrologic and hydraulic watershed-wide modelling of the Kaministiquia Watershed warrants collaboration between all stakeholders because of the scale and scope needed to get worthwhile results.

## 2.4 Recommendations

The following sections outline the recommendations for data collection and the development of Comprehensive Watershed Management Models from the Base Models. Model development is recommended to continue with six of the seven Base Models, excluding the Kaministiquia River Watershed Base Model, and modelling efforts are recommended to commence for the subwatersheds of the Waterfront Watershed along the shoreline of Lake Superior in Thunder Bay.

A recommended order of prioritizing the watersheds is also provided for the City to consider in the implementation of the recommendations and estimates the costs of the recommendations.

### 2.4.1 Data Collection

As precipitation, climate, and flow monitoring data are targeted and obtained it will be possible to improve the results of the Base Models. Continuing the data collection programs already in place in the Lakehead Watershed is recommended.
The recommendations for data collection should be reviewed with the EarthCare Water Working Group to identify common data needs and opportunities for data sharing as monitoring programs proceed. Coordination will help establish a common awareness of the data available and partnerships with other agencies (e.g. LRCA), programs (e.g. research at Lakehead University), and community groups that can efficiently collect and use that data.

There is an endless amount of data that could be collected to improve model accuracy, but efforts will be limited by available resources. Prioritizing the information likely to be useful to the modelling (e.g. precipitation distribution, infrastructure inventory or flow monitoring) and most important to the City, is paramount.

The recommended monitoring programs should include in-house QA/QC of the monitoring data to identify and fix anomalies and compile the data into a usable format for modelling purposes. It is most efficient for this to be done by the team collecting the data as they are most familiar with the methodology and process used. All review and compilation should be completed before it is provided to the model developers.

#### *2.4.1.1 Precipitation Data*

The Base Models currently use the precipitation data from tipping bucket rain gauges jointly operated by the LRCA and Water Survey of Canada to provide the best possible resolution of rainfall data across the watersheds. It is recommended that the existing nine stations be upgraded to weather stations to provide more climate data across the watersheds. In addition, installation of four new heated and wind-shielded precipitation gauges is recommended to improve the spatial resolution of precipitation monitoring in the upper McVicar Creek Watershed, McIntyre River Watershed, Pennock Creek Watershed, and Mosquito Creek Watershed. Potential locations for the four new rain gauge locations are shown in Maps 57 to 61 in Volume 3 of the SMP.

Heated rain and wind-shielded gauges should be used to fully account for the water content in snowfall and to increase gauge capture accuracy. Use of heated rain and wind-shielded gauges will allow for a better calibration of the Comprehensive Watershed Management Models in the winter as the snowpack builds and then in the spring when snow melt

An emerging alternative to rain gauges is the possibility of incorporating radar-derived rainfall directly into the model, providing greater spatial and temporal resolution than is possible with any number of rain gauges. The radar-derived rainfall option is newly supported for Canadian radar in PCSWMM and is recommended for consideration in future modelling efforts.

#### *2.4.1.2 Climate Data*

The Base Models currently use the daily maximum and minimum temperatures recorded at the Environment Canada Station 6048268 to calculate daily evapotranspiration rates. The climate dataset could be improved by processing the hourly dew point, humidity, and wind speed into daily averages from Environment Canada Station 6048262 (also located at the Thunder Bay Airport). Dew point and humidity will help refine the evapotranspiration calculations while daily wind speed will be used to distribute snow accumulation in continuous models. The conversion of the existing tipping bucket rain gauges to weather stations will also provide a better spatial resolution of climate data.

#### *2.4.1.3 Snow Pack Survey*

Snowpack depth and water equivalent should be monitored at multiple locations in each watershed where monitoring provides a good representation of depth, such as open spaces with no plowing impacts and not affected by wind action (i.e. accumulation or thinning of snow). On average, snowpack should be monitored 3 times each winter/spring season although the frequency may vary depending on the number of snowmelts that occur each season. A total of 19 snowpack monitoring locations are recommended as follows in coordination with the LRCA’s current snowpack monitoring program:

- Current River Watershed – 4 locations
- McIntyre River Watershed – 4 locations
- McVicar Creek Watershed – 1 locations
- Mosquito Creek Watershed – 2 locations
- Neebing River Watershed – 4 locations
- Pennock Creek Watershed – 1 locations
- Waterfront Watershed – 3 locations

The LRCA's snowpack monitoring program has been in place since 1974 and consists of bimonthly surveys between November 15th and May 15th of each year at Hazelwood Lake Conservation Area (Current River Watershed), Madeline Street (McVicar Creek Watershed) and Vibert Road (Pennock Creek Watershed). Snow depth and weight (water content) are collected and forwarded to the MNRF's Surface Water Monitoring Centre as part of the Flood Forecasting Program. As of 2014, LRCA staff are also participating in the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) and have begun year round monitoring including snow measurements at their office at 130 Conservation Road.

#### *2.4.1.4 Flow Monitoring*

At least two flow monitoring gauges should be used to calibrate and validate the models, preferably one in the upper watershed at the upstream boundary of the City and one near the outlet of the watershed. To provide this level of detail for the development of each Comprehensive Watershed Management Model, the following 19 additional flow monitoring stations should be installed as shown in Maps 55 to 61 in Volume 3 of the SMP:

- 1 station on the Current River near Cumberland Street
- 3 stations on McVicar Creek, including 1 at City limits near Gorevale Road crossing, 1 at Onion Lake Road, and 1 at Wardrope Avenue
- 3 stations on the McIntyre River, including 1 upstream of the confluence with the Neebing-McIntyre Floodway, 1 at Island Drive, and 1 at City limits near the Dog Lake Road/Highway 589 crossing 700 m northwest of Gorevale Road
- 3 stations on the Neebing River, including 1 upstream of its confluence with the Neebing-McIntyre Floodway , 1 on a tributary at the City limits, and 1 south of Kline Road and North of Hwy. 11 (downstream of the John Street landfill site)
- 3 stations on Pennock Creek, including 1 near confluence with Neebing River, 1 at City limits near 25th Side Road crossing, and 1 in the upper watershed
- 1 station on the Kaministiquia at existing water quality sampling site near McKellar Island
- 2 stations on the Mosquito Creek, including 1 near the confluence with the Kaministiquia River and 1 near Lock Lomond Road crossing
- 3 flow gauges to be installed at varying locations on an as-needed basis for feasibility-level models and the Waterfront Watershed modelling.

#### *2.4.1.5 Water Quality Monitoring*

The limited water quality data collected throughout the watersheds cannot be used to create a useful model of water quality in the PCSWMM interface at present. With additional data collection, educated assumptions and conclusions can be made to address the data needs. A water quality model may be developed in another platform once sampling programs are expanded. This is the most efficient approach to use the resources available and create a program to address water quality needs and is further discussed in the SMP.

#### 2.4.1.6 *Infrastructure*

Additional information on the existing stormwater infrastructure is required to represent the current system. Collection of this information may also correspond to the City's Asset Management Plan, as outlined in the framework presented in the SMP. The following information should be collected:

- **Bridge and Culvert Inventory**
  A comprehensive inventory of culverts and bridges along the main watercourses within the City's municipal boundaries and at other locations experiencing drainage issues. This will require culvert and bridge inspections in addition to those completed in the Municipal Structure Inspections in 2010. The City recently compiled additional information that has yet to be included in the models, including four updated Municipal Structure Inspections in 2014 and an inventory of 389 culverts less than 3 m in diameter. Supplemental data will be required at the structures included in these inventories and at additional crossing locations to provide all information required for modelling purposes, including upstream and downstream inverts, top of road elevation, span, rise, material, skew angle, shape of culvert, and surveyed cross section of bridge openings. The data collected can be added to the bridge and culvert data sheets included in Attachment 1 (Page 86) for each watershed. The City can also submit information requests to the agencies with crossings on their properties, including Canadian National Railway, Canadian Pacific Railway, and the Ministry of Transportation Ontario (MTO), as they maintain records of their stormwater infrastructure.

- **Critical River and Ditch Cross Sections and Profiles**
  In addition to the survey work completed by the City as part of the bridge and culvert inventory and the information shared from the LRCA floodplain delineation, critical rivers and ditches should be surveyed and added to the model. If high resolution LiDAR data becomes available that measures ground elevation below water surfaces, the survey of critical ditch cross sections and profiles may not be needed.

- **Trunk Storm Sewers**
  A gap analysis of information available in GIS and as-built drawings for the trunk storm sewers should be performed. Information available in the as-built drawings should be added to GIS and any remaining gaps filled by surveys. Any efforts in this area completed by consultants or on site investigations should be merged into the current GIS files.

- **Survey of Other Hydraulic Structures**
  Other structures, such as weirs on McVicar Creek and the Neebing River, should be surveyed if information is not available from the LRCA's floodplain mapping updates.

- **Drainage System Information from Adjacent Municipalities, Townships, and Fort William First Nation (FWFN)**
  Gather drainage information, such as all the shapefiles the City provided listed earlier in this memo, to improve representation where watersheds also cross through Fort William First Nation, Municipality of Shuniah, Municipality of Oliver Paipoonge, Municipality of Neebing, Township of Conmee, Township of O'Connor, and Township of Gillies.

It is also recommended that the City use the new infrastructure data collected to maintain an up-to-date Geographic Information System (GIS) which accurately and comprehensively reflects the existing public stormwater management system, including storm sewers, culverts, bridges, ditches, other hydraulic control structures, and other stormwater management facilities.

#### *2.4.1.7 Topography, soils, and land use*

Particularly important data inputs for the model development are the topography, soils, and land use data sets.

A high resolution Digital Elevation Model (DEM) is recommended to better reflect the storage available in the river and creek floodplains in addition to reflecting the topography of the contributing watersheds. Representing such topography will provide the necessary details required to capture representative cross sections of watercourses and ditches and confirm drainage patterns in particularly flat areas. The DEMs provided by the City and Canadian Digital Elevation Data have low horizontal resolutions of 15 m and 10 m grids respectively, and low vertical resolutions of 1 m elevation intervals. Both appear to have been created using City and Ontario Base Mapping contours. The recommended horizontal resolution (i.e. grid spacing) is less than or equal to 0.5 m while the recommended vertical resolution is less than or equal to 0.25 m. It is assumed that such a DEM can be attained through partnership with the LRCA because the LRCA is attaining new LiDAR for the updates to each watershed’s floodplain mapping.

Runoff from drainage areas is influenced by land uses. Land use helps determine imperviousness, surface roughness and depression storage. The land use dataset used in the Base Model development is a combination of the City’s land use datasets in the zoning layer and Official Plan in addition to provincial land cover mapping. In addition to updates based on information provided by adjacent municipalities, the following updates within the City limits are needed to clearly and consistently reflect, at the same level of detail, the existing and future land uses in two separate datasets:

- in rural areas, the datasets should identify the different types of crops and rural residential land uses that are currently all identified in the rural land use category.
- in rural areas, the datasets should clarify what kind of cover is present in rural industrial areas since the areas zoned for industrial land uses in the rural areas have varying imperviousness.
- in urban areas, separate the small commercial, park, and institutional areas that are currently included in the urban residential land use category
- in urban areas, identify the different densities of urban residential developments (i.e. high, medium, and low)
- in all areas, define the time period being considered for future conditions

The available soils mapping does not cover the upper Current River Watershed. The area is currently assumed to have similar soil types and associated infiltration properties to nearby soils and the assumption can be calibrated during the development of the Comprehensive Watershed Management Model. Alternatively, the possibility for gathering additional soils information should be explored in partnership with the LRCA, provincial government, and federal government (such as Agriculture and Agri-Food Canada).

### 2.4.2 Development of Comprehensive Watershed Management Models

The development of Comprehensive Watershed Management Models is recommended by incorporating the additional data listed in Section 2.4.1 and discretizing the Base Models (except for the Kaministiquia Watershed). The model development recommendations also apply to the Waterfront Watershed, which was not included in this study's scope.

The Comprehensive Watershed Management Models will provide a detailed understanding of the watershed systems in Thunder Bay and allow for continued examination and quantitative analysis of the watershed systems. A detailed understanding will also result in better allocation of financial resources in the long-term. The models will be able to assess each watershed's sensitivity to development pressure and climate change, while being able to evaluate the effectiveness of the existing and proposed stormwater infrastructure to reduce the risk of flooding and the impact of stormwater on the environment. In addition, the improved watershed models will afford more meaningful recommendations for standards, upgrades/improvements and the ability for new stormwater measures to be identified.

The necessary capabilities of the Comprehensive Watershed Management Models should include the following (although definition of scope is subject to change by the City's needs upon commencement of each model's development):

- Assessment of existing conditions in the watersheds to better investigate causes of existing drainage issues at a higher resolution than the Base Models.
  - Evaluate capacity of regional and local existing stormwater infrastructure, including trunk storm sewers and ditches
  - Evaluate functionality of both major and minor watercourse crossings
  - Resource evaluation at higher resolution than the Base Models
- Assessment of existing conditions and the potential hydrological and hydraulic impacts associated to future development
- Assessment of flood risk throughout each watershed.
- Assessment of potential impacts of climate change
- Scenario planning to improve stormwater quality at a more local scale
- Built such as they become the basis for future Feasibility-Level models
- Information used for: Standards evaluation and testing, and refined CIP budgeting

Development of the Comprehensive Watershed Management Models to provide the above capabilities may include the following non-exclusive tasks:

- Collect monitoring data for the appropriate period (1 to 2 years) and all other necessary data prior to model development.
- Incorporate new precipitation, climate, and flow time series.
- Discretize watercourse reaches to incorporate new cross sections using the high resolution DEM and the PCSWMM Transect Creator tool.
- Add new and updated culvert and bridge information from inventory.
- Add trunk storm sewers and ditches.
- Add details from surveying, such as spot elevations at crossings and priority cross sections.
- Discretize subcatchments to provide more detailed assessment of flows to tributaries, trunk storm sewers, and main ditches.
- Update subcatchment parameterization with high resolution DEM and land use data.
- Add drainage details from adjacent municipalities, townships, and FWFN.
- Consider using the 2-D floodplain analysis tools in PCSWMM to assess and visualize flood elevations in the model.
- Calibrate and validate the model results using a continuous, multi-year simulation including the winter and spring to consider snowpack accumulation and snowmelt.
- Validate event simulations of the models during the 2- to 100-year events and Regional Storm in comparison to a flood frequency analysis of flow monitoring stations with sufficient data.

### 2.4.3 Costs

The costs of implementing the recommendations for data collection and model development are in Table 21 and total approximately $1.3 million or $79,200 per year over 17 years (Year 4 to Year 20 of the SMP Implementation). Several data collection recommendations are assumed will be attained through partnership with other organizations, such as the High Resolution DEM from the LRCA, or will be included within the City's organizational costs, such as GIS management and improving land use mapping.

**Table 21. Cost Estimate for Future Model Development**

| Task | Unit Cost | | Quantity | Cost |
|---|---|---|---|---|
| **Upgrade existing 9 LRCA rain gauges to weather stations** | $2,479 | /station | 9 | $22,300 |
| **Install heated and wind-shielded tipping buckets** ***(in McIntyre, McVicar, Mosquito, & Pennock Watersheds)*** | $1,959 | /station | 4 | $7,800 |
| **Snow Survey for 2 years at 19 stations** | $288 | /station | 19 | $5,500 |
| **Flow Monitoring at 18 new stations** | $767 | /station | 18 | $13,800 |
| **Inventory and Create GIS Layer of Existing Ditch System** | $20,000 | /watershed | 8 | $160,000 |
| **Bridge and Culvert Inventory** | $12,000 | /watershed | 8 | $96,000 |
| **Critical Ditch Cross Sections and Profiles** | $24,000 | /watershed | 8 | $192,000 |
| **Trunk Storm Sewers Gap Analysis, Survey, and Information Management** | $14,152 | /watershed | 8 | $113,200 |
| **Survey of Other Hydraulic Structures** | $2,000 | /watershed | 8 | $16,000 |
| **Drainage System Information from Adjacent Municipalities, Townships, and Fort William First Nation** | | | | |
| *Kaministiquia* | $7,500 | | 1 | $7,500 |
| *Other 7 Watersheds* | $1,500 | /watershed | 7 | $10,500 |
| **PCSWMM License for City's use (for one user, other options available)** | $1,440 | /yr | 17 | $24,500 |
| **Model Updates to Develop Comprehensive Watershed Management Models** | | | | |
| *Neebing & Pennock* | $125,000 | | 1 | $125,000 |
| *McIntyre & McVicar* | $225,000 | | 1 | $225,000 |
| *Waterfront* | $100,000 | | 1 | $100,000 |
| *Current & Mosquito* | $200,000 | | 1 | $200,000 |
| | | | **Total Cost** | **$1,319,100** |
| | | | **Annual Cost** | **$77,600** |

### 2.4.4 Implementation

Implementing the recommendations for data collection and model development is recommended to commence in Year 4 following the completion of the SMP to provide time for the City to develop resources for this and many other recommended implementation items in the SMP. To spread the cost of the recommendations over multiple years, it is recommended that the City prioritize the data collection and model development of certain watersheds to make early progress on watersheds of particular concern. The Neebing River, McIntyre River, and Waterfront watersheds appear to have the most concerns regarding stormwater impacts with regards to historic flooding, new development pressures, and infill development. In addition, the LRCA has identified the McIntyre River as the first watershed to undergo a floodplain delineation update and can share the data used for the analysis with the City to reduce needed resources for both studies. The City has made progress in assessing and addressing issues in the McVicar Creek watershed and so it is also recommended that the momentum is continued by also prioritizing the model development in this area. The following is a complete prioritized list for implementing model development improvements:

1. Neebing River and Pennock Creek Watersheds
2. McIntyre River and McVicar Creek Watersheds
3. Waterfront Watershed
4. Current River & Mosquito Creek Watersheds

There are multiple other recommendations in the SMP specific to each of the eight watersheds, such as a stream assessment of each main river and creek. It is recommended that all watershed-specific data and studies recommended here and as part of the SMP be compiled into Watershed Plans for each of the eight watersheds in Thunder Bay. In consultation with the LRCA, the Watershed Plans will further develop watershed specific goals and stormwater management performance criteria, as recommended in the MOECC's Interpretation Bulletin on expectations or stormwater management (2015). Each Watershed Plan's recommendations can then be implemented immediately and incorporated into the next 5-year review of the SMP.

## 3 Northwest Arterial Golf Links Feasibility-Level Model

The Northwest Arterial Golf Links Study Area (hereafter in this section referred to as the Golf Links Study Area) was assessed to compare the costs and benefits of applying different development approaches to the urban expansion planned in the area. The impact of development on peak flow and runoff volume was estimated for each scenario using a feasibility-level model in addition to pollutant loadings. The model scenarios below were developed to illustrate what may occur in cases where site plan control does not apply. The model scenarios then illustrate how the SMP can improve stormwater management through application of additional rate and volume control requirements.

The Golf Links Study Area is bounded by Oliver Road to the south, Golf Links Road and the Hydro One easement to the east, and the Thunder Bay Expressway (Highway 11/17), hereafter referred to as the Expressway, to the west and north. As shown in Figure 13, a significant portion of the 80 hectare Golf Links Study Area is coniferous forest identified as a swamp.

Development scenarios with varying levels of stormwater management (SWM) were assessed using stormwater models developed in PCSWMM. Annual pollutant loading calculations (including total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN)) and cost estimates were also developed for the different scenarios. These development scenarios were completed only for the 80 hectare Golf Links Study Area, while an additional existing conditions model was prepared to assess the local and regional drainage. The different SWM facilities were located and sized in a broad way for comparison purposes and are subject to change during a more detailed design.

The following development scenarios were considered:

***Existing Conditions***

The Golf Links Study Area under current conditions, including the development fronting Oliver Road but not including recent improvements to the Lakehead Region Conservation Authority (LRCA) property and Golf Links Road. Local and regional drainage were assessed in two stormwater models.

***Proposed Conditions***

**Scenario 1** The fully developed Golf Links Study Area following past development practices with uncontrolled runoff directed to storm sewers and ditches designed for the 2-year event.

**Scenario 2** The fully developed Golf Links Study Area with the same land use plan as Scenario 1 but with the additional regulatory requirements of universal site plan control. SWM ponds were designed to match existing conditions peak flows and other standards defined in the City’s Engineering and Development Standards (2014).

**Scenario 3** The fully developed Golf Links Study Area with the same land use plan as Scenario 1. Infiltration facilities were sized to retain 28 mm of runoff from impervious surfaces and SWM ponds were calculated to control the remaining runoff from the area to existing peak flows.

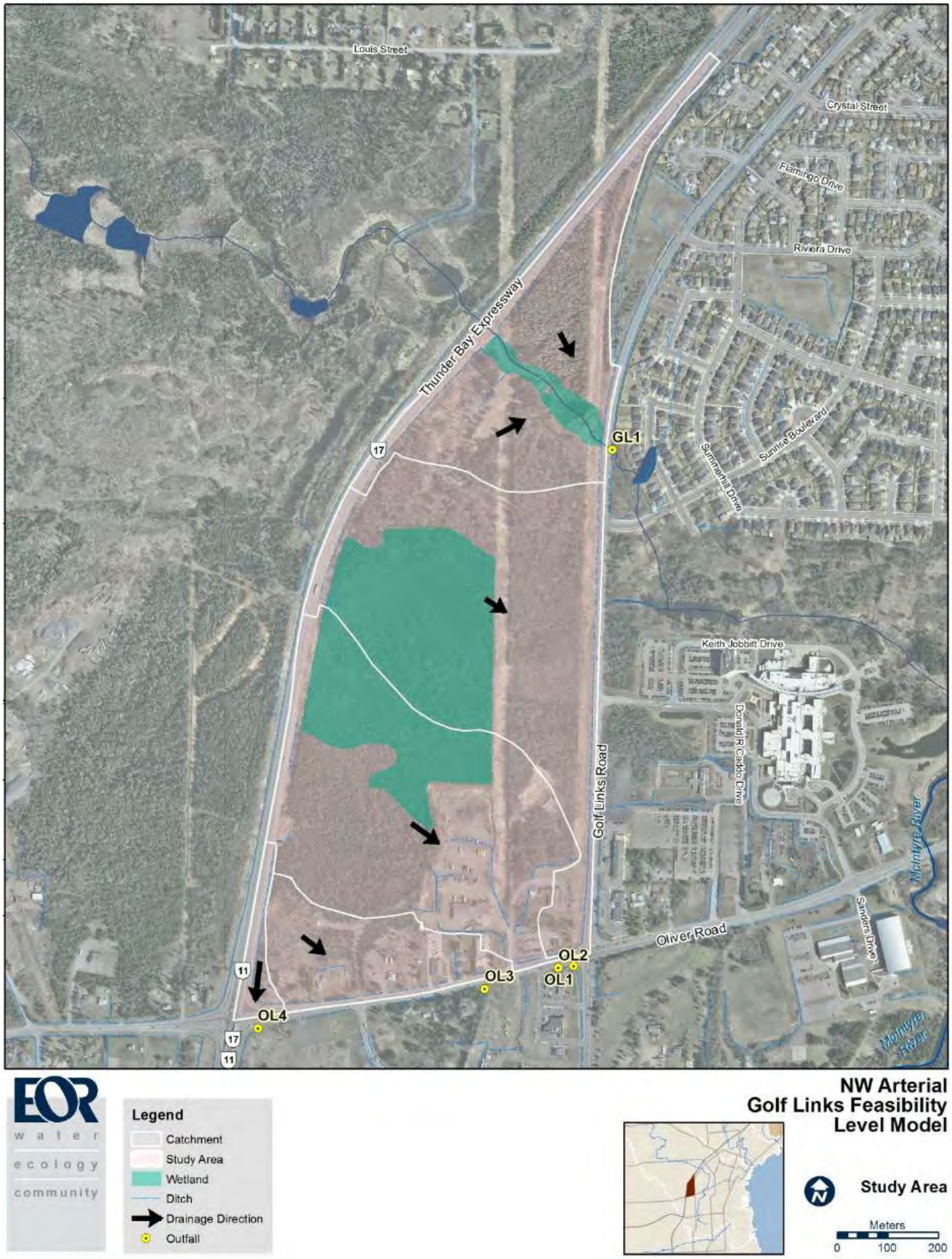


**Figure 13. Golf Links Study Area**

## 3.1 Background

Pertinent information on drainage conditions in the Golf Links Study Area was obtained through a review of the following material:

- Renew Thunder Bay Golf Links Road / Junot Avenue Corridor Study, prepared by IBI on behalf of the City, 2012
- Golf Links Road / Junot Ave Reconstruction and Widening, Stage 1, Drawing Set Issued for Construction, 2013
- Oliver Road Reconstruction As-Built Drawings, 2004
- Draft Culvert Inspection Report for Thunder Bay Expressway Planning and Preliminary Design, Arthur Street to Balsam Street, prepared by URS on behalf of MTO, 2014

Available soils mapping, GIS data, and aerial photography from the City and provincial sources was also used, including the following:

- Provincial soils mapping from Land Information Ontario
- Provincial Land Cover
- Zoning maps
- Parcel maps
- Aerial imagery, 2012
- Contours, 1 m
- Wetlands mapping by Ministry of Natural Resources and Forestry (MNRF)

A site visit was completed on September 17$^{th}$, 2014 by EOR to confirm existing stormwater infrastructure and drainage pathways.

In addition to the land development planned in the Study Area, improvements to the roads bounding the site are also proposed. The MTO plans to reconstruct Oliver Road in the form of a flyover or overpass over the Expressway and is considering widening the Expressway.

The City owns the majority of the land within the Study Area. The properties not within municipal ownership include the residential, commercial, and privately owned lands fronting the north side of Oliver Road, lands owned by the Lakehead Regional Conservation Authority (LRCA) which front onto Golf Links Road, and the properties between Golf Links Road and the unopened road allowance for Conservation Road.

Mapping of wetlands in Thunder Bay was updated in April, 2014 by the Spatial Data Infrastructure (SDI) staff of the MNRF, Lakehead Forest Management Unit. Using the current 3D summer leaf-on orthophotography to capture wetland features increased the representation of features from past mapping. Certain wetlands have been evaluated through the Ontario Wetland Evaluation System (OWES) in the past. Wetlands that meet certain criteria are identified as Provincially Significant Wetlands (PSW) and have protection under the Provincial Policy Statement (PPS). Delineation of the wetlands evaluated through the OWES were not altered during the 2014 update.

## 3.2 Rainfall and Design Storms

In addition to the Regional Timmins Storm, design storms were generated using the updated IDF curves developed for the SMP and the 24 hour SCS Type II distribution. The rainfall depth of each return period is summarized in Table 22.

**Table 22. Depth-Frequency for Thunder Bay Airport Station (6048261) for the 24-hour Duration**

| Return Period (years) | Rainfall Depth (mm) |
|---|---|
| 2 | 48.7 |
| 5 | 67.0 |
| 10 | 79.0 |
| 25 | 94.2 |
| 50 | 105 |
| 100 | 117 |

## 3.3 Existing Conditions

As shown in Figure 13, runoff from the Golf Links Study Area currently drains overland and along ditches to five outfalls: four of which cross Oliver Road (referred to as OL1, OL2, OL3, and OL4) and one on the McIntyre River tributary crossing the Golf Links Road (referred to as GL1). The soils in the Golf Links Study Area are predominantly organic and sandy loam, with one small deposit of very fine sandy loam, as shown in Figure 14. The existing land use is primarily coniferous forest and swamp with a small developed area along Oliver Road including hamlet residential, institutional, commercial, and industrial, as shown in Figure 15.

A model of the existing conditions in the Golf Links Study Area was developed in PCSWMM. Area-weighted average Green-Ampt infiltration parameters were calculated for each catchment based on the soils. The land use was used to determine impervious coverage, depression storage, and Manning's Roughness of overland flow. The culverts at outfalls OL1, OL2, and OL3 were modelled as shown in the as-built drawings provided by the City for Oliver Road and Golf Links Road improvements. The culvert at outfall OL4 was modelled as shown in the MTO draft culvert inspection forms. No information was available regarding the culvert crossing Golf Links Road at outfall GL1, and so it was assumed to be the same size as the upstream culvert crossing the Expressway. The size and elevations of the ditches was estimated based on 1 m contour mapping and on site investigation. The peak flow and runoff volumes from the Golf Links Study Area under existing conditions are summarized in Table 23 for each return period.

**Table 23. Existing Conditions Model Results**

| Storm | Peak Flow ($m^3/s$) | | | | | Runoff Volume ($m^3$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | GL1 | OL1 | OL2 | OL3 | OL4 | GL1 | OL1 | OL2 | OL3 | OL4 |
| 2-year | 0.03 | 0.13 | 0.34 | 0.19 | 0.05 | 762 | 576 | 2,156 | 831 | 161 |
| 5-year | 0.10 | 0.20 | 0.49 | 0.28 | 0.09 | 1,856 | 1,144 | 3,374 | 1,624 | 294 |
| 10-year | 0.15 | 0.26 | 0.59 | 0.34 | 0.12 | 2,792 | 1,672 | 4,568 | 2,192 | 396 |
| 25-year | 0.23 | 0.33 | 0.78 | 0.38 | 0.16 | 4,168 | 2,529 | 6,899 | 2,399 | 523 |
| 50-year | 0.28 | 0.38 | 0.90 | 0.42 | 0.19 | 5,238 | 3,233 | 8,469 | 2,792 | 625 |
| 100-year | 0.18 | 0.42 | 1.03 | 0.47 | 0.23 | 3,052 | 4,149 | 10,290 | 3,229 | 736 |
| Regional (Timmins) | 0.46 | 0.17 | 0.75 | 0.35 | 0.13 | 9,792 | 5,744 | 19,770 | 5,360 | 1,291 |

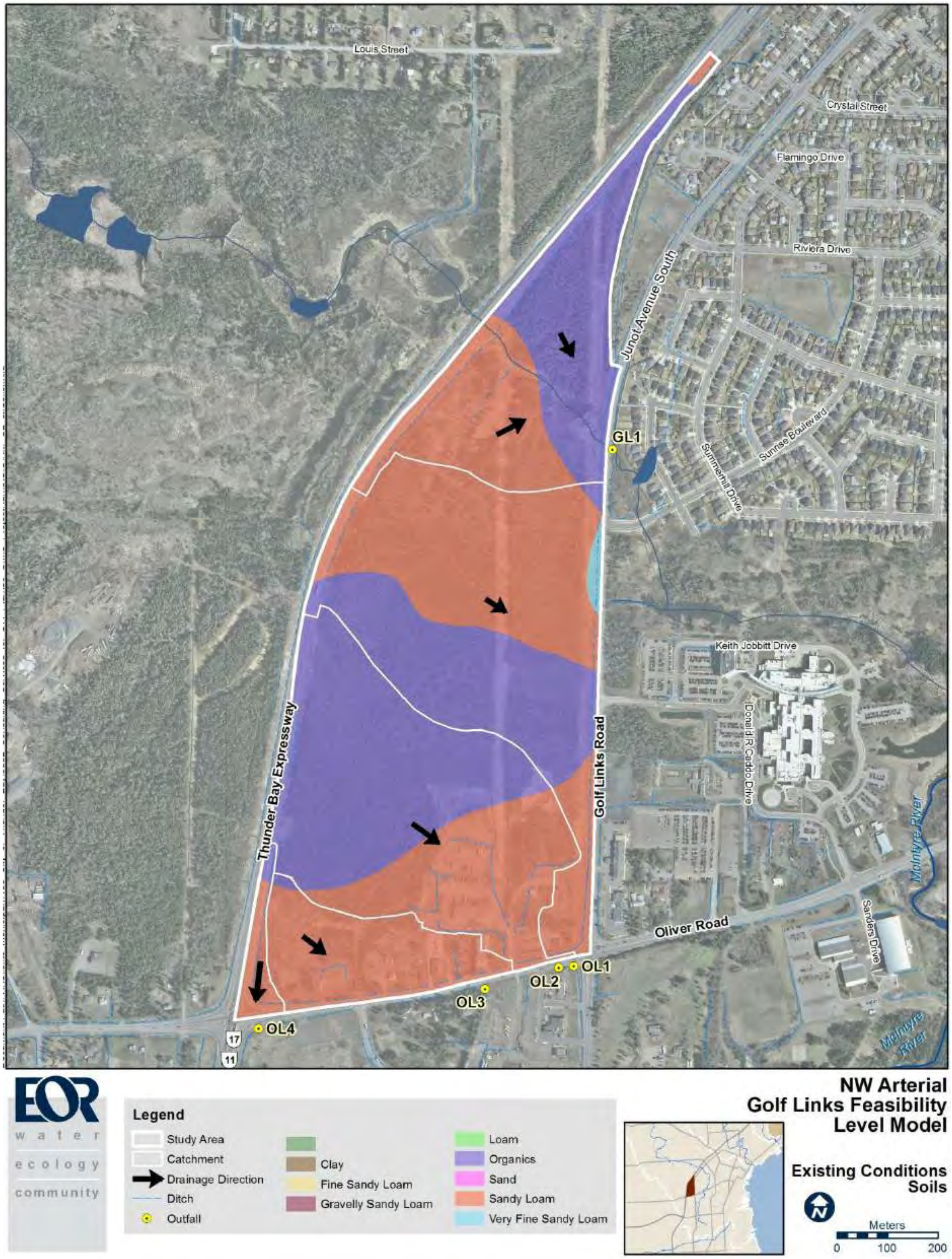


**Figure 14. Soils in Golf Links Study Area**

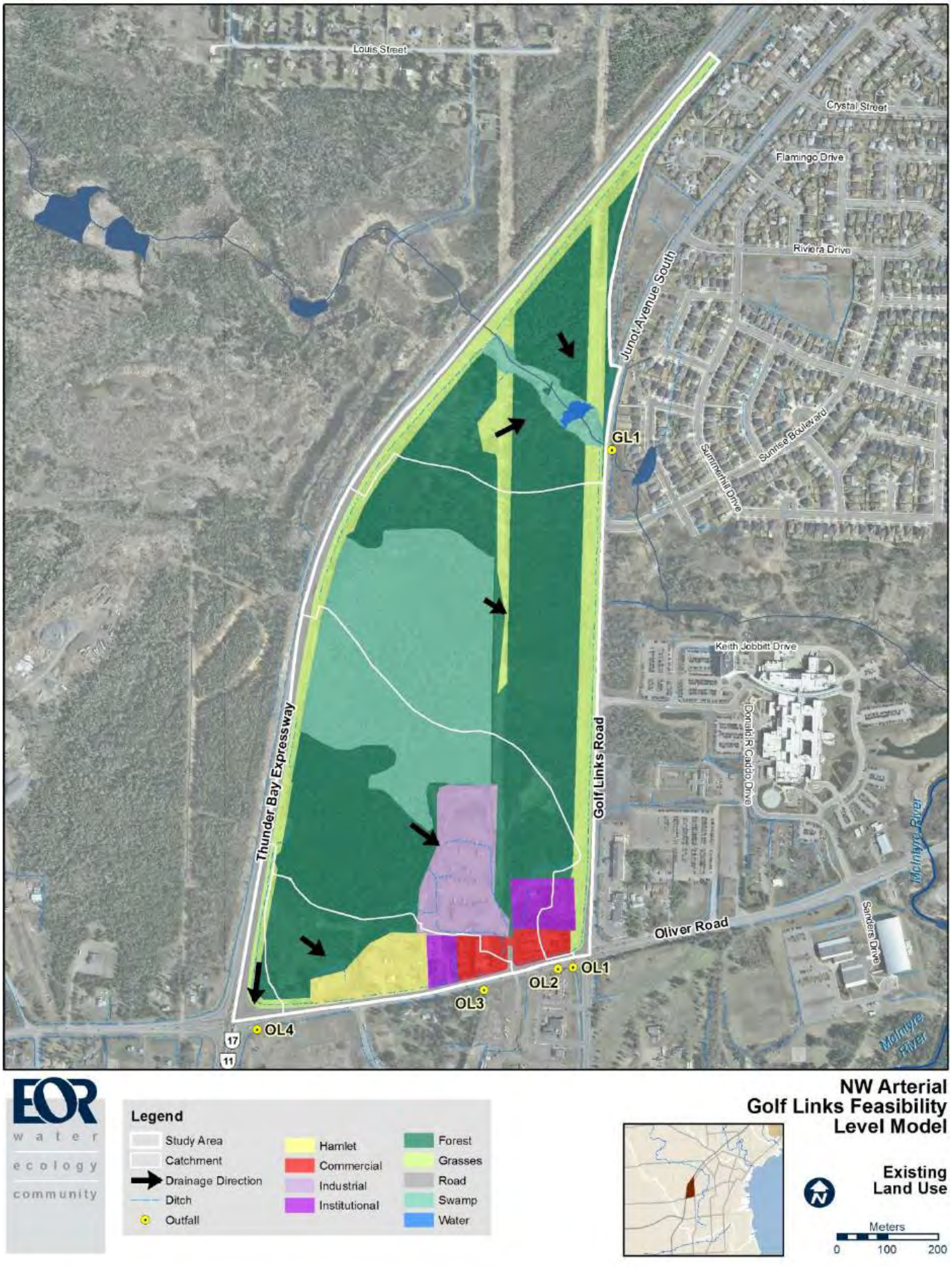


**Figure 15. Existing Land Use in Golf Links Study Area**

The existing conditions model was also expanded into a regional model to include the external drainage area. This model was prepared to provide an indication of potential flooding and capacity issues. The total area of this model is 709 ha and is located entirely within the McIntyre River Watershed. The external drainage area northwest of the Golf Links Study Area drains to the McIntyre River tributary and several culverts crossing the Expressway into the Study Area. A smaller external drainage area extends along the roadside ditch on the west side of Golf Links Road draining to the north side of the Study Area. The soils include sandy loam, organics, gravel pits, gravelly sandy loam, and bedrock, as shown in Figure 16. The land uses beyond the local drainage area are predominantly forest, wetland, hamlet residential, and gravel pits and are shown in Figure 5.

Golf Links Road and Oliver Road are major arterial municipal roads while the Expressway is an arterial highway. As such, culverts crossing Golf Links Road and Oliver Road should accommodate the 25-year storm in accordance with the City's Engineering and Development Standards (2014). In comparison, the culverts crossing the Expressway should accommodate the 100-year design flows in accordance with the MTO Highway Drainage Design Standards. The culvert at outfall GL1 should therefore also be sized to the 100-year design storm. The entrance culverts crossing driveways should convey the 10-year storm in accordance with the City's Engineering and Development Standards (2014).

The regional model results indicated that the culverts crossing Conservation Road and driveways off of Oliver Road are undersized with a 2-year event level of service. The model estimated that the culvert at OL4 has a 25-year event level of service whereas all others have a 100-year event or greater level of service. Although the culverts crossing Oliver Road conveyed the 25-year design flow, the ditches upstream of the culverts at OL2 and OL1 flooded in the model simulation. Improving the representation of the ditch cross sections would clarify the cause, extent, and location of the flooding.

While constructing the model, it was also noted that the Golf Links Road/Junot Avenue Reconstruction Drawings show a 760 mm diameter culvert downstream of the culvert at OL1 (a 900 mm diameter culvert). The reduction in downstream culvert capacity may represent a significant problem that would have to be addressed at the time development occurs to remove the constriction point in the system.

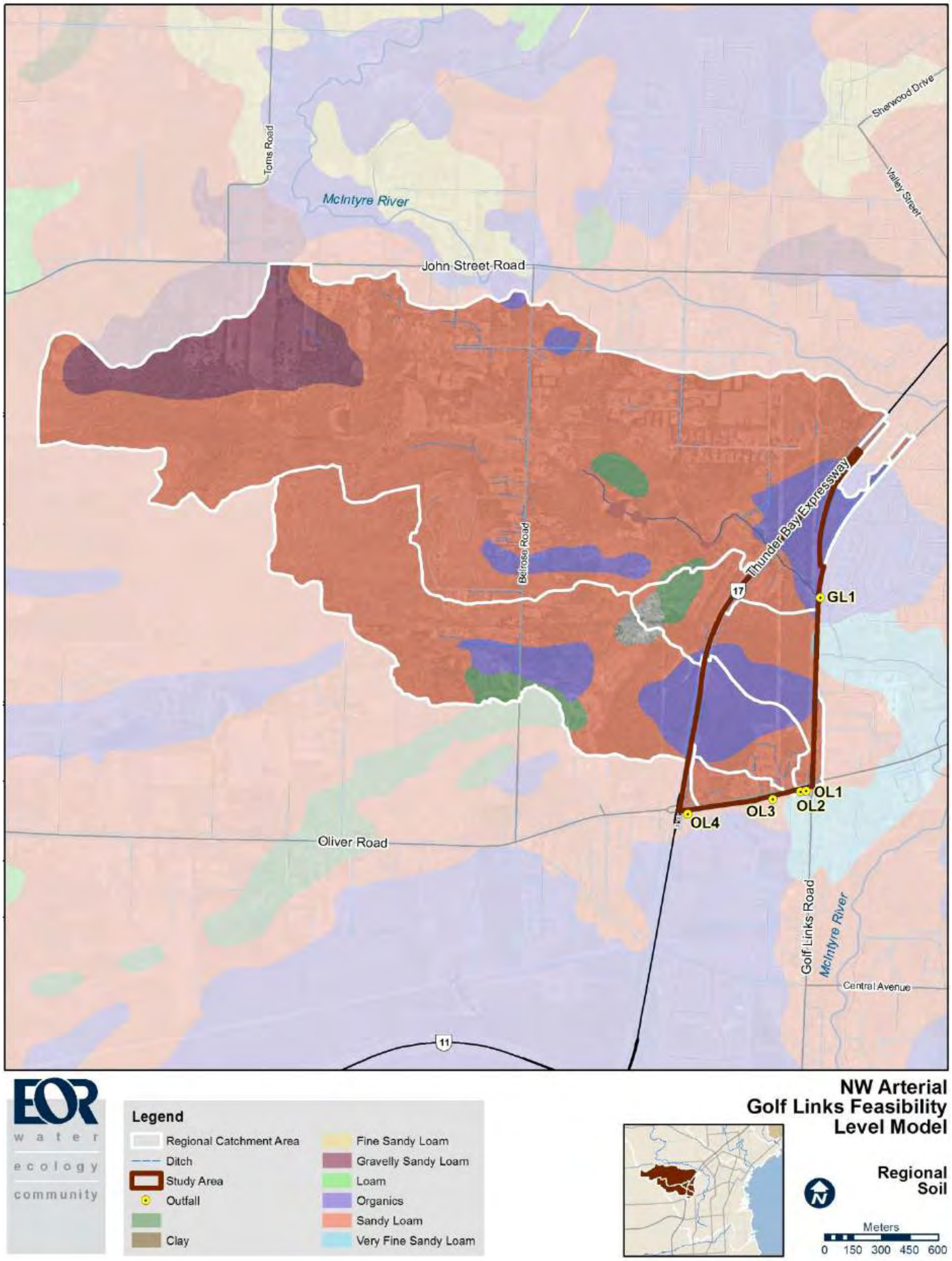


**Figure 16. Soils in Extents of Golf Links Regional Model**

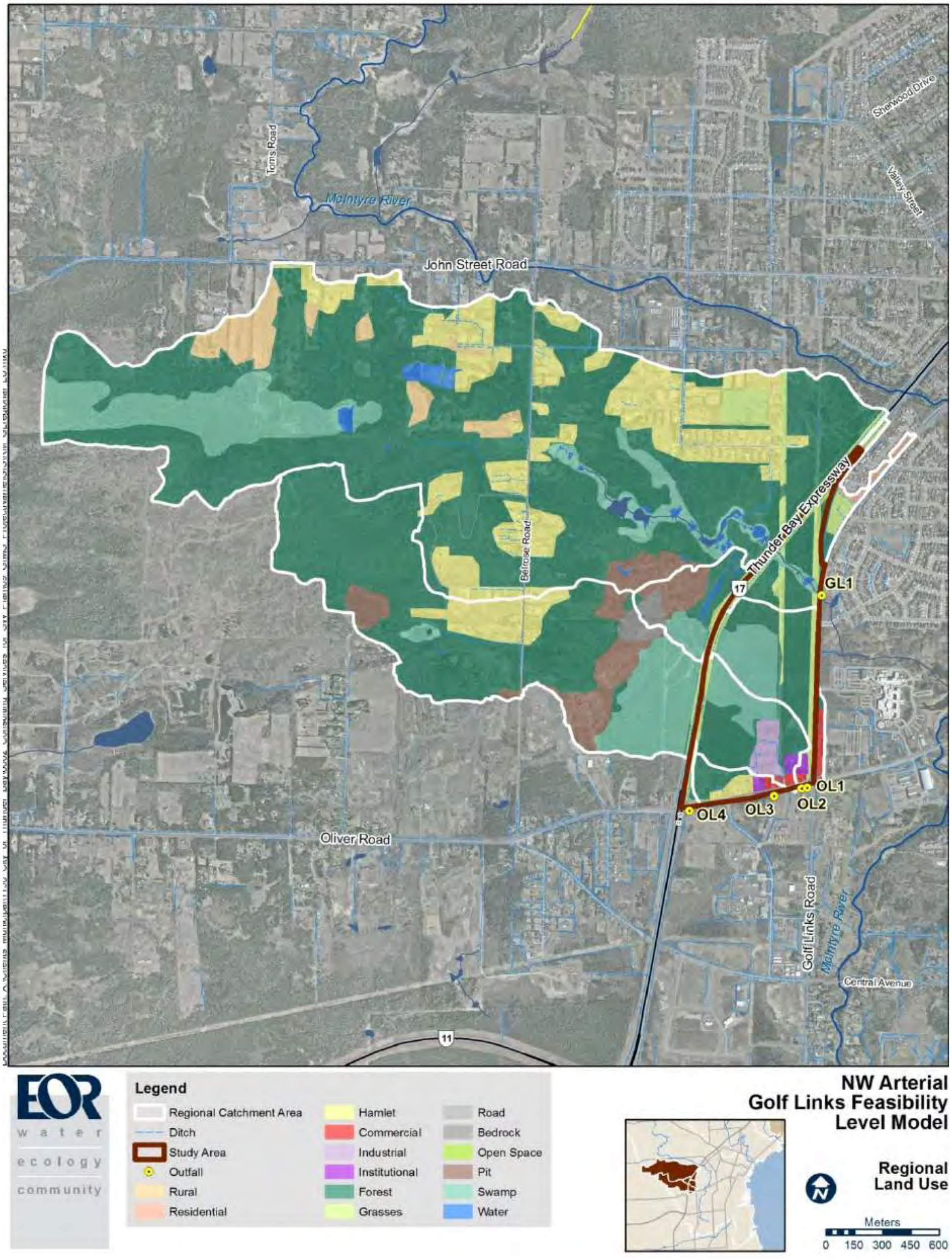


**Figure 17. Land Use in Extents of Golf Links Regional Model**

## 3.4 Proposed Conditions

### 3.4.1 Scenario 1: No Stormwater Management Controls

A land use plan for future development in the Golf Links Study Area was recommended in the Renew Thunder Bay Golf Links Road/Junot Avenue Corridor Study (2012). The proposed land uses include single family residential, dense residential, institutional, commercial, parks, and undeveloped land, as shown in Figure 18. The entire wetland area is proposed to be filled and developed into residential land use.

The storm sewers and ditches in the Golf Links Study Area were designed to meet the following criteria outlined in the City's Engineering and Development Standards (2014):

- Minor system storm sewers and ditches designed to convey 2-year storm.
- Culverts crossing arterial roads should accommodate the 25-year storm. All other culverts, including culverts crossing driveways off of Arterial roads, should be designed to convey 10-year storm.

The model included the following assumptions:

- Ditches and culverts at southeast corner were left the same as in existing conditions.
- Runoff from most of the new developments is conveyed by storm sewers to the roadside ditches and then to the outfalls.
- 50% of the impervious area in subdivisions is directed to pervious area (ex. Rooftops drain onto lawns).
- 100% of the impervious area along major roads drains to pervious area (ditches).

As expected, the increase in impervious area from 12% to 41% without any stormwater management controls greatly increased peak flows and runoff volumes to all outfalls for each return period, as shown in Table 24.

The implications of increased peak flows would mainly be felt downstream of the Golf Links Study Area where stormwater infrastructure will receive increased peak flows it was not designed for. The result will be flooding damage downstream. Increasing the size of the downstream culvert from the Golf Links Study Area would address the constriction at that culvert. The resulting new flow will then impact the next downstream culvert. The impacts would be passed downstream as each successive piece of infrastructure is upgraded. The effect of repetitive upgrades will be expensive and unnecessary work. The alternative is to implement one or more modern stormwater management option(s) within the proposed development at lesser cost and work.

Another impact of simply fixing one piece of infrastructure at a time, versus dealing with it on site, is that there would be increases in pollutants, such as sediment, phosphorus, and nitrogen to the McIntyre River tributary. Erosion along ditches and watercourses will increase, requiring ditch maintenance. The quality of aquatic habitats in the tributary will be affected by the pollutant loadings.

Although City design standards do not support this development approach, the scenario was included to illustrate what may still occur in the cases where site plan control does not apply.

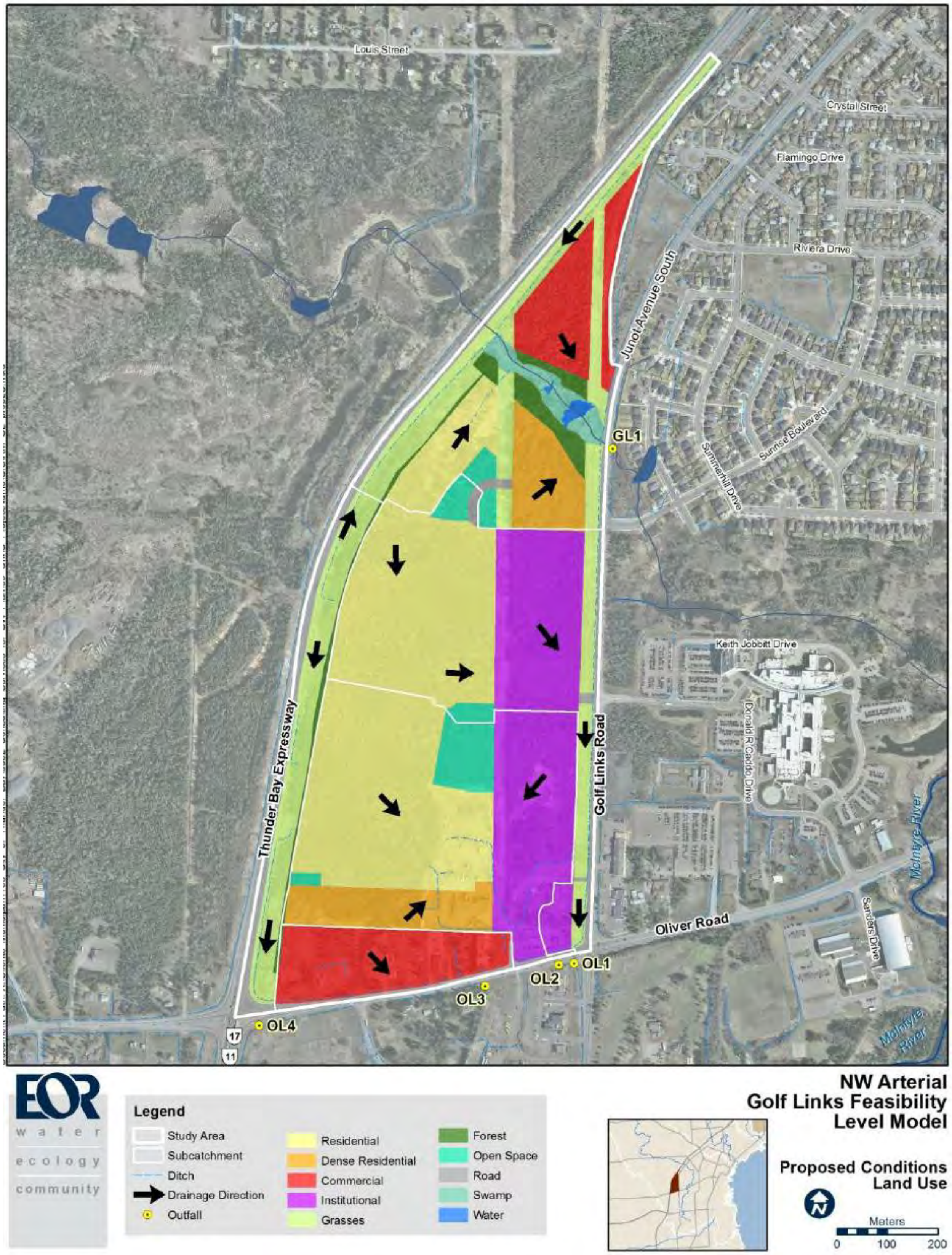


Figure 18. Proposed Land Use in Golf Links Study Area

**Table 24. Comparison of Proposed Scenario 1 to Existing Conditions**

| Storm | Peak Flow ($m^3$/s) | | | | | Runoff Volume ($m^3$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | GL1 | OL1 | OL2 | OL3 | OL4 | GL1 | OL1 | OL2 | OL3 | OL4 |
| **Existing Conditions** | | | | | | | | | | |
| **2-year** | 0.03 | 0.13 | 0.34 | 0.19 | 0.05 | 762 | 576 | 2,156 | 831 | 161 |
| **5-year** | 0.10 | 0.20 | 0.49 | 0.28 | 0.09 | 1,856 | 1,144 | 3,374 | 1,624 | 294 |
| **10-year** | 0.15 | 0.26 | 0.59 | 0.34 | 0.12 | 2,792 | 1,672 | 4,568 | 2,192 | 396 |
| **25-year** | 0.23 | 0.33 | 0.78 | 0.38 | 0.16 | 4,168 | 2,529 | 6,899 | 2,399 | 523 |
| **50-year** | 0.28 | 0.38 | 0.90 | 0.42 | 0.19 | 5,238 | 3,233 | 8,469 | 2,792 | 625 |
| **100-year** | 0.18 | 0.42 | 1.03 | 0.47 | 0.23 | 3,052 | 4,149 | 10,290 | 3,229 | 736 |
| **Regional (Timmins)** | 0.46 | 0.17 | 0.75 | 0.35 | 0.13 | 9,792 | 5,744 | 19,770 | 5,360 | 1,291 |
| **Conditions under Scenario 1 with No Stormwater Management Controls** | | | | | | | | | | |
| **2-year** | 0.26 | 0.95 | 1.26 | 0.41 | 0.08 | 3,736 | 4,333 | 4,326 | 2,260 | 439 |
| **5-year** | 0.42 | 1.43 | 1.92 | 0.57 | 0.16 | 5,935 | 6,819 | 6,938 | 3,197 | 1,024 |
| **10-year** | 0.55 | 1.66 | 2.33 | 0.64 | 0.24 | 7,515 | 8,563 | 8,865 | 3,814 | 1,486 |
| **25-year** | 0.71 | 1.66 | 2.83 | 0.71 | 0.34 | 9,647 | 10,380 | 11,410 | 4,602 | 2,129 |
| **50-year** | 0.85 | 1.66 | 3.15 | 0.75 | 0.42 | 11,230 | 10,320 | 13,300 | 5,160 | 2,615 |
| **100-year** | 0.98 | 1.66 | 3.49 | 0.84 | 0.42 | 12,300 | 11,580 | 15,440 | 5,781 | 2,655 |
| **Regional (Timmins)** | 0.99 | 1.66 | 2.21 | 0.60 | 0.43 | 22,230 | 22,500 | 28,780 | 9,181 | 6,312 |
| **Increase from Existing Conditions** | | | | | | | | | | |
| **2-year** | 0.22 | 0.81 | 0.92 | 0.22 | 0.03 | 2,974 | 3,757 | 2,170 | 1,429 | 278 |
| **5-year** | 0.33 | 1.23 | 1.43 | 0.29 | 0.07 | 4,079 | 5,675 | 3,564 | 1,573 | 730 |
| **10-year** | 0.40 | 1.41 | 1.74 | 0.30 | 0.12 | 4,723 | 6,891 | 4,297 | 1,622 | 1,090 |
| **25-year** | 0.47 | 1.33 | 2.04 | 0.33 | 0.18 | 5,479 | 7,851 | 4,511 | 2,203 | 1,606 |
| **50-year** | 0.57 | 1.29 | 2.25 | 0.33 | 0.23 | 5,992 | 7,087 | 4,831 | 2,368 | 1,990 |
| **100-year** | 0.81 | 1.24 | 2.46 | 0.38 | 0.20 | 9,248 | 7,431 | 5,150 | 2,552 | 1,919 |
| **Regional (Timmins)** | 0.52 | 1.49 | 1.46 | 0.25 | 0.30 | 12,438 | 16,756 | 9,010 | 3,821 | 5,021 |

### 3.4.2 Scenario 2: Universal Site Plan Control

The second development scenario assessed the benefits of applying the current Engineering and Development Standards (2014) to all future developments, including the following:

- Match existing peak flows for all storm events up to the 100-year storm event.
- Provide water quality controls with the Ministry of Environment and Climate Change's (MOECC's) enhanced level of protection (80% of suspended solids).
- Minor system, including storm sewers and ditches, designed to convey the 2-year storm.
- Culverts crossing arterial roads accommodate the 25-year storm while all others convey 10-year storm

The ponds were designed with simplified, v-notch weir outlets that over-controlled smaller storms while allowing increases in the larger storms. The result of this stormwater control infrastructure approach is shown in Table 25. The pond design scenario would be addressed during detailed design by using a staged outlet to better match the existing peak flows for each return period. The results indicate that this scenario decreased runoff volumes in comparison to Scenario 1. The difference is an artifact of the model due to the drawdown time required for the ponds to drain through the bottom of the v-notch weirs. In reality, reducing peak flows in SWM ponds (Scenario 2) does not reduce runoff volumes unless long-term open water evapotranspiration is considered.

**Table 25. Comparison of Proposed Scenario 2 and Existing Conditions**

| Storm | Peak Flow ($m^3/s$) | | | | | Runoff Volume ($m^3$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | GL1 | OL1 | OL2 | OL3 | OL4 | GL1 | OL1 | OL2 | OL3 | OL4 |
| **Existing Conditions** | | | | | | | | | | |
| 2-year | 0.03 | 0.13 | 0.34 | 0.19 | 0.05 | 762 | 576 | 2,156 | 831 | 161 |
| 5-year | 0.10 | 0.20 | 0.49 | 0.28 | 0.09 | 1,856 | 1,144 | 3,374 | 1,624 | 294 |
| 10-year | 0.15 | 0.26 | 0.59 | 0.34 | 0.12 | 2,792 | 1,672 | 4,568 | 2,192 | 396 |
| 25-year | 0.23 | 0.33 | 0.78 | 0.38 | 0.16 | 4,168 | 2,529 | 6,899 | 2,399 | 523 |
| 50-year | 0.28 | 0.38 | 0.90 | 0.42 | 0.19 | 5,238 | 3,233 | 8,469 | 2,792 | 625 |
| 100-year | 0.18 | 0.42 | 1.03 | 0.47 | 0.23 | 3,052 | 4,149 | 10,290 | 3,229 | 736 |
| Regional (Timmins) | 0.46 | 0.17 | 0.75 | 0.35 | 0.13 | 9,792 | 5,744 | 19,770 | 5,360 | 1,291 |
| **Conditions under Scenario 2 with Universal Site Plan Control** | | | | | | | | | | |
| 2-year | 0.03 | 0.08 | 0.15 | 0.12 | 0.02 | 2,938 | 3,926 | 4,139 | 2,198 | 417 |
| 5-year | 0.08 | 0.16 | 0.34 | 0.21 | 0.08 | 5,089 | 6,446 | 6,754 | 3,139 | 1,006 |
| 10-year | 0.13 | 0.24 | 0.50 | 0.28 | 0.11 | 6,654 | 8,129 | 8,660 | 3,750 | 1,469 |
| 25-year | 0.18 | 0.37 | 0.74 | 0.37 | 0.18 | 8,767 | 10,430 | 11,210 | 4,545 | 2,114 |
| 50-year | 0.25 | 0.38 | 0.93 | 0.44 | 0.22 | 10,340 | 10,520 | 13,090 | 5,107 | 2,603 |
| 100-year | 0.26 | 0.46 | 1.16 | 0.52 | 0.25 | 11,410 | 12,190 | 15,250 | 5,743 | 2,629 |
| Regional (Timmins) | 0.48 | 0.98 | 1.34 | 0.45 | 0.35 | 18,410 | 22,130 | 28,570 | 9,127 | 6,289 |
| **Increase from Existing Conditions** | | | | | | | | | | |
| 2-year | 0.00 | -0.05 | -0.19 | -0.07 | -0.03 | 2,176 | 3,350 | 1,983 | 1,367 | 256 |
| 5-year | -0.02 | -0.04 | -0.15 | -0.07 | -0.01 | 3,233 | 5,302 | 3,380 | 1,515 | 712 |
| 10-year | -0.02 | -0.01 | -0.09 | -0.06 | -0.01 | 3,862 | 6,457 | 4,092 | 1,558 | 1,073 |
| 25-year | -0.06 | 0.04 | -0.04 | -0.01 | 0.02 | 4,599 | 7,901 | 4,311 | 2,146 | 1,591 |
| 50-year | -0.03 | 0.00 | 0.04 | 0.02 | 0.03 | 5,102 | 7,287 | 4,621 | 2,315 | 1,978 |
| 100-year | 0.08 | 0.03 | 0.13 | 0.06 | 0.02 | 8,358 | 8,041 | 4,960 | 2,514 | 1,893 |
| Regional (Timmins) | 0.01 | 0.80 | 0.59 | 0.09 | 0.21 | 8,618 | 16,386 | 8,800 | 3,767 | 4,998 |

The required footprints of the ponds are illustrated in Figure 19 at potential locations in the low points of each development site and, when possible, not using development lots.

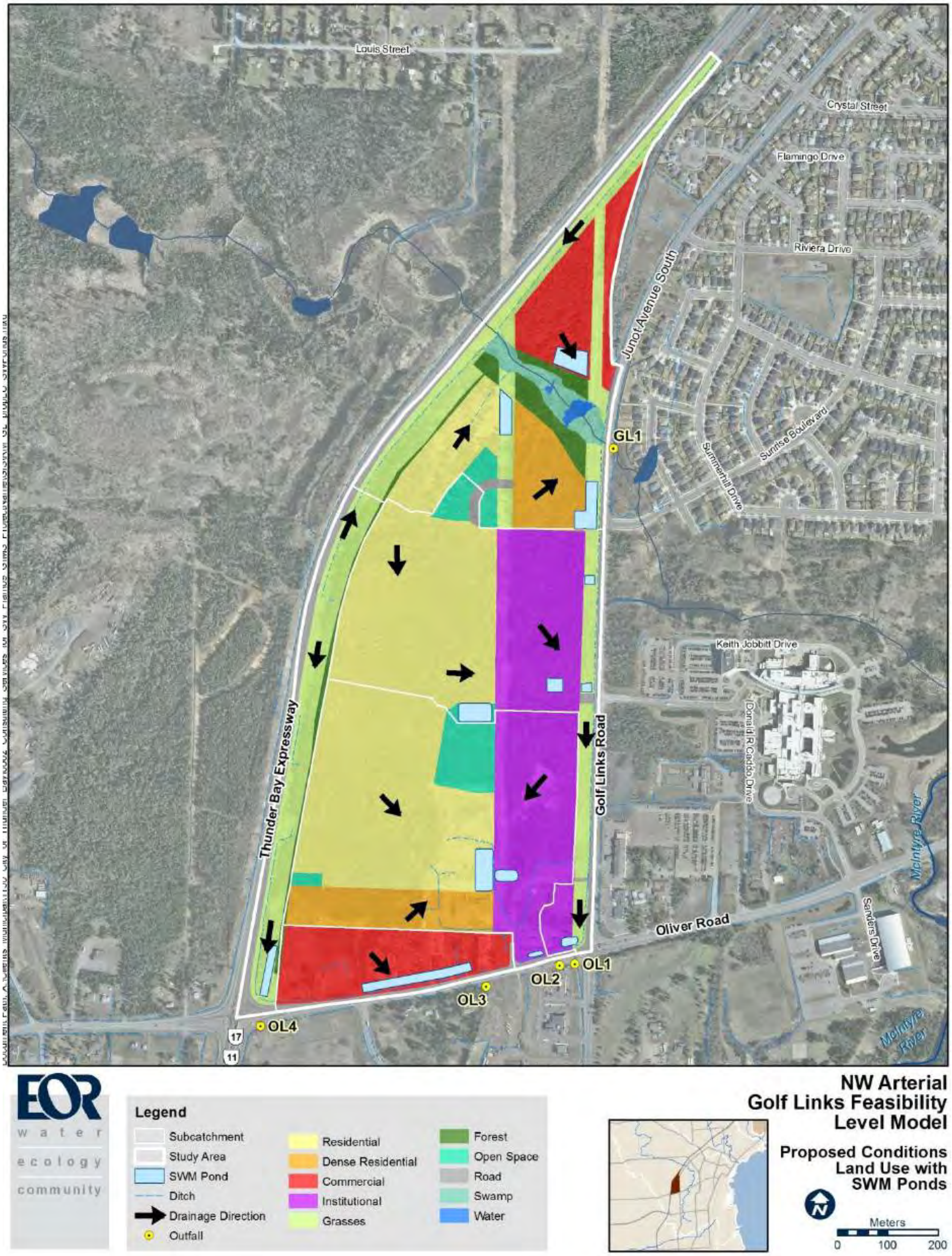


**Figure 19. SWM Facilities for Scenario 2 of Golf Links Study Area**

### 3.4.3 Scenario 3: Low Impact Development (Preserving the Original Site Layout)

Runoff volumes were reduced in the third development scenario using infiltration facilities designed to capture 28 mm of rainfall off of impervious surfaces. This rainfall depth represents approximately 90% of the total rainfall that occurs on an average year. Because the infiltration facilities are located upstream the SWM ponds, the size of each pond was reduced accordingly to still match the required existing conditions peak flow control. As in scenario 2, a similar compromise was made in matching existing conditions peak flows. In this case, the infiltration facilities lowered ponds' peak flows for the small rainfall events even more than in Scenario 2 (see Table 26). Again, this discrepancy would be adjusted to better match all existing peak flows during detailed design. The runoff volumes for all storms exceed existing conditions because each design storm has a depth greater than the 28 mm that the infiltration facilities were sized to retain (e.g. the 2-year, 24 hour is 48.7 mm).

The footprints of the infiltration facilities and ponds are illustrated in Figure 20. Infiltration facilities were only located on appropriate soils and therefore are not be located in the centre and northern portions of the Golf Links Study Area with organics soils.

**Table 26. Comparison of Proposed Scenario 3 to Existing Conditions**

| Storm | Peak Flow ($m^3/s$) | | | | | Runoff Volume ($m^3$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | GL1 | OL1 | OL2 | OL3 | OL4 | GL1 | OL1 | OL2 | OL3 | OL4 |
| **Existing Conditions** | | | | | | | | | | |
| **2-year** | 0.03 | 0.13 | 0.34 | 0.19 | 0.05 | 762 | 576 | 2,156 | 831 | 161 |
| **5-year** | 0.10 | 0.20 | 0.49 | 0.28 | 0.09 | 1,856 | 1,144 | 3,374 | 1,624 | 294 |
| **10-year** | 0.15 | 0.26 | 0.59 | 0.34 | 0.12 | 2,792 | 1,672 | 4,568 | 2,192 | 396 |
| **25-year** | 0.23 | 0.33 | 0.78 | 0.38 | 0.16 | 4,168 | 2,529 | 6,899 | 2,399 | 523 |
| **50-year** | 0.28 | 0.38 | 0.90 | 0.42 | 0.19 | 5,238 | 3,233 | 8,469 | 2,792 | 625 |
| **100-year** | 0.18 | 0.42 | 1.03 | 0.47 | 0.23 | 3,052 | 4,149 | 10,290 | 3,229 | 736 |
| **Regional (Timmins)** | 0.46 | 0.17 | 0.75 | 0.35 | 0.13 | 9,792 | 5,744 | 19,770 | 5,360 | 1,291 |
| **Proposed Conditions Scenario 3 with Low Impact Development** | | | | | | | | | | |
| **2-year** | 0.03 | 0.06 | 0.07 | 0.05 | 0.00 | 2,499 | 1,991 | 1,458 | 978 | 0 |
| **5-year** | 0.09 | 0.19 | 0.33 | 0.14 | 0.06 | 4,643 | 4,405 | 4,018 | 1,890 | 545 |
| **10-year** | 0.15 | 0.25 | 0.57 | 0.22 | 0.11 | 6,210 | 6,117 | 5,914 | 2,497 | 992 |
| **25-year** | 0.25 | 0.36 | 0.83 | 0.34 | 0.19 | 8,321 | 8,426 | 8,427 | 3,286 | 1,635 |
| **50-year** | 0.32 | 0.38 | 1.05 | 0.44 | 0.25 | 9,897 | 8,507 | 10,300 | 3,845 | 2,107 |
| **100-year** | 0.35 | 0.47 | 1.31 | 0.54 | 0.27 | 10,980 | 10,320 | 12,440 | 4,458 | 2,142 |
| **Regional (Timmins)** | 0.60 | 0.79 | 1.48 | 0.48 | 0.39 | 19,330 | 20,460 | 26,160 | 8,051 | 5,754 |
| **Increase from Existing Conditions** | | | | | | | | | | |
| **2-year** | 0.00 | -0.07 | -0.27 | -0.14 | -0.05 | 1,737 | 1,415 | -698 | 148 | -161 |
| **5-year** | 0.00 | -0.01 | -0.16 | -0.14 | -0.03 | 2,787 | 3,261 | 644 | 266 | 252 |
| **10-year** | 0.00 | 0.00 | -0.02 | -0.12 | -0.01 | 3,418 | 4,445 | 1,346 | 305 | 596 |
| **25-year** | 0.01 | 0.03 | 0.04 | -0.04 | 0.03 | 4,153 | 5,897 | 1,528 | 887 | 1,112 |
| **50-year** | 0.04 | 0.00 | 0.15 | 0.01 | 0.06 | 4,659 | 5,274 | 1,831 | 1,053 | 1,482 |
| **100-year** | 0.17 | 0.05 | 0.28 | 0.08 | 0.04 | 7,928 | 6,171 | 2,150 | 1,229 | 1,406 |
| **Regional (Timmins)** | 0.13 | 0.61 | 0.74 | 0.13 | 0.25 | 9,538 | 14,716 | 6,390 | 2,691 | 4,463 |

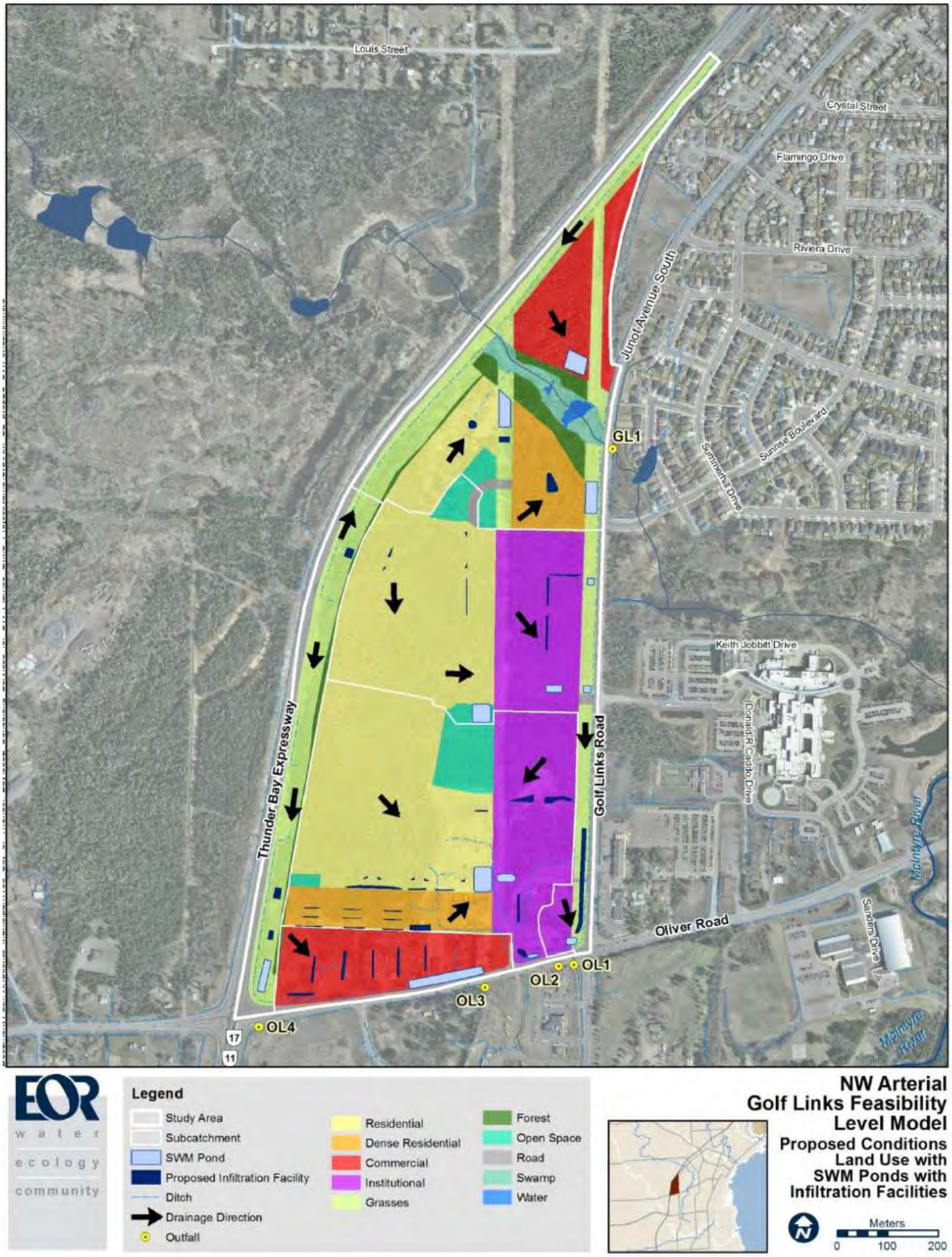


**Figure 20. SWM Facilities for Scenario 3 of Golf Links Study Area**

## 3.5 Estimated Costs

The capital and annual operation and maintenance costs of the stormwater infrastructure in each development scenario were calculated and compared to assess the relative costs of the approaches. The costs were calculated for ditches, pipes, stormwater ponds, and infiltration facilities. The sizes of the facilities changed in each scenario depending on the design requirements described in the previous sections. As summarized in Table 27, the resulting construction costs for the Scenarios was very similar, but when retrofit costs are included, Scenario 1 had the highest capital cost and Scenario 3 the lowest. Operations and maintenance costs were estimated to be highest for Scenario 2 and lowest for Scenario 3. A more detailed copy of costs is provided in Attachment 1 (Page 86).

**Table 27. Cost Comparison of Development Scenarios**

| Item | Capital Cost | | | | Annual Operation and Maintenance Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | *Unit Cost* | Scenario 1 | Scenario 2 | Scenario 3 | *Unit Cost* | Scenario 1 | Scenario 2 | Scenario 3 |
| **Ditch** | *$100/m* | $ 261,000 | $ 235,000 | $ 212,000 | *$/yr* | $10,000 | $ 9,000 | $ 8,000 |
| **Pipe** | *$/m* | $3,107,000 | $2,261,000 | $1,662,000 | *$15/m* | $10,000 | $ 9,000 | $ 8,000 |
| **Pond** | *$16/m$^3$* | $ - | $ 665,000 | $ 388,000 | *$/yr* | $ - | $20,000 | $12,000 |
| **Infiltration Facilities** | *$100/m$^2$* | $ - | $ - | $1,021,000 | *$/yr* | $ - | $ - | $35,000 |
| **Land** | *$7/m$^2$* | $ - | $ 137,000 | $ 89,000 | *$ -* | $ - | $ - | $ - |
| | **Subtotal** | $3,368,000 | $3,298,000 | $3,371,000 | **Subtotal** | $20,000 | $38,000 | $63,000 |
| | Retrofit | $1,722,000 | $1,243,000 | $ - | Retrofit | $47,000 | $35,000 | $ - |
| | **Total** | **$5,090,000** | **$4,541,000** | **$3,371,000** | **Total** | **$67,000** | **$73,000** | **$63,000** |

The retrofit costs accounted for the structural and environmental costs downstream of the Golf Links Study Area when no or limited runoff and pollutant loading controls provided under Scenarios 1 and 2. The systems constructed under Scenarios 1 and 2 will require facilities outside of the development to mitigate flooding and excessive pollutant loadings downstream.

The retrofits for Scenario 1 included the construction of offsite ponds and infiltration facilities with a cost estimated at 20% more than the cost in Scenario 3 due to additional efforts needed in a retrofit situation, such as preliminary site assessment, feasibility analysis, and no economy of scale (since these retrofit facilities will not be constructed as part of the development).

The retrofit of Scenario 2 included the construction of offsite infiltration facilities with a cost estimated at 20% more than the cost in Scenario 3. The retrofit costs for Scenario 1 and Scenario 2 also included the cost of offsite land acquisition. The cost of land in this case was reduced by 80% with respect to the development land cost since the retrofit facilities would not be typically built on prime developable land.

All costs for Scenario 3 assumed that the facilities will be designed and constructed properly so that retrofits will not be necessary.

Ditches were assumed to have an approximate depth of 1.2 m, bottom width of 1.8 m, and side slopes of 3:1. The annual maintenance costs for the ditches were estimated at 4% of the capital cost to include removal of sediment accumulation, re-grading and sodding/seeding.

The capital cost of storm sewers was based on average sizes in Table 28 with an average depth of 2.4 m and includes excavation, manholes, catchbasins and catchbasin leads (based on Hatch Mott McDonald River: Terrace South Subdivision 5 cost estimate). The maintenance cost of pipes included T.V. inspections, performance of minor repairs, and removing sediment accumulation from pipes, manholes, and catch basins. It was assumed that the system would be maintained at least once every 10 years.

**Table 28. Unit Capital Costs of in-place Pipes**

| Scenario | Average Pipe Size | $/m |
|---|---|---|
| **Scenario 1:** No Stormwater Management Controls | 525 mm dia. | 470 |
| **Scenario 2:** Universal Site Plan Control | 450 mm dia. | 380 |
| **Scenario 3:** Low Impact Development (Preserving the Original Site Layout) | 375 mm dia. | 310 |

The ponds' capital cost included excavation, grading, outlet structure, and planting. It was assumed that the full volume will need to be excavated as if there were no natural depressions and that the average pond depth would be 2.4 m. An economy of scale was considered in the estimate as well because the ponds will be built as part of development grading.

The ponds' maintenance cost was estimated at 3% of the capital cost to include minor removal of sediment and debris, cleaning and maintaining outlets, erosion repairs, and plant reestablishment.

Complete sediment removal will be required every 20-30 years. The dredging cost was estimated to be approximately $30/m$^3$ in today's dollars.

The infiltration facilities were assumed to be rain gardens, infiltration trenches and other bioretention facilities integrated in the development landscape. The capital cost included excavation, planting, and engineered medium.

The maintenance cost for infiltration facilities was estimated at $35,000/year on average, with potentially higher costs in earlier years and generally lower thereafter, with possible fluctuations due to sediment accumulation and vegetation health.

Land cost assumes the unserviced, raw cost when the land is purchased by the developer, not the serviced lot cost.

## 3.6 Water Quality Benefits

The water quality impacts were estimated by calculating potential pollutant loadings and removals of each development scenario on an annual basis. Annual runoff volumes were first estimated based on Table 3.1 of the MOECC Stormwater Management Planning and Design Manual (2003), as summarized in Table 29 with the land uses and soil types relevant to the Golf Links Study Area.

It was assumed that 10% of the total average annual precipitation on impervious surfaces is retained by depression storage. The infiltration facilities in Scenario 3 were assumed to retain 80% of annual average rainfall because they were designed to infiltrate 28 mm of precipitation. The resulting runoff volumes and pollutant calculations are summarized in Table 30.

**Table 29. Annual Precipitation and Runoff for Land Uses and Soil Types (MOECC, 2003)**

| Land Use and Soil Type | Precipitation (mm) | Runoff (mm) |
|---|---|---|
| **Mature Forest** - Sandy Loam | 940 | 118 |
| **Mature Forest** - Organics | 940 | 196 |
| **Urban Lawns** - Sandy Loam | 940 | 187 |
| **Urban Lawns** - Silty Loam | 940 | 222 |
| **Urban Lawns** - Organics | 940 | 270 |
| **Impervious** | 940 | 846 |

Average mean concentrations of the pollutants TSS, TP, and TN were assumed based on accepted literature values (USEPA 1983 and Lin 2004), although typical concentrations vary, especially for TSS, based on soils, land uses, and regional differences.

The SWM ponds were designed to provide 80% TSS removal which would result in an approximate removal of 55% of TP and 40% of TN. The resulting annual pollutant loadings are summarized in Table 30 and show large increases (over existing values) in pollutant loadings in Scenario 1, smaller increases in Scenario 2, and reductions or very small increases in Scenario 3.

**Table 30. Impact of Development on Water Quality**

| | EX | PR1 | PR2 | PR3 |
|---|---|---|---|---|
| ***Total Volume of Runoff to Outlet (m3)*** | 198,758 | 385,785 | 385,785 | 165,625 |
| ***Event Mean Concentration (mg/L)*** | | | | |
| TSS | 30 | 170 | 170 | 170 |
| TP | 0.15 | 0.45 | 0.45 | 0.45 |
| TN | 0.97 | 2.5 | 2.5 | 2.5 |
| ***Removal Efficiency (%)*** | | | | |
| TSS | 0 | 0 | 80 | 80 |
| TP | 0 | 0 | 55 | 55 |
| TN | 0 | 0 | 40 | 40 |
| ***Pollutant Loading at Outlet (kg)*** | | | | |
| TSS | 5,963 | 65,583 | 13,117 | 5,631 |
| TP | 30 | 174 | 78 | 34 |
| TN | 192 | 964 | 579 | 248 |
| ***Increase in Annual Pollutant Loading*** | | | | |
| TSS | 0% | 1000% | 120% | -6% |
| TP | 0% | 482% | 162% | 12% |
| TN | 0% | 403% | 202% | 30% |

## 3.7 Discussion

A summary of the cost-benefit analysis of the three development scenarios included in the feasibility-level model is provided in Table 31. With the consideration of the retrofits required to mitigate the impacts of uncontrolled or minimally controlled runoff, the low impact development practices considered in Scenario 3 provide the most benefits at the lowest cost.

**Table 31. Cost-Benefit Analysis of Golf Links Development Scenarios**

| | PR1 | PR2 | | PR3 | |
|---|---|---|---|---|---|
| ***Cost*** | | | | | |
| Capital ($) | $ 5,090,000 | $ 4,541,000 | -11% | $ 3,371,000 | -34% |
| Operation & Maintenance ($/yr) | $ 67,000 | $ 73,000 | 9% | $ 63,000 | -6% |
| ***Average Increase in Event Peak Flow*** | | | | | |
| 2- to 10-year return periods | 296% | -24% | | -32% | |
| ***Annual Runoff*** | | | | | |
| Volume ($m^3$) | 385,785 | 385,785 | | 165,625 | |
| Increase from Existing | 94% | 94% | | -17% | |
| ***Increase in Annual pollutant loading*** | | | | | |
| TSS | 1000% | 120% | | -6% | |
| TP | 482% | 162% | | 12% | |
| TN | 403% | 202% | | 30% | |

There are other stormwater management practices in addition to the infiltration facilities considered in Scenario 3 that could increase the water quality and quantity benefits while lowering the cost. Examples of other practices include rainwater reuse, pervious pavement, native vegetation, subsurface storage, and stormwater wetlands. Even further, adoption of the Low Impact Development (LID) approach would begin discussions of stormwater management from the beginning of the planning and land development process.

### 3.7.1 LID Upfront Coordination

Considering the LID approach from the beginning of the development planning process can create alternative site layout plans to the traditional plan. The plan used in the proposed conditions models is presented in Figure 21. In comparison, the revised plan presented in Figure 22 was prepared with the LID approach in mind. The revised plan has a slight reduction in the number of residential lots (- 10%), a small reduction in institutional parking, and maintains the area of commercial developments. These changes reduce the impervious cover and preserve more of the existing wetland, as described in Figure 22.

Figure 21. Traditional Site Layout of Golf Links Study Area (Source: Renew Thunder Bay Study)

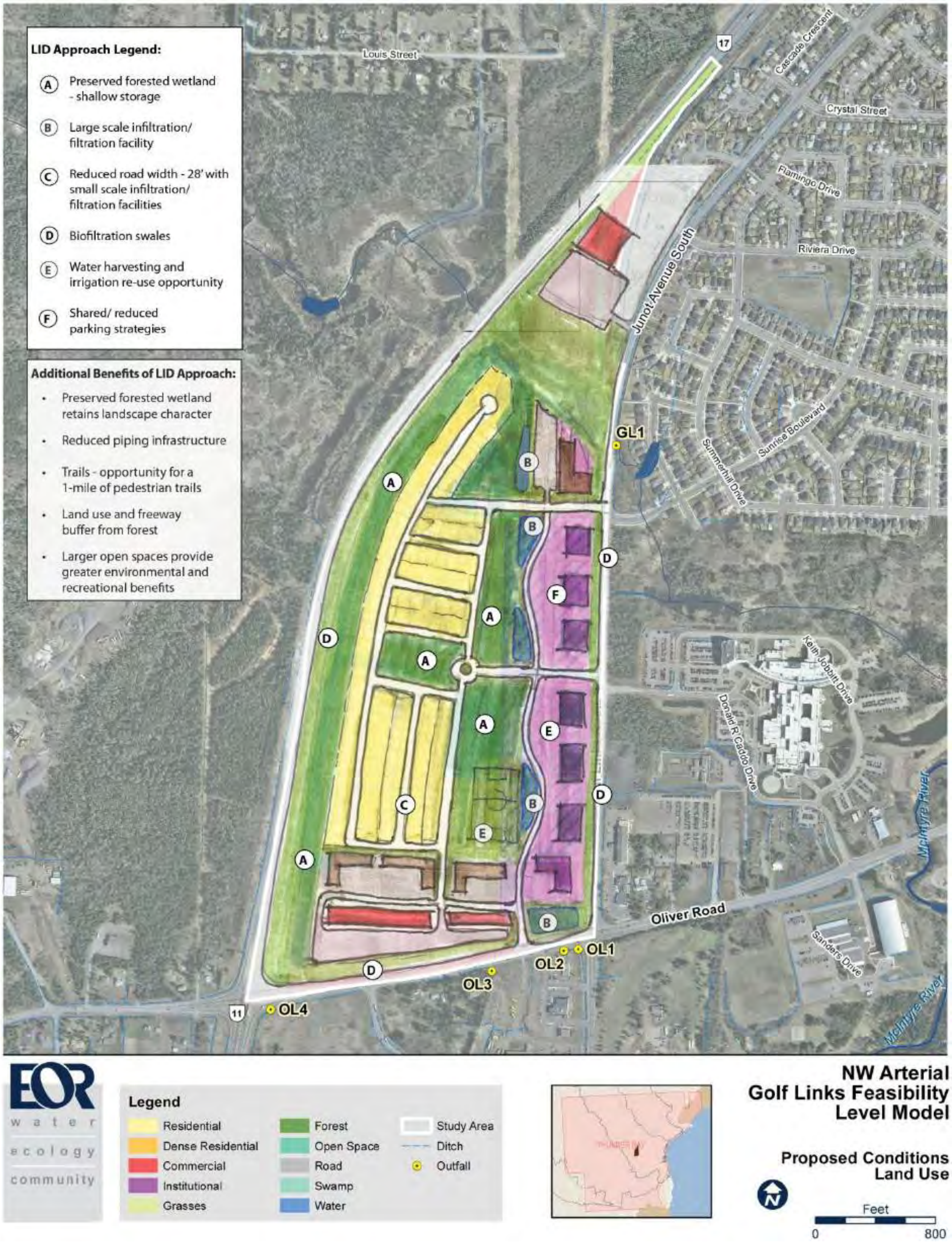


Figure 22. LID Site Layout of Golf Links Study Area

The impact of developing on wetlands such as the 16 ha coniferous swamp with peat soils identified in the Golf Links Study Area was reflected in the models based on the reduction of available storage under proposed conditions. A more comprehensive discussion of the impacts of developing on wetland areas is warranted to consider alternative development approaches. Overall, wetlands provide the following functions:

- Reduce flooding by slowing excess water runoff during heavy rainfall events.
- Improve water quality by filtering sediments, nutrients, and toxic substances before water enters rivers and lakes.
- Provide habitat for fish, wildlife, and plants, of which some can only survive in wetlands.
- Provide opportunities for recreation such as canoeing, hunting, hiking, fishing, and birding.
- Offer commercial uses like growing wild rice or cranberries and trapping animals.
- Provide education opportunities and aesthetic value.

The coniferous swamp in the Golf Links Study Area reduces how much rain and snowfall reaches the ground through interception of rainfall and sublimation of snow. The precipitation and runoff that does reach the ground is retained by the peat soils.

Filling, grading, and constructing on wetlands removes the benefits from the drainage area and changes groundwater levels and drainage patterns. A complete soil amendment would be required to remove all peat and replace with stable soils so that developments would be structurally stable.

The coniferous swamp in the Golf Links Study Area appears to have already faced the impacts of development after the Expressway fragmented it from a contiguous wetland complex, as evident from the 33 ha coniferous swamp on the opposite side of the expressway in Figure 17. Unless the subgrade of the highway was designed to allow groundwater flow between the east and west side, the drainage between the two has been disrupted.

Other potential development pressures on the swamps are increased loadings of road salt and disruption from the gravel pit activities on the west side of the Expressway. If possible, additional future development should not only aim to protect these wetland features but also rehabilitate the disturbance that has already occurred.

### 3.8 Recommendations

The following recommendations are provided as a direct result of the feasibility-level model of the Golf Links Study Area and cost-benefit analysis of different development approaches:

- The City should implement universal site plan control policies to require all future development and redevelopment to comply with the City's Engineering and Development Standards. This will limit the number of developments proceeding with limited or no stormwater management controls, as modelled in Scenario 1, and the significant retrofit costs associated with those practices.
- The City should adjust the Engineering and Development Standards to require runoff volume control in addition to peak flow control. There are multiple options for a runoff volume control standard for the City to consider, one of which is the requirement to infiltrate and retain 25 mm of rainfall. Soil tests at the location of potential infiltration facilities should be performed by developers as part of the permit application to confirm infiltration rates of local soils and size the infiltration facilities.
- The City should require that the Low Impact Development approach be incorporated and discussed from the beginning of the development planning process of rezoning designated growth areas to create profitable and environmentally sound developments.
- Identify locally significant wetlands based on MNRF Wetland Mapping updated in 2014 and consider for future environmental protection zoning.
- Collaborate with the LRCA as they coordinate the evaluation of wetlands in the City based on Ontario Wetlands Evaluation.
- Provide for the protection of wetlands by adopting standards regulating stormwater impacts from new development and redevelopment activity.
- The City should continue assessing the cumulative impacts of future development expansion through feasibility-level models. This will provide a method of evaluating options for compensating for areas with limited opportunities elsewhere in the regional drainage area.
- In light of the additional stormwater management facilities that will be designed for developments and BMPs in the near future in Thunder Bay, it is recommended that the City develop rainfall distributions to be used in simulation models for varying event durations. The IDF parameters in the Engineering and Development Design Manual are currently used to size pipes based on average rainfall intensity and the Rational Method. The City should consider nested distributions or developing distributions specific to Thunder Bay based on historical rainfall records.

## 4 Conclusion

Base models of seven watersheds in Thunder Bay were developed to better describe and evaluate the watersheds using the latest available hydrologic and hydraulic information. It is recommended that all of these seven models, except for the Kaministiquia Watershed and in addition to an eighth model of the Waterfront Watershed, continue to be developed into Comprehensive Watershed Management Models using expanded data collection efforts.

A Feasibility-Level Model was developed of the Northwest Arterial Golf Links area and informed recommendations regarding future infrastructure investments, new approaches to stormwater management, and policy recommendations. The Feasibility-Level Model compared the infrastructure needs of different development approaches and reinforced the need for enhancing stormwater management provided on all developments. The model development and assessment also led to recommendations regarding the City's standards and policies, such as the need for Universal Site Plan Control, wetland protection, and guidance for rainfall distributions necessary for designing SWM facilities in the future.

Implementing the recommendations from this study will help the City enhance the effectiveness of stormwater management infrastructure at reducing the negative impacts of stormwater on the environment, including reduction of peak flows, flooding, erosion, and contaminant loadings.

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## Attachment 1: Tables

**Table 32. Soil Texture-Dependent Subcatchment Properties**

| Soil Texture Code | Conduct (mm/hr) | Suction Head | Porosity | Field Cap | Wilting | Initial Deficit |
|---|---|---|---|---|---|---|
| **Sand** | 120.4 | 49.02 | 0.437 | 0.062 | 0.024 | 0.413 |
| **Loamy Sand** | 29.97 | 60.96 | 0.437 | 0.105 | 0.047 | 0.390 |
| **Sandy Loam** | 10.92 | 109.98 | 0.453 | 0.190 | 0.085 | 0.368 |
| **Loam** | 3.30 | 88.90 | 0.463 | 0.232 | 0.116 | 0.347 |
| **Silt Loam** | 6.60 | 169.93 | 0.501 | 0.284 | 0.135 | 0.366 |
| **Sandy Clay Loam** | 1.52 | 219.96 | 0.398 | 0.244 | 0.136 | 0.262 |
| **Clay Loam** | 1.02 | 210.06 | 0.464 | 0.310 | 0.187 | 0.277 |
| **Silty Clay Loam** | 1.02 | 270.00 | 0.471 | 0.342 | 0.210 | 0.261 |
| **Sandy Clay** | 0.51 | 240.03 | 0.430 | 0.321 | 0.221 | 0.209 |
| **Silty Clay** | 0.51 | 290.07 | 0.479 | 0.371 | 0.251 | 0.228 |
| **Clay** | 0.25 | 320.04 | 0.475 | 0.378 | 0.265 | 0.210 |

Source: Rawls, W.J. et al., (1983). J. Hyd. Engr., 109:1316.

**Table 33. Land Use-Dependent Subcatchment Properties**

| Land Use | Manning s n for Pervious Area | Depression Storage for Pervious Area | Impervious % |
|---|---|---|---|
| **Agr-Annual Cropland** | 0.19 | 2.71 | 0 |
| **Agr-Pasture/Forage** | 0.13 | 2.23 | 0 |
| **Airport** | 0.11 | 2.07 | 40 |
| **Bedrock** | 0.11 | 4.4 | 0 |
| **Broadleaf** | 0.4 | 4.4 | 0 |
| **Broadleaf Dense** | 0.4 | 4.4 | 0 |
| **Commercial** | 0.11 | 2.07 | 75 |
| **Coniferous Dense** | 0.4 | 4.4 | 0 |
| **Developed** | 0.11 | 2.07 | 45 |
| **Exposed/Barren Land** | 0.4 | 4.4 | 0 |
| **Hamlet** | 0.4 | 4.4 | 20 |
| **Herb** | 0.4 | 4.4 | 0 |
| **Industrial** | 0.11 | 2.07 | 72 |
| **Institutional** | 0.11 | 2.07 | 35 |
| **Mixed Wood Dense** | 0.4 | 4.4 | 0 |
| **Mixed Wood Sparse** | 0.4 | 4.4 | 0 |
| **Open Space** | 0.4 | 4.4 | 5 |
| **Residential** | 0.11 | 2.07 | 45 |
| **Shrubland** | 0.4 | 4.4 | 0 |
| **Water** | 0.011 | 1.27 | 100 |
| **Wetland** | 0.8 | 7.62 | 0 |
| **Wetland-Shrub** | 0.8 | 7.62 | 0 |
| **Wetland-Treed** | 0.8 | 7.62 | 0 |

**Table 34. Current River Subcatchment Properties, Existing Conditions**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | N Imperv | N Perv | Dstore Imperv (mm) | Dstore Perv (mm) | Suction Head (mm) | Conductivity (mm/hr) | Initial Deficit (frac.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB01-01 | 28 | 249 | 1110 | 3.9 | 48 | 0.01 | 0.2 | 1.75 | 2.79 | 109.98 | 10.92 | 0.368 |
| SUB01-09 | 17 | 228 | 727 | 7.4 | 46 | 0.01 | 0.159 | 1.75 | 2.46 | 98.41 | 31.7 | 0.377 |
| SUB01-10 | 263 | 835 | 3152 | 2.3 | 38 | 0.01 | 0.224 | 1.75 | 2.98 | 57.01 | 105.96 | 0.407 |
| SUB01-13 | 223 | 750 | 2980 | 6.7 | 9 | 0.01 | 0.343 | 1.75 | 4.18 | 107.54 | 36.91 | 0.356 |
| SUB01-16 | 128 | 702 | 1825 | 8.1 | 6 | 0.01 | 0.395 | 1.75 | 4.41 | 121.98 | 8.73 | 0.353 |
| SUB01-17 | 53 | 407 | 1310 | 8.2 | 13 | 0.01 | 0.363 | 1.75 | 4.11 | 110.6 | 10.86 | 0.367 |
| SUB01-20 | 2390 | 1955 | 12225 | 7.7 | 5 | 0.01 | 0.358 | 1.75 | 4.4 | 129.19 | 8.55 | 0.348 |
| SUB01-21 | 4181 | 2955 | 14149 | 7.4 | 9 | 0.01 | 0.218 | 1.75 | 4.33 | 186.94 | 3.86 | 0.297 |
| SUB01-22 | 4934 | 2940 | 16780 | 11.2 | 4 | 0.01 | 0.171 | 1.75 | 4.43 | 198.56 | 2.65 | 0.287 |
| SUB01-23 | 6895 | 3896 | 17700 | 9.7 | 6 | 0.01 | 0.127 | 1.75 | 4.32 | 210.06 | 1.02 | 0.277 |
| SUB01-24 | 1889 | 1832 | 10311 | 6.3 | 4 | 0.01 | 0.139 | 1.75 | 4.44 | 210.06 | 1.02 | 0.277 |
| SUB01-25 | 3525 | 2231 | 15800 | 6.8 | 1 | 0.01 | 0.128 | 1.75 | 4.44 | 210.06 | 1.02 | 0.277 |
| SUB01-27 | 8171 | 4195 | 19480 | 4.4 | 7 | 0.01 | 0.368 | 1.75 | 4.28 | 210.06 | 1.02 | 0.277 |
| SUB02-01 | 1506 | 1414 | 10650 | 7.1 | 2 | 0.01 | 0.34 | 1.75 | 4.87 | 174.41 | 6.65 | 0.312 |
| SUB03-01 | 1377 | 1337 | 10300 | 4.2 | 5 | 0.01 | 0.437 | 1.75 | 4.74 | 144.69 | 9.06 | 0.342 |
| SUB03-06 | 3572 | 2674 | 13360 | 10.1 | 3 | 0.01 | 0.301 | 1.75 | 4.68 | 167.82 | 5.92 | 0.317 |
| SUB03-07 | 4779 | 2105 | 22700 | 7.7 | 6 | 0.01 | 0.142 | 1.75 | 4.31 | 213.6 | 1.11 | 0.275 |
| SUB04-02 | 3209 | 3107 | 10330 | 7.9 | 5 | 0.01 | 0.178 | 1.75 | 4.58 | 209.98 | 1.03 | 0.277 |
| SUB06-01 | 3046 | 1412 | 21570 | 5.8 | 12 | 0.01 | 0.12 | 1.75 | 4.13 | 210.06 | 1.02 | 0.277 |
| SUB06-02 | 2790 | 2881 | 9683 | 7.0 | 8 | 0.01 | 0.352 | 1.75 | 4.17 | 210.06 | 1.02 | 0.277 |
| SUB08-01 | 5395 | 3216 | 16775 | 3.7 | 7 | 0.01 | 0.184 | 1.75 | 4.31 | 210.06 | 1.02 | 0.277 |
| SUB10-01 | 2181 | 1780 | 12250 | 10.9 | 7 | 0.01 | 0.17 | 1.75 | 4.49 | 211.1 | 1.01 | 0.276 |
| SUB11-01 | 1570 | 2119 | 7410 | 6.1 | 9 | 0.01 | 0.191 | 1.75 | 4.26 | 194.83 | 3.03 | 0.292 |
| SUB12-01 | 4078 | 2320 | 17580 | 7.8 | 7 | 0.01 | 0.189 | 1.75 | 4.39 | 210.06 | 1.02 | 0.277 |

**Table 35. Current River Subcatchment Properties, Future Conditions**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | N Imperv | N Perv | Dstore Imperv (mm) | Dstore Perv (mm) | Suction Head (mm) | Conductivity (mm/hr) | Initial Deficit (frac.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB01-01 | 28 | 249 | 1110 | 3.9 | 43 | 0.01 | 0.215 | 1.75 | 2.92 | 109.98 | 10.92 | 0.368 |
| SUB01-09 | 17 | 228 | 727 | 7.4 | 47 | 0.01 | 0.15 | 1.75 | 2.39 | 98.41 | 31.7 | 0.377 |
| SUB01-10 | 263 | 835 | 3152 | 2.3 | 43 | 0.01 | 0.192 | 1.75 | 2.73 | 57.01 | 105.96 | 0.407 |
| SUB01-13 | 223 | 750 | 2980 | 6.7 | 13 | 0.01 | 0.326 | 1.75 | 3.97 | 107.54 | 36.91 | 0.356 |
| SUB01-16 | 128 | 702 | 1825 | 8.1 | 6 | 0.01 | 0.393 | 1.75 | 4.4 | 121.98 | 8.73 | 0.353 |
| SUB01-17 | 53 | 407 | 1310 | 8.2 | 13 | 0.01 | 0.363 | 1.75 | 4.11 | 110.6 | 10.86 | 0.367 |
| SUB01-20 | 2390 | 1955 | 12225 | 7.7 | 5 | 0.01 | 0.359 | 1.75 | 4.41 | 129.19 | 8.55 | 0.348 |
| SUB01-21 | 4181 | 2955 | 14149 | 7.4 | 9 | 0.01 | 0.218 | 1.75 | 4.33 | 186.94 | 3.86 | 0.297 |
| SUB01-22 | 4934 | 2940 | 16780 | 11.2 | 4 | 0.01 | 0.171 | 1.75 | 4.43 | 198.56 | 2.65 | 0.287 |
| SUB01-23 | 6895 | 3896 | 17700 | 9.719 | 5.5 | 0.01 | 0.127 | 1.75 | 4.32 | 210.06 | 1.02 | 0.277 |
| SUB01-24 | 1889 | 1832 | 10311 | 6.271 | 3.6 | 0.01 | 0.139 | 1.75 | 4.44 | 210.06 | 1.02 | 0.277 |
| SUB01-25 | 3525 | 2231 | 15800 | 6.8 | 1.4 | 0.01 | 0.128 | 1.75 | 4.44 | 210.06 | 1.02 | 0.277 |
| SUB01-27 | 8171 | 4195 | 19480 | 4.429 | 7 | 0.01 | 0.368 | 1.75 | 4.28 | 210.06 | 1.02 | 0.277 |
| SUB02-01 | 1506 | 1414 | 10650 | 7.123 | 1.9 | 0.01 | 0.34 | 1.75 | 4.87 | 174.41 | 6.65 | 0.312 |
| SUB03-01 | 1377 | 1337 | 10300 | 4.224 | 4.6 | 0.01 | 0.437 | 1.75 | 4.74 | 144.69 | 9.06 | 0.342 |
| SUB03-06 | 3572 | 2674 | 13360 | 10.09 | 3.4 | 0.01 | 0.301 | 1.75 | 4.68 | 167.82 | 5.92 | 0.317 |
| SUB03-07 | 4779 | 2105 | 22700 | 7.685 | 6.3 | 0.01 | 0.142 | 1.75 | 4.31 | 213.6 | 1.11 | 0.275 |
| SUB04-02 | 3209 | 3107 | 10330 | 7.9 | 5 | 0.01 | 0.178 | 1.75 | 4.58 | 209.98 | 1.03 | 0.277 |
| SUB06-01 | 3046 | 1412 | 21570 | 5.754 | 11.6 | 0.01 | 0.12 | 1.75 | 4.13 | 210.06 | 1.02 | 0.277 |
| SUB06-02 | 2790 | 2881 | 9683 | 6.981 | 8.1 | 0.01 | 0.352 | 1.75 | 4.17 | 210.06 | 1.02 | 0.277 |
| SUB08-01 | 5395 | 3216 | 16775 | 3.653 | 6.7 | 0.01 | 0.184 | 1.75 | 4.31 | 210.06 | 1.02 | 0.277 |
| SUB10-01 | 2181 | 1780 | 12250 | 10.88 | 6.7 | 0.01 | 0.17 | 1.75 | 4.49 | 211.1 | 1.01 | 0.276 |
| SUB11-01 | 1570 | 2119 | 7410 | 6.05 | 9.4 | 0.01 | 0.191 | 1.75 | 4.26 | 194.83 | 3.03 | 0.292 |
| SUB12-01 | 4078 | 2320 | 17580 | 7.824 | 6.7 | 0.01 | 0.189 | 1.75 | 4.39 | 210.06 | 1.02 | 0.277 |

**Table 36. Kaministiquia River Subwatershed Properties, Existing Conditions**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | N Imperv | N Perv | Dstore Imperv (mm) | Dstore Perv (mm) | Suction Head (mm) | Conductivity (mm/hr) | Initial Deficit (frac.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KM-SUB00-01 | 504 | 1291 | 3900 | 0.7 | 76 | 0.01 | 0.094 | 1.75 | 1.94 | 169.16 | 10.23 | 0.323 |
| KM-SUB01-00 | 232 | 769 | 3020 | 1.1 | 60 | 0.01 | 0.143 | 1.75 | 2.33 | 207.09 | 42.67 | 0.292 |
| KM-SUB01-03 | 263 | 728 | 3610 | 0.5 | 64 | 0.01 | 0.128 | 1.75 | 2.21 | 128.46 | 20.55 | 0.350 |
| KM-SUB01-04 | 151 | 540 | 2800 | 1.5 | 55 | 0.01 | 0.108 | 1.75 | 2.06 | 128.11 | 10.00 | 0.354 |
| KM-SUB01-05 | 1246 | 1767 | 7047 | 4.2 | 57 | 0.01 | 0.127 | 1.75 | 2.33 | 139.27 | 8.91 | 0.345 |
| KM-SUB01-07 | 624 | 876 | 7120 | 5.8 | 39 | 0.01 | 0.182 | 1.75 | 2.74 | 170.60 | 6.55 | 0.336 |
| KM-SUB01-09 | 1227 | 2028 | 6050 | 5.3 | 19 | 0.01 | 0.293 | 1.75 | 3.59 | 144.89 | 7.79 | 0.347 |
| KM-SUB01-11 | 6891 | 4166 | 16540 | 5.8 | 3 | 0.01 | 0.255 | 1.75 | 3.39 | 171.95 | 5.22 | 0.336 |
| KM-SUB01-12 | 11082 | 3618 | 30626 | 8.3 | 3 | 0.01 | 0.314 | 1.75 | 4.21 | 206.02 | 3.56 | 0.299 |
| KM-SUB02-01 | 4033 | 2010 | 20065 | 4.1 | 10 | 0.01 | 0.275 | 1.75 | 3.40 | 131.76 | 9.41 | 0.352 |
| KM-SUB02-03 | 2418 | 2182 | 11084 | 4.3 | 8 | 0.01 | 0.276 | 1.75 | 3.40 | 156.69 | 16.25 | 0.335 |
| KM-SUB02-04 | 1320 | 1862 | 7090 | 6.9 | 14 | 0.01 | 0.331 | 1.75 | 3.85 | 120.86 | 21.98 | 0.360 |
| KM-SUB02-06 | 592 | 1238 | 4780 | 4.9 | 7 | 0.01 | 0.392 | 1.75 | 4.61 | 142.54 | 34.35 | 0.354 |
| KM-SUB03-01 | 4748 | 2078 | 22847 | 9.1 | 8 | 0.01 | 0.302 | 1.75 | 3.92 | 163.01 | 6.60 | 0.340 |
| KM-SUB04-01 | 2870 | 1599 | 17945 | 2.6 | 3 | 0.01 | 0.312 | 1.75 | 3.70 | 195.98 | 8.65 | 0.307 |
| KM-SUB04-02 | 4272 | 2548 | 16770 | 4.5 | 3 | 0.01 | 0.345 | 1.75 | 4.35 | 163.21 | 6.50 | 0.324 |
| KM-SUB05-01 | 36017 | 8001 | 45016 | 6.4 | 3 | 0.01 | 0.355 | 1.75 | 4.42 | 189.36 | 4.91 | 0.318 |
| KM-SUB05-02 | 22559 | 5054 | 44638 | 7.0 | 2 | 0.01 | 0.349 | 1.75 | 4.59 | 197.85 | 3.18 | 0.304 |

Note: See other table for Mosquito Creek Subcatchment Properties

**Table 37. McIntyre River Subwatershed Properties, Existing Conditions**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | N Imperv | N Perv | Dstore Imperv (mm) | Dstore Perv (mm) | Suction Head (mm) | Conductivity (mm/hr) | Initial Deficit (frac.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MI-SUB01-02 | 63 | 339 | 1850 | 1 | 63 | 0.01 | 0.129 | 1.75 | 2.22 | 94.82 | 38.15 | 0.379 |
| MI-SUB01-19 | 205 | 604 | 3400 | 1 | 70 | 0.01 | 0.110 | 1.75 | 2.07 | 140.71 | 26.05 | 0.345 |
| MI-SUB01-40 | 243 | 763 | 3190 | 2 | 45 | 0.01 | 0.150 | 1.75 | 2.39 | 185.64 | 7.08 | 0.311 |
| MI-SUB01-41 | 358 | 664 | 5400 | 2 | 52 | 0.01 | 0.127 | 1.75 | 2.21 | 189.13 | 12.28 | 0.308 |
| MI-SUB02-17 | 156 | 727 | 2146 | 3 | 31 | 0.01 | 0.183 | 1.75 | 2.65 | 271.28 | 2.73 | 0.247 |
| MI-SUB02-29 | 780 | 1419 | 5500 | 3 | 37 | 0.01 | 0.267 | 1.75 | 3.34 | 206.50 | 5.99 | 0.295 |
| MI-SUB02-33 | 134 | 515 | 2600 | 3 | 27 | 0.01 | 0.285 | 1.75 | 3.48 | 159.39 | 8.41 | 0.331 |
| MI-SUB03-01 | 98 | 394 | 2480 | 1 | 27 | 0.01 | 0.256 | 1.75 | 3.24 | 254.81 | 3.56 | 0.259 |
| MI-SUB05-01 | 60 | 352 | 1700 | 2 | 34 | 0.01 | 0.143 | 1.75 | 2.33 | 111.15 | 10.86 | 0.367 |
| MI-SUB05-07 | 320 | 801 | 4000 | 2 | 37 | 0.01 | 0.176 | 1.75 | 2.60 | 136.58 | 31.76 | 0.348 |
| MI-SUB05-11 | 588 | 1897 | 3100 | 3 | 34 | 0.01 | 0.185 | 1.75 | 2.67 | 165.91 | 8.08 | 0.326 |
| MI-SUB05-18 | 558 | 846 | 6600 | 3 | 9 | 0.01 | 0.440 | 1.75 | 4.72 | 162.50 | 29.35 | 0.327 |
| MI-SUB07-01 | 526 | 798 | 6600 | 4 | 20 | 0.01 | 0.306 | 1.75 | 3.65 | 136.06 | 9.60 | 0.348 |
| MI-SUB08-01 | 214 | 527 | 4050 | 2 | 10 | 0.01 | 0.378 | 1.75 | 4.23 | 196.75 | 6.49 | 0.303 |
| MI-SUB08-04 | 147 | 406 | 3627 | 2 | 10 | 0.01 | 0.352 | 1.75 | 4.02 | 110.45 | 15.82 | 0.368 |
| MI-SUB08-07 | 700 | 844 | 8300 | 4 | 7 | 0.01 | 0.396 | 1.75 | 4.38 | 100.57 | 58.40 | 0.374 |
| MI-SUB09-01 | 407 | 865 | 4700 | 2 | 6 | 0.01 | 0.419 | 1.75 | 4.56 | 125.22 | 9.71 | 0.355 |
| MI-SUB10-01 | 690 | 734 | 9400 | 3 | 4 | 0.01 | 0.412 | 1.75 | 4.51 | 155.07 | 10.49 | 0.332 |
| MI-SUB10-02 | 1320 | 1885 | 7000 | 8 | 4 | 0.01 | 0.418 | 1.75 | 4.56 | 119.67 | 6.37 | 0.344 |
| MI-SUB11-03 | 608 | 951 | 6400 | 8 | 5 | 0.01 | 0.353 | 1.75 | 4.32 | 114.72 | 31.98 | 0.347 |
| MI-SUB11-08 | 7110 | 2873 | 24750 | 6 | 4 | 0.01 | 0.394 | 1.75 | 4.73 | 207.60 | 3.42 | 0.286 |
| MI-SUB13-01 | 621 | 887 | 7000 | 6 | 4 | 0.01 | 0.356 | 1.75 | 4.71 | 200.77 | 4.53 | 0.294 |

**Table 38. McIntyre River Subwatershed Properties, Future Conditions**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | N Imperv | N Perv | Dstore Imperv (mm) | Dstore Perv (mm) | Suction Head (mm) | Conductivity (mm/hr) | Initial Deficit (frac.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MI-SUB01-02 | 63 | 339 | 1850 | 1 | 50 | 0.01 | 0.178 | 1.75 | 2.62 | 94.82 | 38.15 | 0.379 |
| MI-SUB01-19 | 205 | 604 | 3400 | 1 | 65 | 0.01 | 0.131 | 1.75 | 2.24 | 140.71 | 26.05 | 0.345 |
| MI-SUB01-40 | 243 | 763 | 3190 | 2 | 42 | 0.01 | 0.160 | 1.75 | 2.47 | 185.64 | 7.08 | 0.311 |
| MI-SUB01-41 | 358 | 664 | 5400 | 2 | 54 | 0.01 | 0.118 | 1.75 | 2.13 | 189.13 | 12.28 | 0.308 |
| MI-SUB02-17 | 156 | 727 | 2146 | 3 | 37 | 0.01 | 0.136 | 1.75 | 2.28 | 271.28 | 2.73 | 0.247 |
| MI-SUB02-29 | 780 | 1419 | 5500 | 3 | 38 | 0.01 | 0.242 | 1.75 | 3.13 | 206.50 | 5.99 | 0.295 |
| MI-SUB02-33 | 134 | 515 | 2600 | 3 | 34 | 0.01 | 0.191 | 1.75 | 2.72 | 159.39 | 8.41 | 0.331 |
| MI-SUB03-01 | 98 | 394 | 2480 | 1 | 23 | 0.01 | 0.268 | 1.75 | 3.34 | 254.81 | 3.56 | 0.259 |
| MI-SUB05-01 | 60 | 352 | 1700 | 2 | 29 | 0.01 | 0.176 | 1.75 | 2.60 | 111.15 | 10.86 | 0.367 |
| MI-SUB05-07 | 320 | 801 | 4000 | 2 | 37 | 0.01 | 0.168 | 1.75 | 2.53 | 136.58 | 31.76 | 0.348 |
| MI-SUB05-11 | 588 | 1897 | 3100 | 3 | 39 | 0.01 | 0.149 | 1.75 | 2.39 | 165.91 | 8.08 | 0.326 |
| MI-SUB05-18 | 558 | 846 | 6600 | 3 | 11 | 0.01 | 0.408 | 1.75 | 4.47 | 162.50 | 29.35 | 0.327 |
| MI-SUB07-01 | 526 | 798 | 6600 | 4 | 26 | 0.01 | 0.262 | 1.75 | 3.29 | 136.06 | 9.60 | 0.348 |
| MI-SUB08-01 | 214 | 527 | 4050 | 2 | 7 | 0.01 | 0.397 | 1.75 | 4.38 | 196.75 | 6.49 | 0.303 |
| MI-SUB08-04 | 147 | 406 | 3627 | 2 | 7 | 0.01 | 0.367 | 1.75 | 4.14 | 110.45 | 15.82 | 0.368 |
| MI-SUB08-07 | 700 | 844 | 8300 | 4 | 6 | 0.01 | 0.399 | 1.75 | 4.41 | 100.57 | 58.40 | 0.374 |
| MI-SUB09-01 | 407 | 865 | 4700 | 2 | 6 | 0.01 | 0.419 | 1.75 | 4.55 | 125.22 | 9.71 | 0.355 |
| MI-SUB10-01 | 690 | 734 | 9400 | 3 | 3 | 0.01 | 0.415 | 1.75 | 4.53 | 155.07 | 10.49 | 0.332 |
| MI-SUB10-02 | 1320 | 1885 | 7000 | 8 | 4 | 0.01 | 0.418 | 1.75 | 4.57 | 119.67 | 6.37 | 0.344 |
| MI-SUB11-03 | 608 | 951 | 6400 | 8 | 5 | 0.01 | 0.357 | 1.75 | 4.35 | 114.72 | 31.98 | 0.347 |
| MI-SUB11-08 | 7110 | 2873 | 24750 | 6 | 4 | 0.01 | 0.394 | 1.75 | 4.73 | 207.60 | 3.42 | 0.286 |
| MI-SUB13-01 | 621 | 887 | 7000 | 6 | 3 | 0.01 | 0.357 | 1.75 | 4.72 | 200.77 | 4.53 | 0.294 |

**Table 39. McVicar Creek Subwatershed Properties, Existing Conditions**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | N Imperv | N Perv | Dstore Imperv (mm) | Dstore Perv (mm) | Suction Head (mm) | Conductivity (mm/hr) | Initial Deficit (frac.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB01-01 | 175 | 590 | 2960 | 4.8 | 45 | 0.01 | 0.136 | 1.75 | 2.28 | 109.98 | 10.92 | 0.368 |
| SUB01-19 | 140 | 305 | 4610 | 3.8 | 28 | 0.01 | 0.235 | 1.75 | 3.08 | 92.96 | 27.9 | 0.37 |
| SUB01-20 | 105 | 487 | 2160 | 4.4 | 31 | 0.01 | 0.206 | 1.75 | 2.84 | 60.33 | 92.74 | 0.399 |
| SUB01-26 | 185 | 615 | 3013 | 2.9 | 38 | 0.01 | 0.162 | 1.75 | 2.49 | 77.79 | 68.73 | 0.392 |
| SUB01-38 | 717 | 1828 | 3924 | 3.5 | 21 | 0.01 | 0.304 | 1.75 | 3.63 | 125.59 | 11.83 | 0.356 |
| SUB01-44 | 81 | 352 | 2315 | 2.7 | 14 | 0.01 | 0.385 | 1.75 | 4.28 | 120.95 | 10.71 | 0.36 |
| SUB01-47 | 1732 | 1270 | 13643 | 6.5 | 4 | 0.01 | 0.388 | 1.75 | 4.52 | 119.01 | 16.45 | 0.343 |
| SUB03-02 | 1005 | 1438 | 6990 | 3.2 | 6 | 0.01 | 0.413 | 1.75 | 4.51 | 132.51 | 17.91 | 0.342 |
| SUB04-01 | 658 | 716 | 9186 | 5.1 | 5 | 0.01 | 0.439 | 1.75 | 4.78 | 120.17 | 5.27 | 0.339 |

**Table 40. McVicar Creek Subwatershed Properties, Future Conditions**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | N Imperv | N Perv | Dstore Imperv (mm) | Dstore Perv (mm) | Suction Head (mm) | Conductivity (mm/hr) | Initial Deficit (frac.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUB01-01 | 175 | 590 | 2960 | 4.8 | 43 | 0.01 | 0.147 | 1.75 | 2.36 | 109.98 | 10.92 | 0.368 |
| SUB01-19 | 140 | 305 | 4610 | 3.8 | 25 | 0.01 | 0.252 | 1.75 | 3.21 | 92.96 | 27.9 | 0.37 |
| SUB01-20 | 105 | 487 | 2160 | 4.4 | 33 | 0.01 | 0.194 | 1.75 | 2.74 | 60.33 | 92.74 | 0.399 |
| SUB01-26 | 185 | 615 | 3013 | 2.9 | 38 | 0.01 | 0.166 | 1.75 | 2.52 | 77.79 | 68.73 | 0.392 |
| SUB01-38 | 717 | 1828 | 3924 | 3.5 | 25 | 0.01 | 0.278 | 1.75 | 3.42 | 125.59 | 11.83 | 0.356 |
| SUB01-44 | 81 | 352 | 2315 | 2.7 | 12 | 0.01 | 0.399 | 1.75 | 4.4 | 120.95 | 10.71 | 0.36 |
| SUB01-47 | 1732 | 1270 | 13643 | 6.5 | 4 | 0.01 | 0.388 | 1.75 | 4.52 | 119.01 | 16.45 | 0.343 |
| SUB03-02 | 1005 | 1438 | 6990 | 3.2 | 6 | 0.01 | 0.419 | 1.75 | 4.55 | 132.51 | 17.91 | 0.342 |
| SUB04-01 | 658 | 716 | 9186 | 5.1 | 5 | 0.01 | 0.439 | 1.75 | 4.78 | 120.17 | 5.27 | 0.339 |

**Table 41. Mosquito Creek Subwatershed Properties, Existing Conditions**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | N Imperv | N Perv | Dstore Imperv (mm) | Dstore Perv (mm) | Suction Head (mm) | Conductivity (mm/hr) | Initial Deficit (frac.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MQ-SUB01-01 | 8 | 113 | 720 | 5 | 11 | 0.01 | 0.371 | 1.75 | 4.17 | 133.00 | 8.79 | 0.348 |
| MQ-SUB01-03 | 144 | 547 | 2630 | 7 | 14 | 0.01 | 0.292 | 1.75 | 3.59 | 153.85 | 21.53 | 0.353 |
| MQ-SUB01-05 | 43 | 368 | 1162 | 2 | 42 | 0.01 | 0.135 | 1.75 | 2.27 | 136.13 | 8.86 | 0.361 |
| MQ-SUB03-01 | 14 | 222 | 650 | 6 | 12 | 0.01 | 0.326 | 1.75 | 3.81 | 176.74 | 4.96 | 0.328 |
| MQ-SUB03-02 | 33 | 259 | 1260 | 5 | 38 | 0.01 | 0.163 | 1.75 | 2.50 | 162.87 | 6.39 | 0.343 |
| MQ-SUB03-03 | 275 | 781 | 3526 | 3 | 34 | 0.01 | 0.167 | 1.75 | 2.53 | 164.22 | 4.68 | 0.340 |
| MQ-SUB03-05 | 807 | 937 | 8606 | 9 | 7 | 0.01 | 0.212 | 1.75 | 3.55 | 175.64 | 4.44 | 0.334 |
| MQ-SUB05-01 | 31 | 221 | 1390 | 4 | 16 | 0.01 | 0.240 | 1.75 | 3.11 | 184.55 | 4.57 | 0.334 |
| MQ-SUB05-02 | 278 | 918 | 3032 | 17 | 7 | 0.01 | 0.191 | 1.75 | 4.00 | 174.03 | 9.63 | 0.315 |
| MQ-SUB06-01 | 268 | 669 | 4009 | 15 | 12 | 0.01 | 0.230 | 1.75 | 3.96 | 184.18 | 3.92 | 0.325 |
| MQ-SUB08-01 | 841 | 1184 | 7103 | 11 | 7 | 0.01 | 0.274 | 1.75 | 4.14 | 183.79 | 3.81 | 0.324 |
| MQ-SUB09-01 | 346 | 1573 | 2203 | 20 | 6 | 0.01 | 0.203 | 1.75 | 4.18 | 194.28 | 2.53 | 0.303 |

**Table 42. Mosquito Creek Subwatershed Properties, Future Conditions**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | N Imperv | N Perv | Dstore Imperv (mm) | Dstore Perv (mm) | Suction Head (mm) | Conductivity (mm/hr) | Initial Deficit (frac.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MQ-SUB01-01 | 8 | 113 | 720 | 5 | 10 | 0.01 | 0.378 | 1.75 | 4.22 | 133.00 | 8.79 | 0.348 |
| MQ-SUB01-03 | 144 | 547 | 2630 | 7 | 9 | 0.01 | 0.315 | 1.75 | 3.77 | 153.85 | 21.53 | 0.353 |
| MQ-SUB01-05 | 43 | 368 | 1162 | 2 | 39 | 0.01 | 0.145 | 1.75 | 2.35 | 136.13 | 8.86 | 0.361 |
| MQ-SUB03-01 | 14 | 222 | 650 | 6 | 10 | 0.01 | 0.332 | 1.75 | 3.86 | 176.74 | 4.96 | 0.328 |
| MQ-SUB03-02 | 33 | 259 | 1260 | 5 | 33 | 0.01 | 0.187 | 1.75 | 2.69 | 162.87 | 6.39 | 0.343 |
| MQ-SUB03-03 | 275 | 781 | 3526 | 3 | 36 | 0.01 | 0.151 | 1.75 | 2.40 | 164.22 | 4.68 | 0.340 |
| MQ-SUB03-05 | 807 | 937 | 8606 | 9 | 7 | 0.01 | 0.214 | 1.75 | 3.57 | 175.64 | 4.44 | 0.334 |
| MQ-SUB05-01 | 31 | 221 | 1390 | 4 | 14 | 0.01 | 0.242 | 1.75 | 3.13 | 184.55 | 4.57 | 0.334 |
| MQ-SUB05-02 | 278 | 918 | 3032 | 17 | 4 | 0.01 | 0.201 | 1.75 | 4.08 | 174.03 | 9.63 | 0.315 |
| MQ-SUB06-01 | 268 | 669 | 4009 | 15 | 14 | 0.01 | 0.229 | 1.75 | 3.95 | 184.18 | 3.92 | 0.325 |
| MQ-SUB08-01 | 841 | 1184 | 7103 | 11 | 8 | 0.01 | 0.273 | 1.75 | 4.20 | 183.79 | 3.81 | 0.324 |
| MQ-SUB09-01 | 346 | 1573 | 2203 | 20 | 6 | 0.01 | 0.203 | 1.75 | 4.17 | 194.28 | 2.53 | 0.303 |

**Table 43. Neebing River Subwatershed Properties, Existing Conditions**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | N Imperv | N Perv | Dstore Imperv (mm) | Dstore Perv (mm) | Suction Head (mm) | Conductivity (mm/hr) | Initial Deficit (frac.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NB-SUB01-02 | 231 | 548 | 4215 | 3 | 50 | 0.01 | 0.118 | 1.75 | 2.13 | 109.98 | 10.92 | 0.368 |
| NB-SUB01-24 | 97 | 780 | 1250 | 3 | 28 | 0.01 | 0.247 | 1.75 | 3.17 | 109.98 | 10.92 | 0.368 |
| NB-SUB01-32 | 166 | 502 | 3300 | 1 | 44 | 0.01 | 0.132 | 1.75 | 2.24 | 113.21 | 10.76 | 0.366 |
| NB-SUB01-42 | 181 | 905 | 2000 | 2 | 44 | 0.01 | 0.130 | 1.75 | 2.23 | 206.41 | 6.02 | 0.295 |
| NB-SUB01-49 | 288 | 1309 | 2200 | 2 | 43 | 0.01 | 0.165 | 1.75 | 2.51 | 198.79 | 6.41 | 0.301 |
| NB-SUB01-50 | 540 | 1019 | 5300 | 2 | 7 | 0.01 | 0.594 | 1.75 | 5.96 | 244.92 | 4.04 | 0.267 |
| NB-SUB01-51 | 474 | 545 | 8700 | 2 | 56 | 0.01 | 0.114 | 1.75 | 2.10 | 201.25 | 6.28 | 0.299 |
| NB-SUB03-01 | 304 | 810 | 3750 | 2 | 13 | 0.01 | 0.577 | 1.75 | 5.82 | 248.84 | 3.87 | 0.264 |
| NB-SUB03-03 | 390 | 1501 | 2600 | 2 | 29 | 0.01 | 0.299 | 1.75 | 3.59 | 135.92 | 9.60 | 0.348 |
| NB-SUB03-05 | 300 | 638 | 4700 | 2 | 22 | 0.01 | 0.305 | 1.75 | 3.64 | 132.73 | 9.76 | 0.351 |
| NB-SUB03-06 | 29 | 193 | 1500 | 2 | 29 | 0.01 | 0.279 | 1.75 | 3.43 | 109.98 | 10.92 | 0.368 |
| NB-SUB03-07 | 224 | 477 | 4700 | 4 | 27 | 0.01 | 0.225 | 1.75 | 2.99 | 117.37 | 10.54 | 0.362 |
| NB-SUB03-10 | 2287 | 1890 | 12100 | 3 | 9 | 0.01 | 0.385 | 1.75 | 4.28 | 149.53 | 14.44 | 0.334 |
| NB-SUB03-11 | 1337 | 1352 | 9888 | 2 | 5 | 0.01 | 0.319 | 1.75 | 3.75 | 167.81 | 10.79 | 0.334 |
| NB-SUB03-17 | 296 | 732 | 4050 | 2 | 3 | 0.01 | 0.386 | 1.75 | 4.29 | 149.30 | 17.60 | 0.350 |
| NB-SUB03-18 | 1135 | 1013 | 11200 | 2 | 3 | 0.01 | 0.401 | 1.75 | 4.41 | 227.44 | 6.37 | 0.286 |
| NB-SUB06-01 | 217 | 429 | 5060 | 2 | 54 | 0.01 | 0.115 | 1.75 | 2.11 | 226.02 | 5.03 | 0.281 |
| NB-SUB11-01 | 1063 | 1687 | 6300 | 3 | 3 | 0.01 | 0.398 | 1.75 | 4.38 | 150.49 | 10.38 | 0.331 |
| NB-SUB11-02 | 1836 | 1748 | 10500 | 3 | 3 | 0.01 | 0.335 | 1.75 | 3.88 | 145.66 | 10.04 | 0.342 |
| NB-SUB16-02 | 614 | 1428 | 4300 | 2 | 3 | 0.01 | 0.523 | 1.75 | 5.39 | 116.07 | 9.60 | 0.361 |
| NB-SUB16-05 | 1071 | 1147 | 9344 | 3 | 4 | 0.01 | 0.428 | 1.75 | 4.63 | 182.90 | 8.34 | 0.306 |
| NB-SUB16-08 | 1680 | 1697 | 9900 | 7 | 3 | 0.01 | 0.351 | 1.75 | 4.85 | 177.82 | 3.46 | 0.302 |
| NB-SUB23-01 | 1255 | 1255 | 10000 | 4 | 4 | 0.01 | 0.431 | 1.75 | 4.83 | 147.01 | 7.88 | 0.336 |
| NB-SUB25-02 | 1411 | 2015 | 7000 | 4 | 1 | 0.01 | 0.465 | 1.75 | 5.41 | 163.43 | 7.02 | 0.324 |

**Table 44. Neebing River Subwatershed Properties, Future Conditions**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | N Imperv | N Perv | Dstore Imperv (mm) | Dstore Perv (mm) | Suction Head (mm) | Conductivity (mm/hr) | Initial Deficit (frac.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NB-SUB01-02 | 231 | 548 | 4215 | 3 | 48 | 0.01 | 0.121 | 1.75 | 2.16 | 109.98 | 10.92 | 0.368 |
| NB-SUB01-24 | 97 | 780 | 1250 | 3 | 27 | 0.01 | 0.253 | 1.75 | 3.22 | 109.98 | 10.92 | 0.368 |
| NB-SUB01-32 | 166 | 502 | 3300 | 1 | 46 | 0.01 | 0.116 | 1.75 | 2.12 | 113.21 | 10.76 | 0.366 |
| NB-SUB01-42 | 181 | 905 | 2000 | 2 | 44 | 0.01 | 0.122 | 1.75 | 2.17 | 206.41 | 6.02 | 0.295 |
| NB-SUB01-49 | 288 | 1309 | 2200 | 2 | 47 | 0.01 | 0.135 | 1.75 | 2.27 | 198.79 | 6.41 | 0.301 |
| NB-SUB01-50 | 540 | 1019 | 5300 | 2 | 20 | 0.01 | 0.544 | 1.75 | 5.56 | 244.92 | 4.04 | 0.267 |
| NB-SUB01-51 | 474 | 545 | 8700 | 2 | 56 | 0.01 | 0.117 | 1.75 | 2.13 | 201.25 | 6.28 | 0.299 |
| NB-SUB03-01 | 304 | 810 | 3750 | 2 | 13 | 0.01 | 0.573 | 1.75 | 5.79 | 248.84 | 3.87 | 0.264 |
| NB-SUB03-03 | 390 | 1501 | 2600 | 2 | 29 | 0.01 | 0.301 | 1.75 | 3.61 | 135.92 | 9.60 | 0.348 |
| NB-SUB03-05 | 300 | 638 | 4700 | 2 | 23 | 0.01 | 0.311 | 1.75 | 3.68 | 132.73 | 9.76 | 0.351 |
| NB-SUB03-06 | 29 | 193 | 1500 | 2 | 22 | 0.01 | 0.316 | 1.75 | 3.72 | 109.98 | 10.92 | 0.368 |
| NB-SUB03-07 | 224 | 477 | 4700 | 4 | 25 | 0.01 | 0.233 | 1.75 | 3.06 | 117.37 | 10.54 | 0.362 |
| NB-SUB03-10 | 2287 | 1890 | 12100 | 3 | 11 | 0.01 | 0.380 | 1.75 | 4.24 | 149.53 | 14.44 | 0.334 |
| NB-SUB03-11 | 1337 | 1352 | 9888 | 2 | 5 | 0.01 | 0.320 | 1.75 | 3.77 | 167.81 | 10.79 | 0.334 |
| NB-SUB03-17 | 296 | 732 | 4050 | 2 | 3 | 0.01 | 0.389 | 1.75 | 4.31 | 149.30 | 17.60 | 0.350 |
| NB-SUB03-18 | 1135 | 1013 | 11200 | 2 | 3 | 0.01 | 0.401 | 1.75 | 4.41 | 227.44 | 6.37 | 0.286 |
| NB-SUB06-01 | 217 | 429 | 5060 | 2 | 53 | 0.01 | 0.133 | 1.75 | 2.25 | 226.02 | 5.03 | 0.281 |
| NB-SUB11-01 | 1063 | 1687 | 6300 | 3 | 3 | 0.01 | 0.397 | 1.75 | 4.38 | 150.49 | 10.38 | 0.331 |
| NB-SUB11-02 | 1836 | 1748 | 10500 | 3 | 3 | 0.01 | 0.335 | 1.75 | 3.88 | 145.66 | 10.04 | 0.342 |
| NB-SUB16-02 | 614 | 1428 | 4300 | 2 | 3 | 0.01 | 0.521 | 1.75 | 5.38 | 116.07 | 9.60 | 0.361 |
| NB-SUB16-05 | 1071 | 1147 | 9344 | 3 | 4 | 0.01 | 0.429 | 1.75 | 4.63 | 182.90 | 8.34 | 0.306 |
| NB-SUB16-08 | 1680 | 1697 | 9900 | 7 | 3 | 0.01 | 0.351 | 1.75 | 4.85 | 177.82 | 3.46 | 0.302 |
| NB-SUB23-01 | 1255 | 1255 | 10000 | 4 | 4 | 0.01 | 0.431 | 1.75 | 4.83 | 147.01 | 7.88 | 0.336 |
| NB-SUB25-02 | 1411 | 2015 | 7000 | 4 | 1 | 0.01 | 0.465 | 1.75 | 5.41 | 163.43 | 7.02 | 0.324 |

**Table 45. Pennock Creek Subwatershed Properties, Existing Conditions**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | N Imperv | N Perv | Dstore Imperv (mm) | Dstore Perv (mm) | Suction Head (mm) | Conductivity (mm/hr) | Initial Deficit (frac.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PN-SUB01-01 | 51 | 178 | 2865 | 5 | 30 | 0.01 | 0.214 | 1.75 | 2.90 | 109.98 | 10.92 | 0.368 |
| PN-SUB01-02 | 247 | 561 | 4410 | 3 | 40 | 0.01 | 0.161 | 1.75 | 2.48 | 119.61 | 10.43 | 0.361 |
| PN-SUB01-07 | 295 | 593 | 4975 | 2 | 30 | 0.01 | 0.177 | 1.75 | 2.61 | 109.97 | 10.94 | 0.368 |
| PN-SUB01-10 | 623 | 1190 | 5235 | 2 | 18 | 0.01 | 0.204 | 1.75 | 2.82 | 154.57 | 13.77 | 0.335 |
| PN-SUB06-01 | 33 | 238 | 1407 | 2 | 30 | 0.01 | 0.183 | 1.75 | 2.65 | 109.98 | 10.92 | 0.368 |
| PN-SUB09-01 | 1419 | 2292 | 6190 | 2 | 6 | 0.01 | 0.356 | 1.75 | 4.04 | 247.48 | 6.47 | 0.273 |
| PN-SUB12-01 | 531 | 945 | 5623 | 2 | 3 | 0.01 | 0.399 | 1.75 | 4.40 | 259.18 | 1.58 | 0.264 |
| PN-SUB12-02 | 55 | 563 | 977 | 3 | 10 | 0.01 | 0.263 | 1.75 | 3.30 | 245.63 | 2.60 | 0.286 |
| PN-SUB12-03 | 1225 | 1081 | 11334 | 3 | 4 | 0.01 | 0.360 | 1.75 | 4.08 | 213.93 | 4.49 | 0.298 |
| PN-SUB13-01 | 442 | 960 | 4604 | 1 | 4 | 0.01 | 0.242 | 1.75 | 3.13 | 163.47 | 7.62 | 0.338 |
| PN-SUB14-01 | 225 | 535 | 4217 | 3 | 9 | 0.01 | 0.289 | 1.75 | 3.51 | 243.55 | 2.79 | 0.289 |
| PN-SUB15-01 | 315 | 762 | 4134 | 3 | 3 | 0.01 | 0.327 | 1.75 | 3.81 | 223.97 | 3.91 | 0.298 |

**Table 46. Pennock Creek Subwatershed Properties, Future Conditions**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | N Imperv | N Perv | Dstore Imperv (mm) | Dstore Perv (mm) | Suction Head (mm) | Conductivity (mm/hr) | Initial Deficit (frac.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PN-SUB01-01 | 51 | 178 | 2865 | 5 | 27 | 0.01 | 0.233 | 1.75 | 3.05 | 109.98 | 10.92 | 0.368 |
| PN-SUB01-02 | 247 | 561 | 4410 | 3 | 38 | 0.01 | 0.169 | 1.75 | 2.55 | 119.61 | 10.43 | 0.361 |
| PN-SUB01-07 | 295 | 593 | 4975 | 2 | 34 | 0.01 | 0.174 | 1.75 | 2.58 | 109.97 | 10.94 | 0.368 |
| PN-SUB01-10 | 623 | 1190 | 5235 | 2 | 18 | 0.01 | 0.206 | 1.75 | 2.84 | 154.57 | 13.77 | 0.335 |
| PN-SUB06-01 | 33 | 238 | 1407 | 2 | 42 | 0.01 | 0.138 | 1.75 | 2.30 | 109.98 | 10.92 | 0.368 |
| PN-SUB09-01 | 1419 | 2292 | 6190 | 2 | 6 | 0.01 | 0.356 | 1.75 | 4.04 | 247.48 | 6.47 | 0.273 |
| PN-SUB12-01 | 531 | 945 | 5623 | 2 | 3 | 0.01 | 0.399 | 1.75 | 4.40 | 259.18 | 1.58 | 0.264 |
| PN-SUB12-02 | 55 | 563 | 977 | 3 | 10 | 0.01 | 0.263 | 1.75 | 3.30 | 245.63 | 2.60 | 0.286 |
| PN-SUB12-03 | 1225 | 1081 | 11334 | 3 | 4 | 0.01 | 0.360 | 1.75 | 4.08 | 213.93 | 4.49 | 0.298 |
| PN-SUB13-01 | 442 | 960 | 4604 | 1 | 4 | 0.01 | 0.242 | 1.75 | 3.13 | 163.47 | 7.62 | 0.338 |
| PN-SUB14-01 | 225 | 535 | 4217 | 3 | 9 | 0.01 | 0.289 | 1.75 | 3.51 | 243.55 | 2.79 | 0.289 |
| PN-SUB15-01 | 315 | 762 | 4134 | 3 | 3 | 0.01 | 0.327 | 1.75 | 3.81 | 223.97 | 3.91 | 0.298 |

**Table 47. Current River Bridge Inventory**

| Structure ID | Structure Name | Stream Name | Culvert/Bridge | Year of Construction | Material | Length (m) | Shape | Degree of Skew | Rise (m) | Span (m) | Barrels | Entry Loss Coefficient | Culvert Code | Roughness | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **B-126** | Shipyard Drive Bridge | Current River | Bridge | 1984 | Concrete | 12 | Box | 0 | 3 | 26 | 2 | 0.5 | 14 | 0.035 | 2 |
| **2-CNR** | CN Bridge | Current River | Bridge | Unknown | Concrete | | Irregular | 0 | 0 | 0 | 1 | 0.5 | 14 | 0.035 | 1 |
| **3-CPR** | CP Bridge | Current River | Bridge | Unknown | Concrete | | Irregular | 0 | 0 | 0 | 1 | 0.5 | 14 | 0.035 | 1 |
| **B-001** | Cumberland Street Bridge | Current River | Bridge | 1972 | Concrete | 21.5 | Box | 30 | 2.5 | 19 | 3 | 0.5 | 14 | 0.035 | 2 |
| **B-002** | Arundel Street Bridge | Current River | Bridge | 1912 | Concrete | 13.4 | Arch | 0 | 5 | 39.6 | 1 | 0.5 | 14 | 0.035 | 2 |
| **B-105** | Centennial Park Bridge | Current River | Bridge | 1960 | Concrete | 3.48 | Box | 0 | 2 | 17.5 | 1 | 0.5 | 14 | 0.035 | 2 |
| **B-009** | Trowbridge Arched Snowmobile Bridge | Current River | Bridge | Unknown | Timber | 3.4 | Box | 0 | 2 | 18.3 | 1 | 0.5 | 45 | 0.035 | 2 |
| **B-010** | Trowbridge Snowmobile Bridge | North Branch of the Current River | Bridge | Unknown | Timber | 3.4 | Box | 0 | 3.2 | 30 | 1 | 0.5 | 14 | 0.035 | 2 |
| **B-064** | Copenhagen Road Bridge | North Branch of the Current River | Bridge | 1990 | Concrete | 9.4 | Box | 20 | 3 | 20 | 1 | 0.5 | 14 | 0.035 | 2 |

Notes:[1] Flood Plain and Fill Line Mapping of Current River (1979)
[2] Municipal Structure Inspection Form (2010)

**Table 48. Kaministiquia River Bridge Inventory**

| Structure ID | Structure Name | Stream Name | Culvert/Bridge | Year of Construction | Material | Length (m) | Shape | Degree of Skew | Rise (m) | Span (m) | Barrels | Entry Loss Coefficient | Culvert Code | Roughness | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **B-003a** | Island Drive Bridge | Kaministiquia River | Bridge | 2003 | Concrete | 12 | Box | 0 | 4.4 | 52.5 | 2 | 0.5 | 14 | 0.035 | 1 |
| **B-003b** | Island Drive Bridge | Kaministiquia River | Bridge | 2003 | Concrete | 12 | Box | 0 | 4.4 | 64.5 | 2 | 0.5 | 14 | 0.035 | 1 |

Notes: [1] Municipal Structure Inspection Form (2010)

**Table 49. McIntyre River Bridge Inventory**

| Structure ID | Structure Name | Stream Name | Culvert/Bridge | Year of Construction | Material | Length (m) | Shape | Degree of Skew | Rise (m) | Span (m) | Barrels | Entry Loss Coefficient | Culvert Code | Roughness | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **B-004a** | Fort William Road Bridge | Neebing-McIntyre Floodway | Bridge | 1981 | Concrete | 20.6 | Box | 0 | 1.4 | 17.5 | 2 | 0.5 | 14 | 0.035 | 1 |
| **B-004b** | Fort William Road Bridge | Neebing-McIntyre Floodway | Bridge | 1981 | Concrete | 20.6 | Box | 0 | 1.4 | 21 | 1 | 0.5 | 14 | 0.035 | 1 |
| **B-005a** | Memorial Avenue Bridge | Neebing-McIntyre Floodway | Bridge | 1981 | Concrete | 21.6 | Box | 21 | 1.5 | 17.5 | 2 | 0.5 | 14 | 0.035 | 1 |
| **B-005b** | Memorial Avenue Bridge | Neebing-McIntyre Floodway | Bridge | 1981 | Concrete | 21.6 | Box | 21 | 1.5 | 21 | 1 | 0.5 | 14 | 0.035 | 1 |
| **B-028** | Woodcrest Road Bridge | McIntyre River | Bridge | 1990 | Concrete | 7.4 | Box | 0 | 1.83 | 13.1 | 1 | 0.5 | 14 | 0.035 | 1 |
| **B-029** | Belrose Road Bridge | McIntyre River | Culvert | 2008 | Asphalt | 20 | Arch | 0 | 1.7 | 12.5 | 1 | 0.5 | 14 | 0.035 | 1 |
| **B-030** | John Street Road Bridge | McIntyre River | Bridge | 1996 | Concrete | 12.7 | Box | 0 | 2.1 | 15.4 | 1 | 0.5 | 14 | 0.035 | 1 |
| **B-031** | Paquette Road Bridge | McIntyre River | Bridge | Unknown | Wood | 6.8 | Box | 0 | 1.8 | 8.3 | 1 | 0.5 | 14 | 0.035 | 1 |
| **B-036** | Kivikoski Road Bridge | McIntyre River | Bridge | 1991 | Wood | 4.5 | Box | 0 | 1.2 | 10.1 | 1 | 0.5 | 14 | 0.035 | 1 |
| **B-037** | Melbourne Road Bridge | McIntyre River | Bridge | Unknown | Wood | 5.5 | Box | 0 | 1.2 | 6.99 | 1 | 0.5 | 14 | 0.035 | 1 |
| **B-117** | Chapples Drive Bridge | Neebing-McIntyre Floodway Diversion Channel | Bridge | 1983 | Concrete | 13.2 | Box | 25 | 2 | 21 | 2 | 0.5 | 14 | 0.035 | 1 |
| **C-173** | Pento Road Bridge | McIntyre River | Bridge | Unknown | Wood | 19.24 | Box | 0 | 1.2 | 3 | 1 | 0.5 | 14 | 0.035 | 1 |
| **B-MI-College** | Confederation College Ped. Bridge | McIntyre River | Bridge | Unknown | Steel | 2.9 | Arch | 0 | 4.57 | 30.4 | 1 | 0.5 | 14 | 0.035 | 2 |
| **B-MI-Nakina** | Nakina Street Bridge | McIntyre River | Bridge | Unknown | Concrete | 13.5 | Box | 0 | 3.76 | 31.8 | 1 | 0.5 | 14 | 0.035 | 2 |
| **C-MI-Central** | Central Avenue Culvert | McIntyre River | Culvert | Unknown | Steel | 24.5 | Arch | 0 | 3.92 | 8.7 | 1 | 0.7 | 46 | 0.035 | 2 |
| **B-MI-Oliver** | Olivier Road Bridge | McIntyre River | Bridge | Unknown | Concrete | 31 | Box | 0 | 3.68 | 6.1 | 1 | 0.4 | 9 | 0.035 | 2 |
| **B-MI-Junot** | Junot Avenue Bridge | McIntyre River | Bridge | Unknown | Concrete | 18.3 | Box | 0 | 3.6 | 6 | 1 | 0.4 | 9 | 0.035 | 2 |
| **B-MI-HWY17** | Highway 17 Bridge | McIntyre River | Bridge | Unknown | Concrete | 24.2 | Arch | 0 | 6.44 | 15.2 | 1 | 0.7 | 46 | 0.035 | 2 |
| **B-MI-Dawson Dog** | Dawson Road Bridge at Dog Lake Road | McIntyre River | Bridge | Unknown | Concrete | 18 | Box | 0 | 2.49 | 6.5 | 1 | 0.4 | 9 | 0.035 | 2 |
| **B-107** | Island Drive Bridge | Neebing-McIntyre Floodway | Bridge | 1982 | Concrete | 12.4 | Custom | 0 | n/a | n/a | n/a | 0.5 | 14 | 0.035 | 3 |
| **B-112** | Harbour Expressway Bridge | McIntyre River | Bridge | Unknown | Concrete | 33.3 | Custom | 0 | n/a | n/a | n/a | 0.5 | 14 | 0.035 | 3 |
| **B-119** | William Street Bridge | McIntyre River | Bridge | 1982 | Concrete | 14.5 | Custom | 0 | n/a | n/a | n/a | 0.5 | 14 | 0.035 | 3 |

Notes: [1] Municipal Structure Inspection Form (2010)
[2] Draft Floodway Integrity Study HEC-RAS Model (2014)
[3] McIntyre Flood and Fill Line Mapping Technical Report (1985)

**Table 50. McVicar Creek Bridge and Culvert Inventory**

| Structure ID | Structure Name | Stream Name | Culvert/Bridge | Year of Construction | Material | Length (m) | Shape | Degree of Skew | Rise (m) | Span (m) | Depth of Depressed Creek Bed | Barrels | Entry Loss Coefficient | Culvert Code | Roughness | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | Marina Park Drive | McVicar Creek | Culvert | 1986 | CSP | 16.5 | Arch | 0 | 3.05 | 4.88 | 0 | 3 | 0.9 | 47 | 0.025 | 1 |
| **2** | Canadian Pacific Railway | McVicar Creek | Bridge | Unknown | Steel | 15 | Box | 10 | 1.4 | 13.2 | 0 | 1 | 0.5 | 20 | 0.035 | 1 |
| **3** | Cumberland | McVicar Creek | Culvert | 1982 | CSP | 43 | Arch | 0 | 2.1 | 4.88 | 0 | 3 | 0.5 | 47 | 0.025 | 1 |
| **B-008** | Court Street | McVicar Creek | Bridge | 1906 | Concrete | 19.9 | Arch | 0 | 2.4 | 15.3 | 0 | 1 | 0.5 | 30 | 0.035 | 2 |
| **B-007** | Algoma Street | McVicar Creek | Bridge | 1987 | Concrete | 18.4 | Box | 0 | 4 | 24.4 | 0 | 1 | 0.5 | 14 | 0.035 | 2 |
| **B-007A** | W/S Algoma Street | McVicar Creek | Bridge | 1987 | Concrete | 6.2 | Rect_Triangular | 0 | 1.7 | 12.5 | 0.8 | 1 | 0.5 | 14 | 0.035 | 2 |
| **6** | River Street | McVicar Creek | Culvert | 1977 | CSP | 45 | Arch | 15 | 4.4 | 4.4 | 0 | 2 | 0.9 | 47 | 0.025 | 1 |
| **B-114** | Farrand to Sunset Pedestrian | McVicar Creek | Bridge | Unknown | Timber | 3.06 | Box | 0 | 1.16 | 8 | 0 | 1 | 0.5 | 14 | 0.035 | 2 |
| **7** | Briarwood Drive | McVicar Creek | Culvert | Unknown | CSP | 15 | Arch | 10 | 3 | 5 | 0 | 1 | 0.9 | 47 | 0.025 | 1 |
| **8** | Margaret Street | McVicar Creek | Culvert | 1990 | Concrete | 17.4 | Box | 26 | 1.5 | 5.2 | 0 | 3 | 0.5 | 20 | 0.013 | 1 |
| **B-096** | Clayte Street Pedestrian - D/S crossing | McVicar Creek | Bridge | Unknown | Concrete | 1.6 | Rect_Triangular | 0 | 1 | 9.4 | 0.3 | 1 | 0.5 | 14 | 0.035 | 2 |
| **B-097** | Hartviksen Street Pedestrian | McVicar Creek | Bridge | Unknown | Steel | 1.55 | Box | 0 | 1.2 | 9.1 | 0 | 1 | 0.5 | 14 | 0.035 | 2 |
| **B-078** | Balsam Street | McVicar Creek | Bridge | 1980 | Concrete | 19.5 | Box | 0 | 1.9 | 18.4 | 0 | 1 | 0.5 | 14 | 0.035 | 2 |
| **B-098** | Brent Street Pedestrian | McVicar Creek | Bridge | Unknown | Steel | 1.9 | Box | 0 | 1.3 | 9.8 | 0 | 1 | 0.5 | 14 | 0.035 | 2 |
| **12** | Bruce Street | McVicar Creek | Culvert | Unknown | CSP | 13 | Arch | 0 | 2.44 | 4.27 | 0 | 1 | 0.9 | 47 | 0.025 | 1 |
| **13** | Madeline Street | McVicar Creek | Culvert | Unknown | CSP | 10.1 | Arch | 0 | 2.44 | 4.27 | 0 | 1 | 0.9 | 47 | 0.025 | 1 |
| **B-110** | Blanchard Street Pedestrian | McVicar Creek | Bridge | Unknown | Steel | 1.9 | Rect_Triangular | 0 | 0.45 | 9 | 0.3 | 1 | 0.5 | 14 | 0.035 | 2 |
| **15** | Hinton Avenue | McVicar Creek | Culvert | Unknown | CSP | 16 | Arch | 10 | 2.44 | 4.27 | 0 | 1 | 0.9 | 47 | 0.025 | 1 |
| **16a** | Lakehead Expressway | McVicar Creek | Culvert | Unknown | Concrete | 54 | Box | 0 | 2.24 | 5.7 | 0 | 1 | 0.5 | 54 | 0.013 | 1 |
| **16b** | Lakehead Expressway | McVicar Creek | Culvert | Unknown | CSP | 54 | Arch | 0 | 3.7 | 4.9 | 0 | 1 | 0.9 | 47 | 0.025 | 1 |
| **B-152** | County Park Pedestrian | McVicar Creek Tributary | Bridge | Unknown | Concrete | 2.44 | Box | 0 | 0.9 | 4.78 | 0 | 1 | 0.5 | 14 | 0.035 | 2 |
| **B-153** | Castlegreen Pedestrian | McVicar Creek | Bridge | Unknown | Concrete | 2.2 | Custom | 0 | 0.8 | 0 | 0 | 1 | 0.5 | 14 | 0.035 | 2 |
| **B-154** | County Park Pedestrian | McVicar Creek Tributary | Bridge | Unknown | Concrete | 2.438 | Custom | 0 | 0.62 | 0 | 0 | 1 | 0.5 | 14 | 0.035 | 2 |
| **17** | Wardrope Avenue | McVicar Creek | Culvert | 1975 | CSP | 30 | Circular | 10 | 3.96 | 3.96 | 0 | 1 | 0.9 | 6 | 0.025 | 1 |
| **19** | Onion Lake Road | McVicar Creek | Culvert | 1975 | CSP | 18 | Arch | 30 | 1.83 | 3.1 | 0 | 1 | 0.9 | 47 | 0.025 | 1 |
| **21a** | Hilldale Road | McVicar Creek | Culvert | Unknown | CSP | 16 | Circular | 0 | 1.375 | 1.375 | 0 | 1 | 0.9 | 6 | 0.025 | 1 |
| **21b** | Hilldale Road | McVicar Creek | Culvert | Unknown | Timber | 16 | Box | 0 | 1.52 | 1.83 | 0 | 1 | 0.5 | 54 | 0.012 | 1 |
| **22** | Hazelwood Road - 2.41 km south of Road #8 (Melbourne Road) | McVicar Creek | Culvert | Unknown | CSP | 9 | Circular | 15 | 1.525 | 1.525 | 0 | 1 | 0.9 | 6 | 0.025 | 1 |
| **23** | Hazelwood Road - 305 m south of Road #8 (Melbourne Road) | McVicar Creek | Culvert | Unknown | CSP | 11 | Circular | 0 | 1.05 | 1.05 | 0 | 2 | 0.9 | 6 | 0.025 | 1 |
| **24** | Melbourne Road East of Hazelwood Drive | McVicar Creek | Culvert | Unknown | Timber | 10 | Box | 0 | 1.22 | 1.37 | 0 | 1 | 0.5 | 54 | 0.012 | 1 |
| **East-1** | Bolton Road north of Maxwell | McVicar Creek East Tributary | Culvert | Unknown | CSP | 21 | Arch | 0 | 1.52 | 2.06 | 0 | 1 | 0.9 | 47 | 0.025 | 1 |
| **East-2** | Balsam Street South of Lancaster | McVicar Creek East Tributary | Culvert | Unknown | CSP | 12 | Circular | 0 | 0.75 | 0.75 | 0 | 1 | 0.9 | 6 | 0.025 | 1 |

Notes:
[1] Structural Inventory in McVicar Creek Floodplain Study (1995)
[2] Municipal Structure Inspection Form (2010)

**Table 51. Mosquito Creek Bridge Inventory**

| Structure ID | Structure Name | Stream Name | Culvert/Bridge | Year of Construction | Material | Length (m) | Shape | Degree of Skew | Rise (m) | Span (m) | Barrels | Entry Loss Coefficient | Culvert Code | Roughness | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **B-113** | Chippewa Road Bridge | Mosquito Creek | Bridge | 1969 | Concrete | 12.8 | Box | 0 | 3.15 | 17.1 | 1 | 0.5 | 14 | 0.035 | 1 |

Notes:
[1] Municipal Structure Inspection Form (2010)

**Table 52. Neebing River Bridge Inventory**

| Structure ID | Structure Name | Stream Name | Culvert/Bridge | Year of Construction | Material | Length (m) | Shape | Degree of Skew | Rise (m) | Span (m) | Depth of Depressed Creek Bed (m) | Barrels | Entry Loss Coefficient | Culvert Code | Roughness | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B-017 | Simpson Street Bridge | Neebing River | Bridge | 2003 | Concrete | 20 | Box | 27 | 2.85 | 19.5 | 0 | 1 | 0.5 | 14 | 0.035 | 1 |
| B-019 | Vickers Street Bridge | Neebing River | Bridge | 2007 | Concrete | 25 | Box | 0 | 2.6 | 10 | 0 | 2 | 0.5 | 14 | 0.035 | 1 |
| B-020 | Cameron Street Bridge | Neebing River | Bridge | 1952 | Concrete | 11.7 | Arch | 30 | 1.5 | 18.3 | 0 | 1 | 0.5 | 14 | 0.035 | 1 |
| B-021a | Waterloo Street Bridge | Neebing River | Bridge | 1989 | Concrete | 19.9 | Box | 0 | 1 | 7.7 | 0 | 2 | 0.5 | 14 | 0.035 | 1 |
| B-021b | Waterloo Street Bridge | Neebing River | Bridge | 1989 | Concrete | 19.9 | Box | 0 | 1 | 19.3 | 0 | 1 | 0.5 | 14 | 0.035 | 1 |
| B-022a | Edward Street Bridge | Neebing River | Bridge | 1989 | Concrete | 32 | Box | 0 | 1.3 | 7.32 | 0 | 2 | 0.5 | 14 | 0.035 | 1 |
| B-022b | Edward Street Bridge | Neebing River | Bridge | 1989 | Concrete | 32 | Box | 0 | 1.3 | 17.37 | 0 | 1 | 0.5 | 14 | 0.035 | 1 |
| B-034 | Government Road Bridge | Neebing River | Bridge | Unknown | Wood | 6.3 | Box | 0 | 0.8 | 3.57 | 0 | 1 | 0.5 | 14 | 0.035 | 1 |
| B-038 | John Street Road Bridge | Neebing River | Bridge | 1997 | Concrete | 11.1 | Box | 0 | 1.4 | 6.7 | 0 | 1 | 0.5 | 14 | 0.035 | 1 |
| B-093 | Ford Street Pedestrian Bridge | Neebing River | Bridge | Unknown | Concrete | 3 | Rect_Triangular | 0 | 3.44 | 34.2 | 1 | 1 | 0.5 | 14 | 0.035 | 1 |
| B-094 | Syndicate Avenue Pedestrian Bridge | Neebing River | Bridge | Unknown | Concrete | 2 | Rect_Triangular | 0 | 2.6 | 42.8 | 2.05 | 1 | 0.5 | 14 | 0.035 | 1 |
| B-095 | James Street Bridge | Neebing River | Bridge | 1978 | Concrete | 15.8 | Box | 25 | 4 | 15.75 | 0 | 1 | 0.5 | 14 | 0.035 | 1 |
| B-106 | Legion Pedestrian Track Bridge | Neebing River | Bridge | Unknown | Concrete | 2.4 | Rect_Triangular | 0 | 3 | 33 | 1.9 | 3 | 0.5 | 14 | 0.035 | 1 |
| B-108 | Leland Avenue Pedestrian Bridge | Neebing River | Bridge | Unknown | Concrete | 2.134 | Rect_Triangular | 0 | 2.5 | 45.72 | 2.03 | 1 | 0.5 | 14 | 0.035 | 1 |
| B-109 | Pole Line Road Bridge over Neebing River at Cathy Creek | Neebing River | Bridge | Unknown | Wood and Steel | 5.2 | Box | 0 | 0.9 | 9.2 | 0 | 1 | 0.5 | 14 | 0.035 | 1 |
| B-111 | Prince Arthur Boulevard Pedestrian Bridge | Neebing River | Bridge | Unknown | Concrete | 2.2 | Box | 0 | 1.7 | 36.8 | 0 | 1 | 0.5 | 14 | 0.035 | 1 |
| B-131a | Parkdale Boulevard Bridge | Neebing River | Bridge | 1993 | Concrete | 19.7 | Box | 0 | 1.3 | 14.5 | 0 | 3 | 0.5 | 14 | 0.035 | 1 |
| B-131b | Parkdale Boulevard Bridge | Neebing River | Bridge | 1993 | Concrete | 19.7 | Box | 0 | 1.3 | 23.5 | 0 | 3 | 0.5 | 14 | 0.035 | 1 |
| B-134 | Arthur Street Bridge near 20th Side Road | Neebing River | Bridge | 2004 | Concrete | 20.8 | Rect_Triangular | 0 | 2.8 | 30 | 2.3 | 1 | 0.5 | 14 | 0.035 | 1 |
| C-NB-Arthur | Arthur Street Bridge near Vanguard Avenue | Neebing River | Culvert | Unknown | Concrete | 24 | Box | 0 | 5.86 | 9.6 | 0 | 1 | 0.5 | 9 | 0.035 | 2 |

Notes:
[1] Municipal Structure Inspection Form (2010)
[2] Neebing River Flood and Fill Mapping Technical Report (1985)

**Table 53. Golf Links Detailed Cost Estimate**

| | Size of Facilities | | | | Capital Cost | | | | | Annual Operation and Maintenance Cost | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Item** | ***Units*** | **Scenario 1** | **Scenario 2** | **Scenario 3** | ***Unit Cost*** | | **Scenario 1** | **Scenario 2** | **Scenario 3** | ***Unit Cost*** | | **Scenario 1** | **Scenario 2** | **Scenario 3** |
| Ditch[1] | *Length (m)* | 2,610 | 2,350 | 2,120 | *100* | *$/m* | $ 261,000 | $ 235,000 | $ 212,000 | *$/yr* | | $ 10,000 | $ 9,000 | $ 8,000 |
| Pipe[2] | *Length (m)* | 6,610 | 5,950 | 5,360 | *varies* | *$/m* | $ 3,107,000 | $ 2,261,000 | $ 1,662,000 | *15* | *$/m* | $ 10,000 | $ 9,000 | $ 8,000 |
| Pond[3] | *Volume ($m^3$)* | 0 | 41,550 | 24,220 | *16* | *$/$m^3$* | $ - | $ 665,000 | $ 388,000 | *$/yr* | | $ - | $ 20,000 | $ 12,000 |
| Infiltration Facilties[4] | *Footprint ($m^2$)* | 0 | 0 | 10,210 | *100* | *$/$m^2$* | $ - | $ - | $ 1,021,000 | *$/yr* | | $ - | $ - | $ 35,000 |
| Land [5] | *$m^2$* | 0 | 19,600 | 12,760 | *7* | *$/$m^2$* | $ - | $ 137,000 | $ 89,000 | *$ -* | | $ - | $ - | $ - |
| | | | | | | **Subtotal** | $ 3,368,000 | $ 3,298,000 | $ 3,371,000 | | **Subtotal** | $ 20,000 | $ 38,000 | $ 63,000 |
| | | | | | | Retrofit [6] | $ 1,722,000 | $ 1,243,000 | $ - | | Retrofit [6] | $ 47,000 | $ 35,000 | $ - |
| | | | | | | **Total** | **$ 5,090,000** | **$ 4,541,000** | **$ 3,371,000** | | **Total** | **$ 67,000** | **$ 73,000** | **$ 63,000** |

***Notes:***

**Scenario Descriptions**

**PR1** - Conveyed by pipes and ditches
**PR2** - Stormwater ponds to control water quantity (peak flows) and quality
**PR3** - Infiltration facilities and stormwater ponds to control water quantity (peak flows and volume) and quality to predevelopment rates
**PR4** - LID design with revised site layout

[1] Ditches are assumed to be 1.2 m deep and 1.8 m bottom with 3:1 side slopes. Annual maintenance costs include removal of sediment accumulation, re-grading and sodding/seeding when needed and it is estimated at 4% of the capital cost.

[2] Pipe capital cost based on the following average sizes with an average depth of 2.4 m and includes excavation, manholes, catchbasins and CB leads (costs based on Hatch Mott McDonald River Terrace South Subdivision 5 cost estimate).
Maintenance cost includes T.V. inspections, cleaning sediment accumulation from pipes, MHs, catch basins and perform minor repairs.
Assumes that the system is maintained at least 1 time every 10 years.

| Scenario | Average Pipe Size | $/m |
|---|---|---|
| PR1 | 525 mm dia. | 470 |
| PR2 | 450 mm dia. | 380 |

[3] Ponds' capital cost includes excavation, grading, outlet structure, and planting.
Full volume would need to be excavated as if there were no natural depressions. Assumed average depth = 2.4 m.
Cost assumes economy of scale since the ponds will be built as part of development grading.
The ponds' maintenance cost includes minor removal of sediment and debris, cleaning and maintaining outlets, erosion repairs and plants reestablishment.
The M&O annual cost is estimated at 3% of the capital cost.
Complete sediment removal will have to be done every 20 years approximately.
This dredging cost is expected to be about $30/m3 in today's dollars.

[4] Infiltration facilities are assumed to be rain gardens, infiltration trenches and other bioretention facilities integrated in the development landscape.
Cost includes excavation, planting, and engineered medium when needed.
The cost for proper maintenance of infiltration facilities is estimated at $35,000 each year.
This cost may be higher in the early years of the facilities and lower thereafter.
Annual costs may also fluctuate based on sediment accumulation and health of vegetation.

[5] Land cost assumes the unserved, raw cost (when the land is purchased by the developer), not the served lot cost.

[6] The structural and environmental costs downstream due to not reducing and treating runoff to predevelopment rates need to be considered for a fair cost comparison.
Therefore, the systems constructed under the scenarios PR1 and PR2 would require retrofitting outside of the development to mitigate flooding problems and excessive pollutant loadings downstream.
The retrofit of PR1 includes the construction of ponds and infiltration facilities with a cost estimated at 20% more than the cost in PR3 due to additional efforts needed in a retrofit situation (preliminary site assessment, feasibility analysis, no economy of scale, etc.).
The retrofit of PR2 includes the construction of infiltration facilities with a cost estimated also at 20% more than the cost in PR3.
The retrofit costs for PR1 and PR2 also include the cost of land required to build those facilities somewhere else.
The cost of land in this case has been reduced by 80% assuming that the retrofit facilities would not be built on prime developable land.
All costs for PR3 assume that the facilities are designed and constructed properly so that retrofits are not necessary.

# APPENDIX E IDF Curves Development & Climate Change Assessment

## 1 Executive Summary

Precipitation data from Environment Canada (EC) monitoring stations was used to generate Intensity-Duration-Frequency (IDF) curves. The data was analyzed for trends due to climate change during the period of record using Kendall's tau test. For stations with hourly rainfall data, the IDF curves fit exceptionally well to those developed by the Ministry of Transportation of Ontario (MTO) in 2013. The fits were not as good for stations with only daily rainfall data.

Overall, the IDF curves for one station in particular (at the Thunder Bay airport) verified that the MTO IDF curves at this location are useful for storm durations shorter than 24 hours and return periods smaller than 100 years. For longer durations and longer return periods, the IDF curves developed in the SMP should be used.

Due to the low resolution of rainfall data at other stations, comparisons between the IDF curves developed in the SMP and those developed by the MTO remain inconclusive at those locations.

The existing IDF curves from Drawing M-108 of the 2014 Engineering and Development Standards for Thunder Bay were also compared with the IDF curves updated with the latest Thunder Bay Airport rainfall gauge data up to 2014. The updated curves were also extended to provide longer event duration information than Drawing M-108. Due to the significant expansion of the ranges of durations and frequencies resulting from the update, in addition to the observed underestimation of intensities for the 25-year storms, it is recommended that the Drawing M-108 be replaced with the updated IDF curves (Figure 24) and intensity and depth duration frequency tables (Table 55 and Table 56).

Climate change analysis showed relatively few statistically significant trends during the period of record for the five stations closest to the study area. Generally, those trends that were significant showed that the occurrences of both wet and dry periods (i.e. sequential, multi-day periods with either rainfall or no rainfall on all days, respectively) are increasing in frequency, while the analysis of trends in the depths of rainfall during wet periods showed mixed results.

Overall, while the trends toward longer dry periods are more apparent than those toward longer wet periods, the results suggest that longer duration storms (>24 hours) could be important to consider as part of stormwater infrastructure designs. Little information currently exists regarding the best methods for appropriately distributing rainfall for multi-day design storms, so a historical multi-day storm of a specified depth or intensity might be considered an appropriate alternative.

A related recommendation in the SMP is that runoff flow calculations for review of existing City CIP program infrastructure should use the updated IDF curves with an additional 15% increase in rainfall depth and intensity. Runoff flow calculations for review of development applications should use the updated IDF curves for pre-development conditions and use the updated IDF curves with an additional 15% increase in rainfall depth and intensity for post-development conditions. This proactive measure plans for the uncertainty associated with intensity and frequency of storms and is consistent with the policies of other municipalities in Ontario.

## 2 Data Available for Analysis

Precipitation data from rain gauges operated by Environment Canada were obtained for a total of 45 stations. A few of these stations had distinct identifiers but were actually located in the same place as another (i.e. different periods of the record were recorded under different climate IDs). All stations had at least daily resolution, and four of the stations had hourly resolution. Filtering was performed to exclude those years in which >20% of data was missing during the wet season (May-September), and for which at least 20 years of data was available, as suggested by Perica et al. (2013). Following filtering and after combining those stations that were located in the same place, 12 daily stations (one of which – station 6048261 at the airport – had hourly data) were found to have adequate data for use in the analysis. Of the 12 stations, five were deemed close enough to the study area to be of interest. Table 54 summarizes the data for these five stations, and Figure 23 displays their locations.

**Table 54. Environment Canada Weather Stations**

| Climate ID | Station Name | Latitude | Longitude | Elevation (m) | Record Length (years) | % of Wet Season Missing |
|---|---|---|---|---|---|---|
| **6048261** | FT WILLIAM PT ARTHUR A | 48.37 | -89.32 | 199 | 48 | 2.6 |
| **6049096** | UPSALA | 49.05 | -90.47 | 484 | 24 | 0.4 |
| **6049466** | WHITEFISH LAKE | 48.28 | -89.92 | 399 | 29 | 0.0 |
| **6042MJ7** | FLINT | 48.35 | -89.68 | 274 | 35 | 0.7 |
| **604HBFA** | THUNDER BAY WPCP | 48.40 | -89.23 | 184 | 28 | 0.0 |

Although precipitation data from the Lakehead Regional Conservation Authority (LRCA) was also acquired, the data had not been processed and no metadata was provided upon request to staff at both the LRCA and the Water Survey (which cooperatively operates these rain gauges). Performing QA/QC without proper metadata would constitute a significant effort, and so although some of the data was quite desirable for inclusion in the analysis – in that many of these stations had hourly or sub-hourly rainfall data – these datasets were deemed unusable at this time.

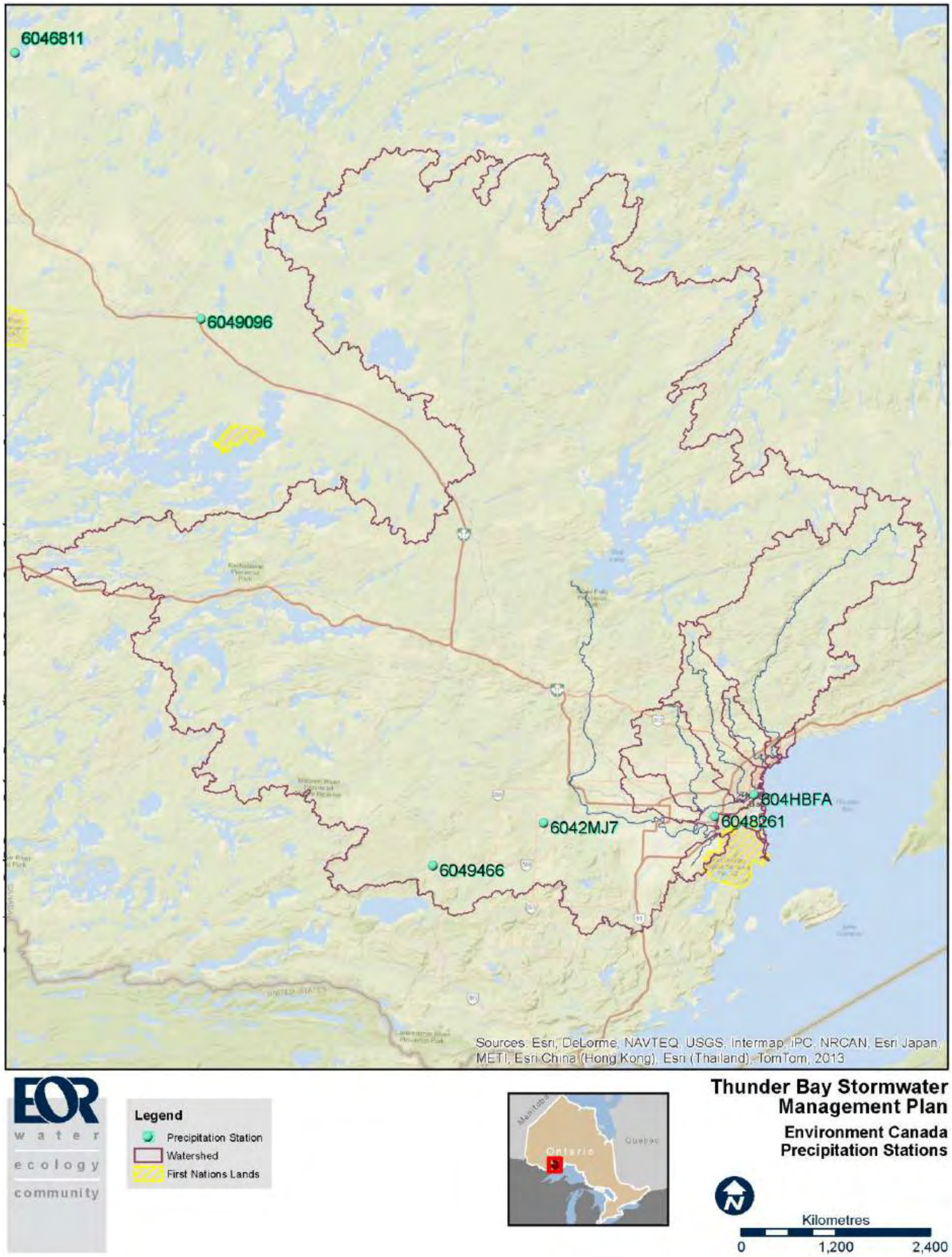


**Figure 23: Map showing the five precipitation stations near or within the watershed study area.**

# 3 IDF Development

## 3.1 Definition of IDF

Intensity-Duration-Frequency (IDF) curves are useful in hydrologic design projects. IDF curves are typically constructed with the Y-axis representing average storm intensity, the X-axis representing storm duration, and a line drawn through the plot representing the return period (i.e. the inverse of frequency) of the storms, such that for any storm duration one can determine the intensity that occurs with a given frequency, or vice-versa. For example, one might wish to know the rainfall intensity that can be expected to occur over a 10-minute period once every 10 years (i.e. a 10-year, 10-minute storm). It should be noted that the Y-axis can also represent storm depth instead of intensity in the case of a Depth-Duration-Frequency (DDF) curve, and that these two curves – while not equivalent – can be derived from one another using the duration in hours, such that intensity = (depth / duration).

The generation of IDF curves is possible when local rainfall data is available for an extended period of time. The shape and magnitude of the frequency plots depends entirely on the dataset that is used to generate them, so generally only long datasets of 20 or more years of precipitation records are be used reliably for this type of analysis without adjustment.

## 3.2 Current IDF availability

In December of 2012 the Ontario Ministry of Transportation (MTO), along with Environment Canada (EC), released a web-based IDF Curve Lookup tool(2). The tool allows a user to generate IDF curves for any location in Ontario by clicking on an interactive map. Data is available for 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, and 100-yr return periods at 5-min, 10-min, 15-min, 30-min, 1-hr, 2-hr, 6-hr, 12-hr, and 24-hr durations.

Although this analysis may be adequate for some purposes, there has been recent scientific evidence suggesting that storm durations longer than 24 hours are of particular interest in the context of climate change. In the Midwestern United States, for example, the 5-day storm depth has been shown to be increasing, and in northern Minnesota in particular the duration of dry days (days between rainfall events) has been decreasing significantly(3) – characteristics not well-described by standard daily or sub-daily design storms.

Another drawback of the IDF curves generated by Soulis(2) is the sparseness of the input dataset. To facilitate the generation of IDF curves anywhere on the map, topography was analyzed using 10 km grid squares, with the assumption that the IDF curve parameters are "strongly influenced by local and regional topography". With the higher resolution dataset available for this project, a comparison can be made between these empirically-derived IDF curves and those generated through interpolation by the IDF Lookup Tool at the location of each rain gauge.

### 3.3 IDF Curve Generation Methodology

The generation of IDF curves involves performing frequency analysis on observed datasets for varying durations by fitting a probability density function (PDF) to the data, then tabulating the resulting intensity statistics for each return period of interest. The durations and return periods analyzed were:

- Durations – 5-minute, 10-minute, 15-minute, 30-minute, 1-hour, 2-hour, 6-hour, 12-hour, 1-day, 2-day, 3-day, 5-day, 10-day, 30-day, and 60-day
- Return periods – 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, 500-year, and 1000-year

To some extent the model of choice depends on which distribution best fits the dataset, but the most commonly-used statistical model for frequency analysis of rainfall is the Gumbel or Extreme Value Type I distribution [(4)], which is the distribution that was used to generate the PDF used by Soulis for the MTO's web-based IDF Curve Lookup tool. The model used for frequency analysis and the method of IDF curve generation should be considered independent of the platform (e.g. software package) with which they are implemented.

The approach used for generating IDF curves and climate changes statistics involved the writing of custom code in the programming language, R. R is a programming language and software environment for statistical computing and graphics supported by the R Foundation for Statistical Computing. The first R module written to develop the IDF curves decodes the fixed-width-formatted raw Environment Canada data and generates a report summarizing the extent of missing data by station, year, and month.

In the second R module, annual maxima (i.e. the maximum rainfall depth that occurs in a given year during a given sequential period of time or "duration") are extracted for a set of storm durations from 1-hour up to 12-hours for the hourly datasets, and from 24-hours up to 60 days for the daily datasets. Consistent with the work by Perica et al. (2013), annual maxima are then checked for compliance with the filtering requirements (<20% of wet season data missing), and values are either accepted or conditionally rejected. To ensure that known annual maxima are included in the dataset, statistics are then computed for the accepted data and the conditionally rejected values are checked against them. If a conditionally rejected value is greater than 95% of the accepted values, it is added to the set of accepted values; otherwise it is rejected.

The third R module takes data from the MTO web tool (manually extracted for each of the 12 locations) and generates IDF tables for comparison in the next module.

The fourth R module performs several operations. First, it uses the annual maxima datasets to generate both an empirical and a derived DDF table for each station. The empirical curves are generated first by computing statistics of the observed annual maxima, then using these statistics to generate an Extreme Value Type I probability density function (PDF). A depth for each duration and frequency (i.e. return period) combination is generated as:

$$\boldsymbol{R = \alpha + Y_T * \beta}$$

where:

$R$ is the rainfall depth
$\bar{X}$ is the sample mean of the annual maxima for a given duration
$s_d$ is the sample standard deviation of the annual maxima for a given duration
$\gamma$ is the Euler-Mascheroni constant ≈ 0.5772157
$T$ is the return period.
$\alpha = \bar{X} - \gamma * \beta$
$\beta = s_d * \sqrt{6}/\pi$
$Y_T = (-\ln(-\ln(1 - (1/T))))$

These DDF tables are then converted to IDF tables by dividing the values by the duration in hours, effectively converting a depth in *mm* to intensity in *mm/hr*. For those stations with both hourly and daily data, the IDF tables are combined.

The derived IDF curves are then generated using linear regression by least squares fit on a log-log transformation of the empirical IDF curve. The coefficient, A, and exponent, B, for each return period were then extracted from the linear model as:

$$\mathbf{ln}(\boldsymbol{y}) = \boldsymbol{b} * \mathbf{ln}(\boldsymbol{x}) + \mathbf{ln}(\boldsymbol{a})$$
$$\boldsymbol{A = e^{a}}$$
$$\boldsymbol{B = b}$$

where:

$b$ is the slope of the curve
$\ln(a)$ is the intercept of the curve
$x$ represents the durations
$y$ represents the intensities

and the derived IDF curve is expressed as

$$\boldsymbol{y = Ax^{B}}.$$

Several IDF plots are generated for each location, which report:

1. The derived IDF curve
2. The derived IDF curves plotted with the empirical IDF curves
3. The derived IDF curves plotted with the MTO IDF curves

For each of the three comparison plots, the root-mean-square error (RMSE) between the datasets is computed for the overlapping points in the datasets as a whole (i.e. the aggregated dataset) as well as for each individual return period. These values are reported on the plots.

### 3.4 IDF Curve Analysis Summary

The plots for the five stations of interest – which include the RMSE statistics for the comparisons – can be found at the end of this Section. In general, the derived IDF curves that were generated from daily data alone did not fit well with the MTO IDF curves. However, for the one station that had both hourly and daily data (the airport station) the fit is exceptional, with an aggregated RMSE of 2 mm/hr. This indicates that the methodology used was consistent with that used by the MTO. The IDF curves for the airport station (6048261) are shown in Figure 24, Figure 25, Figure 26, and Figure 27, and the values for the IDF and DDF can be found in Table 55 and Table 56, respectively.

Due to the low amount of usable data it was difficult to assess the MTO IDF curves at locations other than the airport. It can be inferred from Figure 28 that daily data alone does not appear to be adequate to generate points for durations shorter than one day – although the fit for durations longer than one day cannot be verified, since the MTO IDF curves do not report longer durations. Conversely, the hourly data fit quite well with the points on the MTO IDF curves, even for durations shorter than one hour. It should be noted that the inclusion of any sub-hourly rainfall data in the analysis would likely improve the curves' applicability for short-duration storm events – but these events may not be as important as long-duration events (i.e. wet spells), as discussed previously.

The low RMSE values observed in Figure 26 suggest that, for the overlapping range of durations and frequencies, the values from the derived IDF curves and those from the MTO's curves for the Thunder Bay Airport should be considered virtually equivalent. Any differences between the results from the MTO effort and the current effort can be primarily explained by the potentially different data filtering methodology used (for which no documentation by the MTO was found). For the airport, the MTO's IDF curve appears to be adequate. Regardless, the current effort has increased the upper end of the range for both the durations and frequencies of the curve to 60 days and to 1000 years, respectively (Figure 24).

Figure 27 shows the derived IDF curves plotted against the existing IDF curves from drawing M-108 of the 2014 Engineering and Development Standards for Thunder Bay. The M-108 numbers tend to overestimate precipitation intensity for higher frequency events (2- and 5-year storms) with the exception of the shortest duration storms (5-minute). Conversely, for the lowest frequency events (25-year storms) the M-108 numbers underestimate intensities across all durations. Due to the expanded range of durations and frequencies in the derived IDF curves developed in the current effort, in addition to the observed underestimation of intensities for the 25-year storms, it is recommended that the M-108 Standard IDF curves be replaced with the updated Airport Station curves (Figure 24) and intensity and depth duration frequency tables (Table 55 and Table 56).

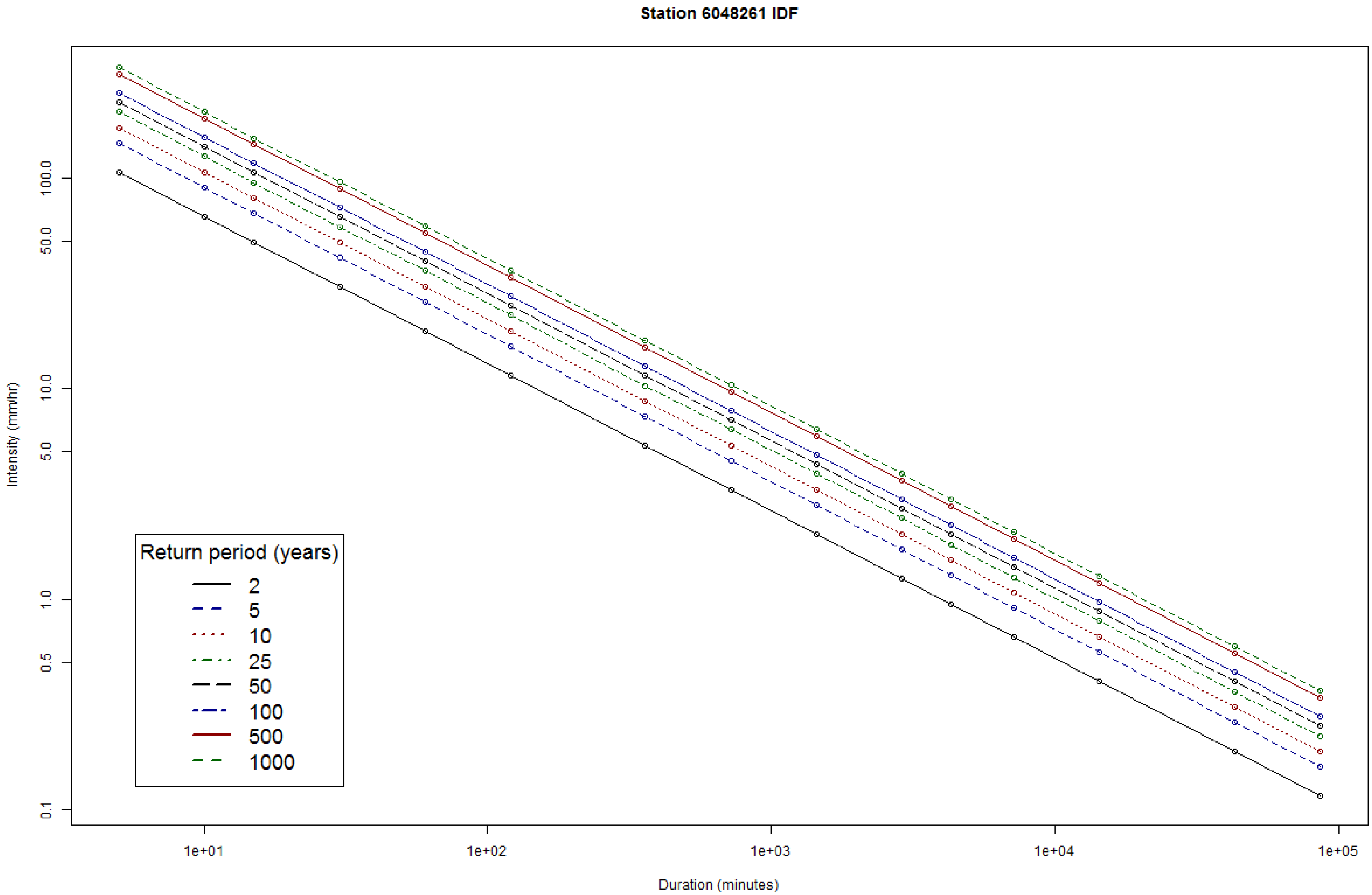


Figure 24. IDF curve for station 6048261 at the airport.

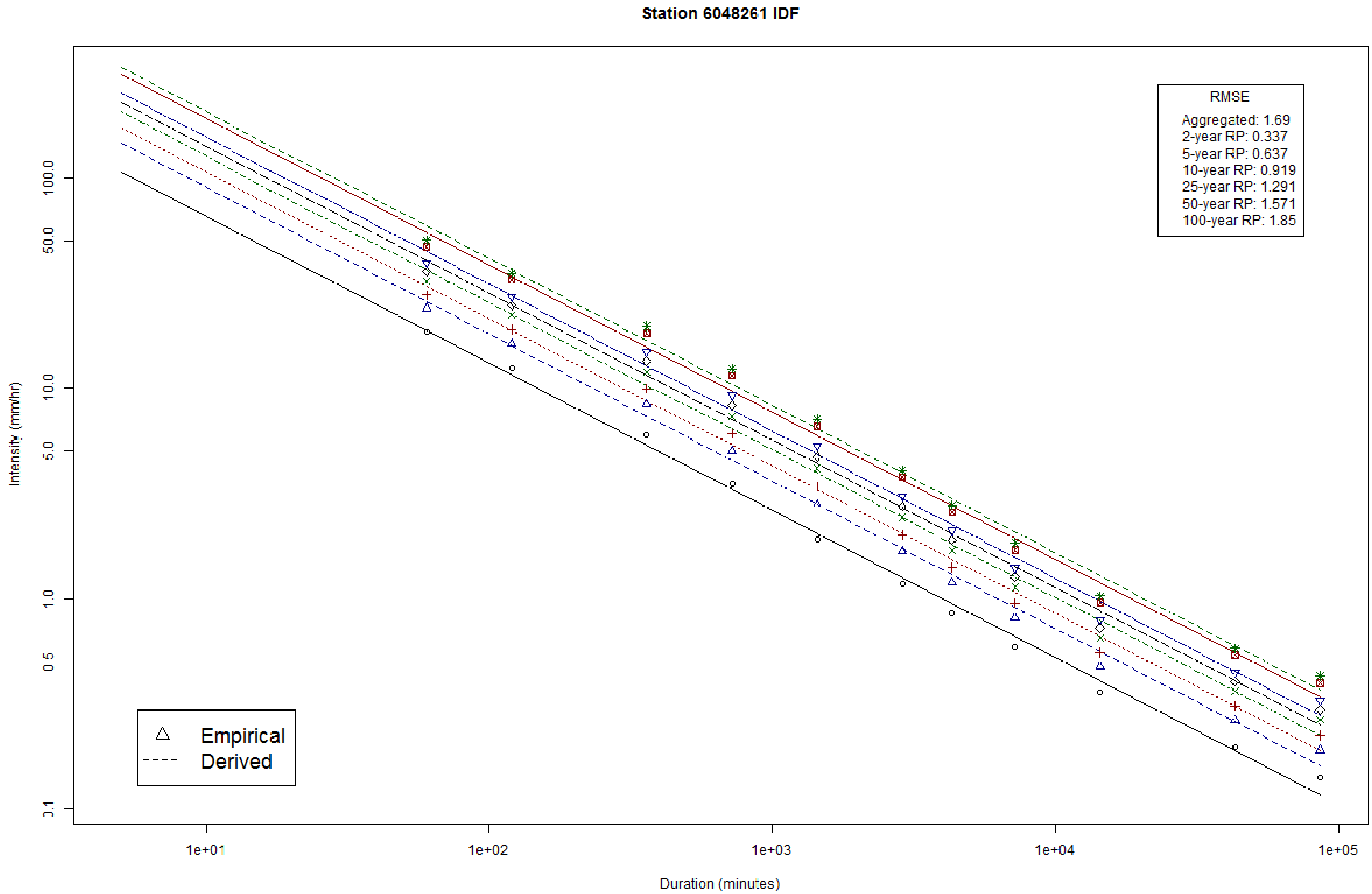


**Figure 25. IDF curve for station 6048261 at the airport, compared with its corresponding empirical IDF curve.**

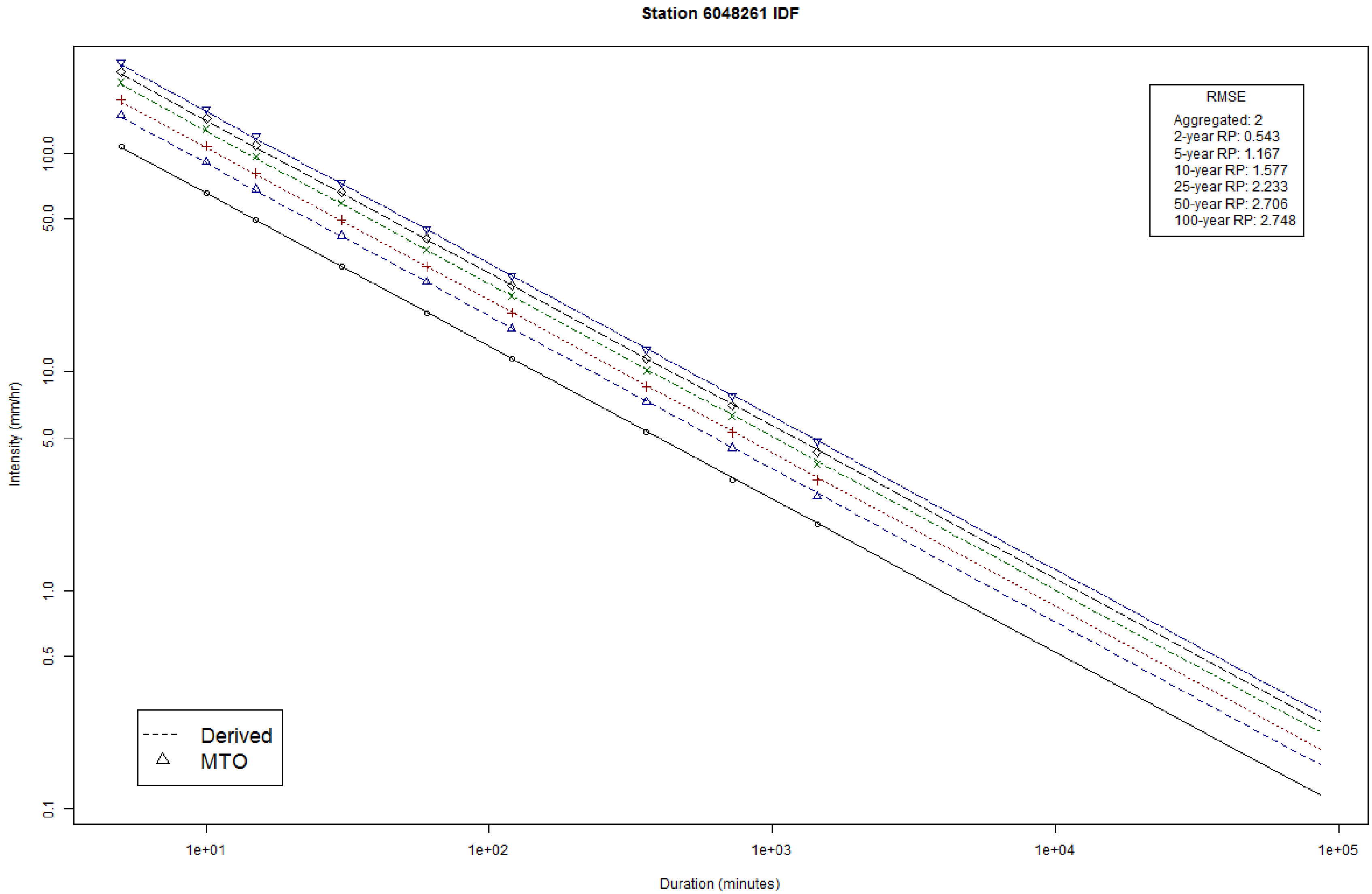


**Figure 26. IDF curve for station 6048261 at the airport, compared with the MTO IDF curve for the same location.**

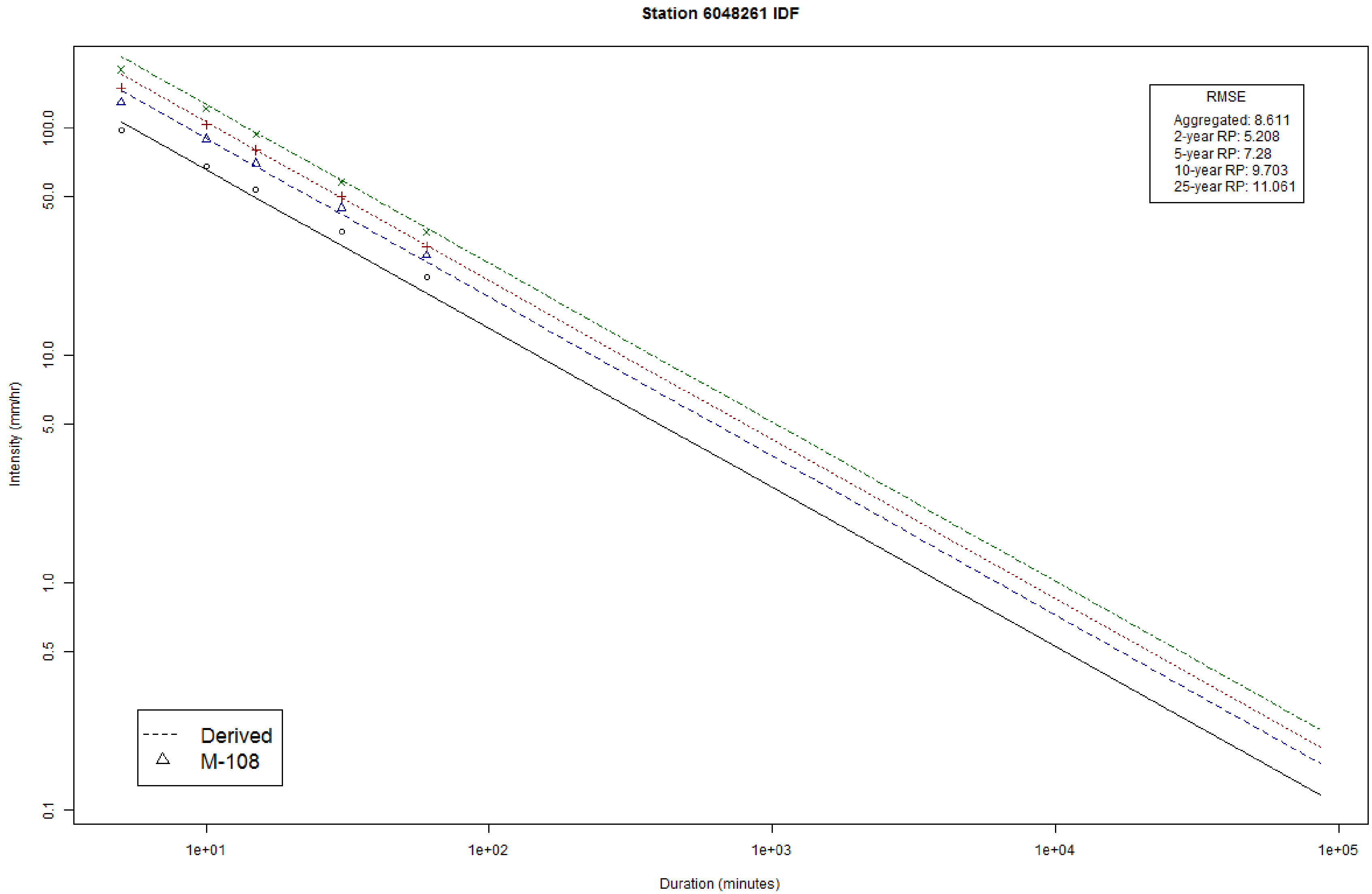


**Figure 27. IDF curve for station 6048261 at the airport, compared with the M-108 Standard IDF curve. Return periods shown are 2, 5, 10, and 25 years.**

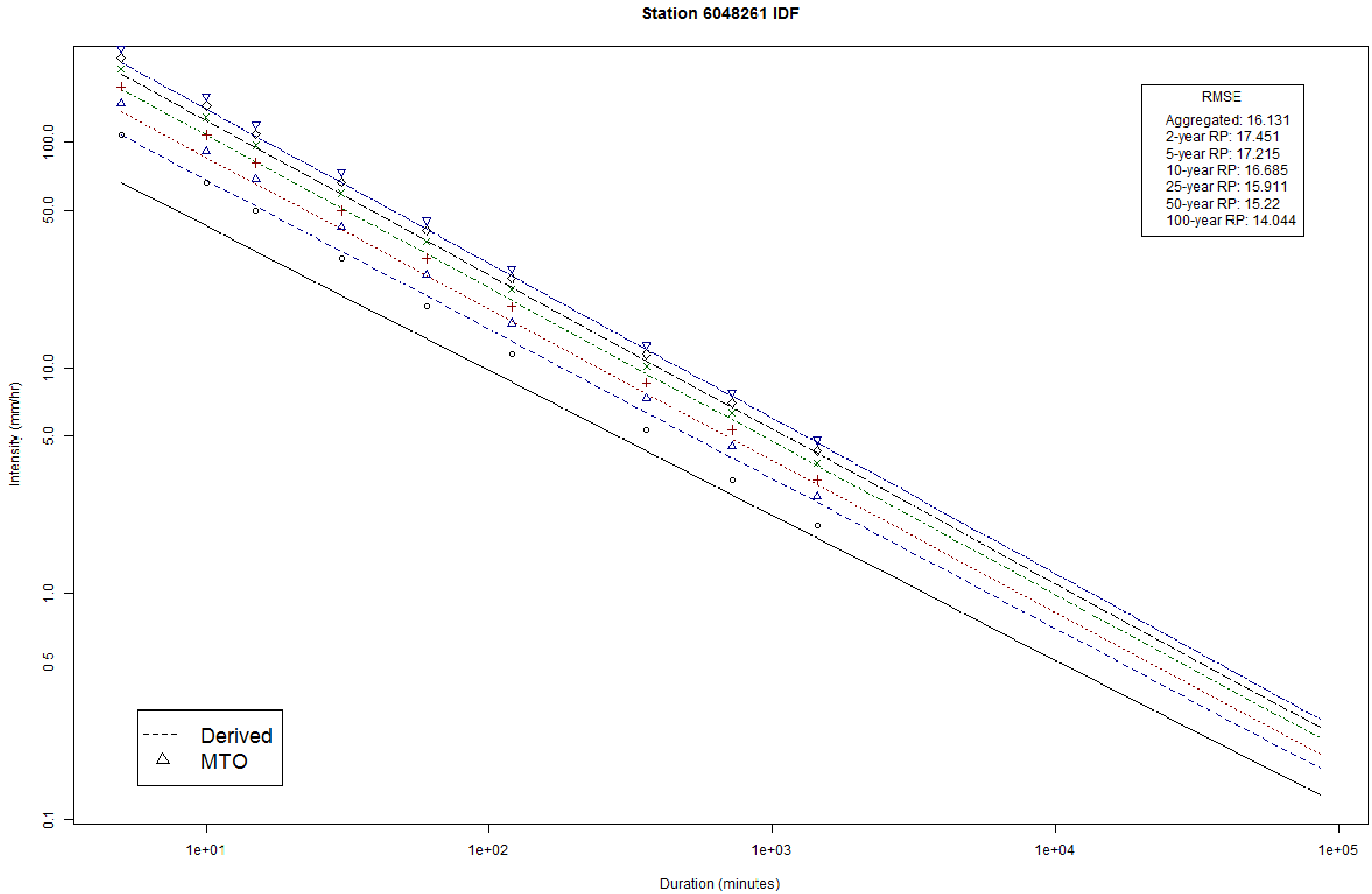


**Figure 28. IDF curve for station 6048261 at the airport, compared with the MTO IDF curve. Return periods shown are 2, 5, 10, 25, 50, and 100 years.**

**Table 55: Intensity-Duration-Frequency (IDF) table for the airport station (6048261). Intensities are in *mm/hr*.**

| Return Period (years) | Duration, *x* (minutes) | | | | | | | | | | | | | | | Power Function Coefficients | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 30 | 60 | 120 | 360 | 720 | 1440 | 2880 | 4320 | 7200 | 14400 | 43200 | 86400 | | |
| | (5 min) | (10 min) | (15 min) | (30 min) | (1 hr) | (2 hr) | (6 hr) | (12 hr) | (1 day) | (2 day) | (3 day) | (5 day) | (10 day) | (30 day) | (60 day) | A | B |
| **2** | 107 | 65.7 | 49.5 | 30.5 | 18.8 | 11.5 | 5.35 | 3.30 | 2.03 | 1.25 | 0.942 | 0.659 | 0.406 | 0.188 | 0.116 | 328.8 | -0.6995 |
| **5** | 146 | 90.2 | 67.9 | 41.8 | 25.8 | 15.9 | 7.36 | 4.53 | 2.79 | 1.72 | 1.29 | 0.906 | 0.558 | 0.259 | 0.159 | 451.3 | -0.6993 |
| **10** | 173 | 106 | 80.1 | 49.3 | 30.4 | 18.7 | 8.68 | 5.35 | 3.29 | 2.03 | 1.53 | 1.07 | 0.658 | 0.305 | 0.188 | 531.8 | -0.6992 |
| **25** | 206 | 127 | 95.4 | 58.8 | 36.2 | 22.3 | 10.3 | 6.37 | 3.93 | 2.42 | 1.82 | 1.27 | 0.785 | 0.364 | 0.224 | 633.2 | -0.6990 |
| **50** | 230 | 142 | 107 | 65.8 | 40.5 | 25.0 | 11.6 | 7.14 | 4.40 | 2.71 | 2.04 | 1.43 | 0.879 | 0.408 | 0.251 | 708.3 | -0.6988 |
| **100** | 254 | 157 | 118 | 72.7 | 44.8 | 27.6 | 12.8 | 7.89 | 4.86 | 3.00 | 2.26 | 1.58 | 0.973 | 0.452 | 0.278 | 782.7 | -0.6987 |
| **500** | 310 | 191 | 144 | 88.7 | 54.7 | 33.7 | 15.6 | 9.63 | 5.94 | 3.66 | 2.76 | 1.93 | 1.19 | 0.552 | 0.340 | 954.5 | -0.6985 |
| **1000** | 334 | 206 | 155 | 95.6 | 58.9 | 36.3 | 16.9 | 10.4 | 6.40 | 3.94 | 2.97 | 2.08 | 1.28 | 0.595 | 0.367 | 1028.2 | -0.6984 |

Note: Intensities can be calculated for any duration using the coefficients A and B in the relationship $y = Ax^B$, where $y$ is the intensity and $x$ is the duration in minutes.
The dark shaded region represents the extent of the existing M-108 Standard IDF curve; the light shaded region represents the extent of the existing MTO Standard IDF curve.

**Table 56: Depth-Duration-Frequency (DDF) table for the airport station (6048261). Depths are in *mm*.**

| Return Period (years) | Duration (minutes) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 30 | 60 | 120 | 360 | 720 | 1440 | 2880 | 4320 | 7200 | 14400 | 43200 | 86400 |
| | (5 min) | (10 min) | (15 min) | (30 min) | (1 hr) | (2 hr) | (6 hr) | (12 hr) | (1 day) | (2 day) | (3 day) | (5 day) | (10 day) | (30 day) | (60 day) |
| **2** | 8.89 | 10.9 | 12.4 | 15.2 | 18.8 | 23.1 | 32.1 | 39.6 | 48.7 | 60.0 | 67.8 | 79.0 | 97.3 | 135 | 167 |
| **5** | 12.2 | 15.0 | 17.0 | 20.9 | 25.8 | 31.7 | 44.2 | 54.4 | 67.0 | 82.5 | 93.2 | 109 | 134 | 186 | 229 |
| **10** | 14.4 | 17.7 | 20.0 | 24.7 | 30.4 | 37.4 | 52.1 | 64.2 | 79.0 | 97.4 | 110 | 128 | 158 | 220 | 271 |
| **25** | 17.1 | 21.1 | 23.8 | 29.4 | 36.2 | 44.6 | 62.1 | 76.5 | 94.2 | 116 | 131 | 153 | 188 | 262 | 323 |
| **50** | 19.2 | 23.6 | 26.7 | 32.9 | 40.5 | 49.9 | 69.5 | 85.6 | 105 | 130 | 147 | 171 | 211 | 294 | 362 |
| **100** | 21.2 | 26.1 | 29.5 | 36.3 | 44.8 | 55.2 | 76.8 | 94.7 | 117 | 144 | 162 | 189 | 233 | 325 | 401 |
| **500** | 25.8 | 31.8 | 36.0 | 44.4 | 54.7 | 67.4 | 93.8 | 116 | 142 | 176 | 198 | 231 | 285 | 397 | 490 |
| **1000** | 27.8 | 34.3 | 38.8 | 47.8 | 58.9 | 72.6 | 101 | 125 | 154 | 189 | 214 | 250 | 308 | 428 | 528 |

Shaded region represents the extent of the existing MTO IDF curve.
The dark shaded region represents the extent of the existing M-108 Standard IDF curve; the light shaded region represents the extent of the existing MTO Standard IDF curve.

## 4 Climate Change Analysis

The precipitation data (period of record identified in Table 54) were analyzed by transforming the daily precipitation depths to binary factors, where each day is either wet or dry. As suggested by Zolina et al. (2010), for each day, if the precipitation depth was > 1 mm it was considered a wet day; otherwise, it was considered a dry day. Then, for each year of data at each station the number of sequential wet and dry days was accumulated for periods from 2 days up to 12 days, and these data were analyzed over the period of record using "zyp" – a prewhitened non-linear trend analysis package for R that includes a function for performing Kendall's tau test. Two statistics were extracted from this analysis: Kendall's tau – for which a positive value signifies an increasing trend and vice-versa – and the two-tailed p-statistic.

A summary for statistically significant trends for the five stations of interest are shown in Table 57 and Table 58. Most periods did not exhibit a significant trend, but generally trends were increasing. The incidence of statistically significant trends was higher for dry periods than for wet periods. For the airport station, the 2- and 7-day wet periods exhibited a statistically significant increasing trend (i.e. the occurrence of 2- and 7-day wet periods has become increasingly common over the period of record). An increasing trend is also observed for the 2-, 3-, 5-, and 6-day dry periods. The results appear to be in general agreement with the findings by Moss (2013).

**Table 57: Statistically significant Kendall's tau test statistics for wet periods.**

| Climate ID | Station Name | Wet Period Length | tau | p | significance |
|---|---|---|---|---|---|
| **6048261** | FT WILLIAM PT ARTHUR A | 2 days | 0.206 | 0.043 | 5% |
| | | 7 days | 0.208 | 0.088 | 10% |
| **6049466** | WHITEFISH LAKE | 3 days | 0.301 | 0.031 | 5% |
| **6042MJ7** | FLINT | 5 days | -0.217 | 0.098 | 10% |

**Table 58: Statistically significant Kendall's tau test statistics for dry periods.**

| Climate ID | Station Name | Dry Period Length | tau | p | significance |
|---|---|---|---|---|---|
| **6048261** | FT WILLIAM PT ARTHUR A | 2 days | 0.184 | 0.071 | 10% |
| | | 3 days | 0.173 | 0.088 | 10% |
| | | 5 days | 0.196 | 0.054 | 10% |
| | | 6 days | 0.207 | 0.042 | 5% |
| **6049466** | WHITEFISH LAKE | 4 days | 0.246 | 0.069 | 10% |
| | | 5 days | 0.446 | 0.001 | 1% |
| | | 6 days | 0.274 | 0.044 | 5% |
| **6042MJ7** | FLINT | 2 days | 0.247 | 0.042 | 5% |
| | | 3 days | 0.225 | 0.062 | 10% |
| | | 4 days | 0.234 | 0.053 | 10% |

For wet periods, the average depths of precipitation for each duration in each year were also analyzed for trends. Few trends with statistical significance at the 10% level or better were discovered, and none of the trends were significant for the airport station (6048261). A summary of this analysis can be found in Table 59.

**Table 59: Statistically significant Kendall's tau test statistics for wet period depths.**

| Climate ID | Station Name | Wet Period Length | tau | p | significance |
|---|---|---|---|---|---|
| **6048261** | FT WILLIAM PT ARTHUR A | 5 days | 0.260 | 0.072 | 10% |
| **6049466** | WHITEFISH LAKE | 3 days | -0.236 | 0.075 | 10% |
| **6042MJ7** | FLINT | 5 days | -0.239 | 0.087 | 10% |

The annual maxima data were also analyzed for the existence of any trends. Few trends with statistical significance were reported, as shown in Table 60. At the airport station (6048261), the 1-day storm duration is observed to be increasing in depth at the 5% level of significance. At the Upsala station (6049096), the 1-day, 10-day, and 60-day storm durations were observed to be increasing in depth at the 10%, 5%, and 5% levels of significance, respectively. More data would likely be needed to draw more conclusive results from this analysis, but it is notable that all of the statistically significant trends were observed to be increasing during the period of record.

**Table 60: Statistically significant Kendall's tau test statistics for annual maxima.**

<table>
<tr><th>Climate ID</th><th>Station Name</th><th>Wet Period Length</th><th>tau</th><th>p</th><th>significance</th></tr>
<tr><td>6048261</td><td>FT WILLIAM PT ARTHUR A</td><td>1 day</td><td>0.207</td><td>0.046</td><td>5%</td></tr>
<tr><td rowspan="3">6049466</td><td rowspan="3">WHITEFISH LAKE</td><td>1 day</td><td>0.284</td><td>0.056</td><td>10%</td></tr>
<tr><td>10 day</td><td>0.333</td><td>0.024</td><td>5%</td></tr>
<tr><td>60 day</td><td>0.304</td><td>0.045</td><td>5%</td></tr>
</table>

The climate change analysis was conducted using a period of record ranging from 24 years to 48 years. Given that the trend analysis relies on annual values, the statistical significance could change if the period of record was longer (i.e. had more data points to evaluate). In addition, analysis of a longer period of record may indicate that what is currently being reported as a lack of significance may in fact be statistically significant. Additional analysis on a longer data set could be performed using the LRCA data (i.e. 100 years of precipitation data) if the data is processed and the metadata is developed.

A recommendation in the SMP related to the Climate Change Analysis and IDF Curve Development is that runoff flow calculations for review of existing City CIP program infrastructure should use the updated IDF curves with an additional 15% increase in rainfall depth and intensity. Runoff flow calculations for review of development applications should use the updated IDF curves for pre-development conditions and use the updated IDF curves with an additional 15% increase in rainfall depth and intensity for post-development conditions. This proactive measure plans for the uncertainty associated with intensity and frequency of storms and is consistent with the policies of other municipalities in Ontario.

# 5 References

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## APPENDIX F Inventory of Retrofit BMP Opportunities & Cost-Benefit Analysis

| | | | | | | | Benefits | | | | 20-year Present Costs in 2015 Canadian Dollars | | | | Cost-Benefit Analysis | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Watershed | BMP Category | Demonstration / Education? | Footprint Area ($m^2$) | Water Quality Volume ($m^3$) | Drainage Area (ha) | TP Removal (kg/yr) | TSS Removal (kg/yr) | Runoff Volume Reduction ($m^3$/yr) | Feasibility Cost (CAD) | Construction (CAD) | Design (CAD) | O & M (CAD) | Total (CAD) | TP Removal (CAD/kg) | TSS Removal (CAD/kg) | Volume Reduction (CAD/$m^3$) |
| CR-2 | Current | Biofiltration | No | 174 | 79 | 1.1 | 0.70 | 190 | 855 | - | $ 56,217 | $ 11,243 | $ 3,373 | $ 70,834 | $ 5,030 | $ 18.63 | $ 4.14 |
| CR-4 | Current | Wetland | Yes | 371 | 339 | 117.4 | 1.36 | 630 | 8,136 | - | $ 51,633 | $ 10,327 | $ 1,033 | $ 62,992 | $ 2,316 | $ 5.00 | $ 0.39 |
| CR-5 | Current | Wetland | No | 149 | 136 | 2.0 | 0.54 | 253 | 489 | - | $ 31,061 | $ 6,212 | $ 621 | $ 37,894 | $ 3,483 | $ 7.48 | $ 3.87 |
| CR-6 | Current | Biofiltration | No | 353 | 161 | 2.3 | 1.43 | 387 | 1,740 | - | $ 97,091 | $ 19,418 | $ 5,825 | $ 122,334 | $ 4,267 | $ 15.80 | $ 3.52 |
| CR-7 | Current | Biofiltration | No | 184 | 84 | 1.2 | 0.74 | 201 | 903 | - | $ 58,675 | $ 11,735 | $ 3,520 | $ 73,930 | $ 4,966 | $ 18.39 | $ 4.09 |
| CR-8 | Current | Biofiltration | No | 297 | 135 | 2.0 | 1.20 | 325 | 1,461 | - | $ 84,909 | $ 16,982 | $ 5,095 | $ 106,986 | $ 4,443 | $ 16.45 | $ 3.66 |
| CR-9 | Current | Biofiltration | Yes | 254 | 116 | 1.7 | 1.03 | 279 | 1,252 | - | $ 75,413 | $ 15,083 | $ 4,525 | $ 95,021 | $ 4,605 | $ 17.05 | $ 3.79 |
| CR-10 | Current | Wetland | Yes | 448 | 410 | 5.9 | 1.64 | 760 | 1,476 | - | $ 57,314 | $ 11,463 | $ 1,146 | $ 69,923 | $ 2,129 | $ 4.60 | $ 2.37 |
| CR-11 | Current | Biofiltration | Yes | 23,324 | 10,628 | 153.8 | 94.57 | 25,537 | 114,783 | $ 459,281 | $ 2,430,059 | $ 486,012 | $ 145,804 | $ 3,061,875 | $ 1,619 | $ 5.99 | $ 1.33 |
| CR-12 | Current | Wetland | No | 24,894 | 22,763 | 329.4 | 91.16 | 41,357 | 81,947 | $ 97,308 | $ 531,735 | $ 106,347 | $ 10,635 | $ 648,717 | $ 356 | $ 0.78 | $ 0.40 |
| CR-14 | Current | Biofiltration | Yes | 67 | 31 | 0.4 | 0.27 | 73 | 329 | - | $ 27,005 | $ 5,401 | $ 1,620 | $ 34,027 | $ 6,273 | $ 23.23 | $ 5.17 |
| CR-15 | Current | Biofiltration | Yes | 42 | 19 | 0.3 | 0.17 | 46 | 207 | - | $ 18,914 | $ 3,783 | $ 1,135 | $ 23,831 | $ 6,983 | $ 25.86 | $ 5.75 |
| CR-16 | Current | Biofiltration | Yes | 43 | 20 | 0.3 | 0.18 | 48 | 214 | - | $ 19,361 | $ 3,872 | $ 1,162 | $ 24,395 | $ 6,934 | $ 25.68 | $ 5.71 |
| CR-17 | Current | Biofiltration | Yes | 46 | 21 | 0.3 | 0.19 | 50 | 226 | - | $ 20,216 | $ 4,043 | $ 1,213 | $ 25,472 | $ 6,844 | $ 25.35 | $ 5.64 |
| CR-18 | Current | Biofiltration | Yes | 374 | 170 | 2.5 | 1.52 | 409 | 1,840 | - | $ 101,358 | $ 20,272 | $ 6,081 | $ 127,711 | $ 4,213 | $ 15.60 | $ 3.47 |
| CR-19 | Current | Biofiltration | Yes | 16 | 7 | 0.1 | 0.07 | 18 | 80 | - | $ 9,105 | $ 1,821 | $ 546 | $ 11,473 | $ 8,702 | $ 32.22 | $ 7.17 |
| CR-20 | Current | Biofiltration | Yes | 44 | 20 | 0.3 | 0.18 | 49 | 219 | - | $ 19,711 | $ 3,942 | $ 1,183 | $ 24,836 | $ 6,896 | $ 25.54 | $ 5.68 |
| CR-21 | Current | Biofiltration | Yes | 55 | 25 | 0.4 | 0.22 | 60 | 270 | - | $ 23,173 | $ 4,635 | $ 1,390 | $ 29,198 | $ 6,569 | $ 24.33 | $ 5.41 |
| CR-22 | Current | Biofiltration | Yes | 43 | 20 | 0.3 | 0.17 | 47 | 211 | - | $ 19,170 | $ 3,834 | $ 1,150 | $ 24,154 | $ 6,955 | $ 25.75 | $ 5.73 |
| CR-23 | Current | Biofiltration | Yes | 369 | 168 | 2.4 | 1.49 | 404 | 1,814 | - | $ 100,252 | $ 20,050 | $ 6,015 | $ 126,318 | $ 4,227 | $ 15.65 | $ 3.48 |
| CR-24 | Current | Biofiltration | No | 49 | 22 | 0.3 | 0.20 | 54 | 244 | - | $ 21,432 | $ 4,286 | $ 1,286 | $ 27,004 | $ 6,725 | $ 24.90 | $ 5.54 |
| CR-25 | Current | Biofiltration | Yes | 49 | 22 | 0.3 | 0.20 | 54 | 244 | - | $ 21,432 | $ 4,286 | $ 1,286 | $ 27,004 | $ 6,725 | $ 24.90 | $ 5.54 |
| CR-26 | Current | Biofiltration | Yes | 35 | 16 | 0.2 | 0.14 | 38 | 171 | - | $ 16,357 | $ 3,271 | $ 981 | $ 20,610 | $ 7,295 | $ 27.02 | $ 6.01 |
| CR-27 | Current | Biofiltration | Yes | 104 | 47 | 0.7 | 0.42 | 114 | 513 | - | $ 37,978 | $ 7,596 | $ 2,279 | $ 47,852 | $ 5,661 | $ 20.96 | $ 4.66 |
| CR-28 | Current | Biofiltration | Yes | 28 | 13 | 0.2 | 0.11 | 30 | 136 | - | $ 13,708 | $ 2,742 | $ 822 | $ 17,272 | $ 7,693 | $ 28.49 | $ 6.34 |
| CR-29 | Current | Biofiltration | Yes | 56 | 26 | 0.4 | 0.23 | 61 | 274 | - | $ 23,444 | $ 4,689 | $ 1,407 | $ 29,539 | $ 6,546 | $ 24.24 | $ 5.39 |
| CR-30 | Current | Biofiltration | Yes | 58 | 26 | 0.4 | 0.24 | 64 | 286 | - | $ 24,252 | $ 4,850 | $ 1,455 | $ 30,558 | $ 6,479 | $ 23.99 | $ 5.34 |
| CR-31 | Current | Wetland | Yes | 341 | 312 | 4.5 | 1.25 | 579 | 1,122 | - | $ 49,224 | $ 9,845 | $ 984 | $ 60,053 | $ 2,406 | $ 5.19 | $ 2.68 |
| CR-32 | Current | Biofiltration | Yes | 174 | 79 | 1.2 | 0.71 | 191 | 859 | - | $ 56,425 | $ 11,285 | $ 3,386 | $ 71,096 | $ 5,025 | $ 18.61 | $ 4.14 |
| CR-33 | Current | Tree Trench | No | 413 | 115 | 1.7 | 0.61 | 300 | 1,237 | - | $ 137,122 | $ 27,424 | $ 17,140 | $ 181,687 | $ 14,846 | $ 30.32 | $ 7.34 |
| CR-34 | Current | Wetland | Yes | 256 | 234 | 3.4 | 0.94 | 435 | 843 | - | $ 42,016 | $ 8,403 | $ 840 | $ 51,260 | $ 2,733 | $ 5.89 | $ 3.04 |
| CR-35 | Current | Biofiltration | Yes | 453 | 206 | 3.0 | 1.84 | 496 | 2,229 | - | $ 117,480 | $ 23,496 | $ 7,049 | $ 148,025 | $ 4,029 | $ 14.92 | $ 3.32 |
| CR-36 | Current | Biofiltration | Yes | 313 | 143 | 2.1 | 1.27 | 343 | 1,542 | - | $ 88,481 | $ 17,696 | $ 5,309 | $ 111,486 | $ 4,388 | $ 16.25 | $ 3.62 |
| CR-37 | Current | Biofiltration | Yes | 365 | 166 | 2.4 | 1.48 | 399 | 1,794 | - | $ 99,397 | $ 19,879 | $ 5,964 | $ 125,240 | $ 4,237 | $ 15.69 | $ 3.49 |
| CR-38 | Current | Tree Trench | Yes | 73 | 20 | 0.3 | 0.11 | 59 | 217 | - | $ 33,113 | $ 6,623 | $ 4,139 | $ 43,874 | $ 20,404 | $ 36.99 | $ 10.09 |
| CR-39 | Current | Tree Trench | Yes | 73 | 20 | 0.3 | 0.11 | 59 | 217 | - | $ 33,113 | $ 6,623 | $ 4,139 | $ 43,874 | $ 20,404 | $ 36.99 | $ 10.09 |
| CR-40 | Current | Tree Trench | Yes | 73 | 20 | 0.3 | 0.11 | 59 | 217 | - | $ 33,113 | $ 6,623 | $ 4,139 | $ 43,874 | $ 20,404 | $ 36.99 | $ 10.09 |
| CR-41 | Current | Biofiltration | Yes | 173 | 79 | 1.1 | 0.70 | 190 | 854 | - | $ 56,171 | $ 11,234 | $ 3,370 | $ 70,775 | $ 5,032 | $ 18.63 | $ 4.15 |
| CR-42 | Current | Biofiltration | Yes | 64 | 29 | 0.4 | 0.26 | 70 | 313 | - | $ 25,990 | $ 5,198 | $ 1,559 | $ 32,748 | $ 6,346 | $ 23.50 | $ 5.23 |
| CR-43 | Current | Biofiltration | Yes | 501 | 228 | 3.3 | 2.03 | 548 | 2,464 | - | $ 126,888 | $ 25,378 | $ 7,613 | $ 159,878 | $ 3,937 | $ 14.58 | $ 3.24 |
| CR-44 | Current | Impervious Removal | Yes | 99 | - | - | 0.00 | 2 | 12 | - | $ 863 | $ 266 | $ 199 | $ 1,328 | $ 17,653 | $ 42.87 | $ 5.35 |
| CR-45 | Current | Biofiltration | Yes | 126 | 57 | 0.8 | 0.51 | 138 | 620 | - | $ 43,955 | $ 8,791 | $ 2,637 | $ 55,383 | $ 5,417 | $ 20.06 | $ 4.46 |
| CR-46 | Current | Biofiltration | Yes | 186 | 85 | 1.2 | 0.75 | 203 | 914 | - | $ 59,199 | $ 11,840 | $ 3,552 | $ 74,591 | $ 4,953 | $ 18.34 | $ 4.08 |
| CR-47 | Current | Biofiltration | Yes | 98 | 45 | 0.6 | 0.40 | 107 | 481 | - | $ 36,170 | $ 7,234 | $ 2,170 | $ 45,574 | $ 5,745 | $ 21.27 | $ 4.73 |
| CR-48 | Current | Biofiltration | Yes | 115 | 52 | 0.8 | 0.47 | 126 | 565 | - | $ 40,885 | $ 8,177 | $ 2,453 | $ 51,515 | $ 5,537 | $ 20.50 | $ 4.56 |
| CR-49 | Current | Biofiltration | Yes | 73 | 33 | 0.5 | 0.30 | 80 | 360 | - | $ 28,945 | $ 5,789 | $ 1,737 | $ 36,471 | $ 6,143 | $ 22.75 | $ 5.06 |
| CR-50 | Current | Biofiltration | Yes | 137 | 62 | 0.9 | 0.56 | 150 | 675 | - | $ 46,913 | $ 9,383 | $ 2,815 | $ 59,111 | $ 5,312 | $ 19.67 | $ 4.38 |
| CR-51 | Current | Biofiltration | Yes | 93 | 42 | 0.6 | 0.38 | 102 | 459 | - | $ 34,896 | $ 6,979 | $ 2,094 | $ 43,968 | $ 5,807 | $ 21.51 | $ 4.78 |
| CR-52 | Current | Biofiltration | Yes | 84 | 38 | 0.6 | 0.34 | 92 | 414 | - | $ 32,195 | $ 6,439 | $ 1,932 | $ 40,565 | $ 5,950 | $ 22.03 | $ 4.90 |
| CR-53 | Current | Biofiltration | Yes | 88 | 40 | 0.6 | 0.36 | 96 | 433 | - | $ 33,310 | $ 6,662 | $ 1,999 | $ 41,971 | $ 5,889 | $ 21.81 | $ 4.85 |
| CR-54 | Current | Biofiltration | Yes | 44 | 20 | 0.1 | 0.16 | 46 | 60 | - | $ 19,616 | $ 3,923 | $ 1,177 | $ 24,716 | $ 7,815 | $ 26.95 | $ 20.46 |

| ID | Watershed | BMP Category | Demonstration / Education? | Footprint Area ($m^2$) | Water Quality Volume ($m^3$) | Drainage Area (ha) | Benefits: TP Removal (kg/yr) | Benefits: TSS Removal (kg/yr) | Benefits: Runoff Volume Reduction ($m^3$/yr) | Feasibility Cost (CAD) | 20-year Present Costs in 2015 Canadian Dollars: Construction (CAD) | Design (CAD) | O & M (CAD) | Total (CAD) | Cost-Benefit Analysis: TP Removal (CAD/kg) | TSS Removal (CAD/kg) | Volume Reduction (CAD/$m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CR-55 | Current | Biofiltration | Yes | 158 | 72 | 1.0 | 0.64 | 173 | 776 | - | $ 52,220 | $ 10,444 | $ 3,133 | $ 65,798 | $ 5,143 | $ 19.05 | $ 4.24 |
| CR-56 | Current | Biofiltration | Yes | 56 | 26 | 0.2 | 0.20 | 58 | 76 | - | $ 23,414 | $ 4,683 | $ 1,405 | $ 29,501 | $ 7,410 | $ 25.55 | $ 19.39 |
| CR-57 | Current | Biofiltration | Yes | 81 | 37 | 0.5 | 0.33 | 88 | 398 | - | $ 31,233 | $ 6,247 | $ 1,874 | $ 39,354 | $ 6,004 | $ 22.24 | $ 4.95 |
| CR-58 | Current | Biofiltration | Yes | 415 | 189 | 2.7 | 1.68 | 454 | 2,041 | - | $ 109,792 | $ 21,958 | $ 6,588 | $ 138,338 | $ 4,112 | $ 15.23 | $ 3.39 |
| CR-59 | Current | Biofiltration | Yes | 91 | 41 | 0.6 | 0.37 | 100 | 448 | - | $ 34,226 | $ 6,845 | $ 2,054 | $ 43,125 | $ 5,841 | $ 21.63 | $ 4.81 |
| CR-60 | Current | Biofiltration | Yes | 211 | 96 | 1.4 | 0.85 | 230 | 1,036 | - | $ 65,188 | $ 13,038 | $ 3,911 | $ 82,136 | $ 4,811 | $ 17.82 | $ 3.96 |
| CR-61 | Current | Biofiltration | Yes | 52 | 24 | 0.2 | 0.19 | 54 | 71 | - | $ 22,170 | $ 4,434 | $ 1,330 | $ 27,934 | $ 7,533 | $ 25.97 | $ 19.72 |
| CR-62 | Current | Biofiltration | Yes | 387 | 176 | 2.6 | 1.57 | 424 | 1,906 | - | $ 104,134 | $ 20,827 | $ 6,248 | $ 131,209 | $ 4,178 | $ 15.47 | $ 3.44 |
| CR-63 | Current | Biofiltration | Yes | 145 | 66 | 1.0 | 0.59 | 159 | 715 | - | $ 49,023 | $ 9,805 | $ 2,941 | $ 61,769 | $ 5,242 | $ 19.41 | $ 4.32 |
| CR-64 | Current | Biofiltration | Yes | 60 | 27 | 0.4 | 0.24 | 66 | 295 | - | $ 24,816 | $ 4,963 | $ 1,489 | $ 31,268 | $ 6,435 | $ 23.83 | $ 5.30 |
| CR-65 | Current | Biofiltration | Yes | 88 | 40 | 0.6 | 0.36 | 96 | 432 | - | $ 33,283 | $ 6,657 | $ 1,997 | $ 41,936 | $ 5,890 | $ 21.81 | $ 4.85 |
| CR-66 | Current | Biofiltration | Yes | 97 | 44 | 0.6 | 0.40 | 107 | 480 | - | $ 36,064 | $ 7,213 | $ 2,164 | $ 45,441 | $ 5,750 | $ 21.29 | $ 4.74 |
| CR-67 | Current | Biofiltration | Yes | 81 | 37 | 0.5 | 0.33 | 89 | 399 | - | $ 31,316 | $ 6,263 | $ 1,879 | $ 39,458 | $ 5,999 | $ 22.22 | $ 4.94 |
| CR-68 | Current | Biofiltration | Yes | 333 | 152 | 2.2 | 1.35 | 365 | 1,641 | - | $ 92,826 | $ 18,565 | $ 5,570 | $ 116,961 | $ 4,326 | $ 16.02 | $ 3.56 |
| CR-69 | Current | Biofiltration | Yes | 128 | 58 | 0.8 | 0.52 | 140 | 629 | - | $ 44,427 | $ 8,885 | $ 2,666 | $ 55,978 | $ 5,400 | $ 20.00 | $ 4.45 |
| CR-70 | Current | Biofiltration | Yes | 399 | 182 | 2.6 | 1.62 | 437 | 1,965 | - | $ 106,622 | $ 21,324 | $ 6,397 | $ 134,344 | $ 4,149 | $ 15.36 | $ 3.42 |
| CR-71 | Current | Biofiltration | Yes | 245 | 112 | 0.8 | 0.88 | 255 | 336 | - | $ 73,266 | $ 14,653 | $ 4,396 | $ 92,316 | $ 5,256 | $ 18.12 | $ 13.76 |
| CR-72 | Current | Biofiltration | Yes | 36 | 16 | 0.1 | 0.13 | 38 | 50 | - | $ 16,924 | $ 3,385 | $ 1,015 | $ 21,324 | $ 8,170 | $ 28.17 | $ 21.39 |
| CR-73 | Current | Pond | Yes | 242 | 295 | 5.3 | 1.72 | 727 | 664 | - | $ 108,539 | $ 21,708 | $ 4,884 | $ 135,131 | $ 3,935 | $ 9.29 | $ 10.17 |
| CR-76 | Current | Biofiltration | No | 140 | 64 | 0.9 | 0.57 | 153 | 688 | - | $ 47,571 | $ 9,514 | $ 2,854 | $ 59,939 | $ 5,290 | $ 19.59 | $ 4.36 |
| CR-77 | Current | Biofiltration | No | 37 | 17 | 0.2 | 0.15 | 40 | 182 | - | $ 17,123 | $ 3,425 | $ 1,027 | $ 21,574 | $ 7,195 | $ 26.65 | $ 5.93 |
| CR-78 | Current | Biofiltration | No | 105 | 48 | 0.7 | 0.43 | 115 | 516 | - | $ 38,160 | $ 7,632 | $ 2,290 | $ 48,081 | $ 5,653 | $ 20.93 | $ 4.66 |
| CR-79 | Current | Ditch Maintenance | Yes | 102 | - | 0.2 | - | - | 47 | - | $ 205 | $ 625 | $ 205 | $ 1,036 | - | - | $ 1.11 |
| CR-80 | Current | Tree Trench | Yes | 323 | 90 | 1.3 | 0.48 | 238 | 967 | - | $ 112,135 | $ 22,427 | $ 14,017 | $ 148,579 | $ 15,530 | $ 31.19 | $ 7.68 |
| CR-81 | Current | Ditch Maintenance | Yes | 76 | - | 0.2 | - | - | 35 | - | $ 153 | $ 625 | $ 153 | $ 930 | - | - | $ 1.35 |
| CR-82 | Current | Ditch Maintenance | Yes | 348 | - | 0.8 | - | - | 159 | - | $ 703 | $ 625 | $ 703 | $ 2,030 | - | - | $ 0.64 |
| CR-83 | Current | Ditch Maintenance | Yes | 970 | - | 2.1 | - | - | 443 | - | $ 1,957 | $ 625 | $ 1,957 | $ 4,539 | - | - | $ 0.51 |
| CR-84 | Current | Tree Trench | Yes | 528 | 146 | 2.1 | 0.78 | 377 | 1,582 | - | $ 167,610 | $ 33,522 | $ 20,951 | $ 222,083 | $ 14,194 | $ 29.48 | $ 7.02 |
| CR-85 | Current | Tree Trench | Yes | 537 | 149 | 2.2 | 0.80 | 383 | 1,610 | - | $ 170,040 | $ 34,008 | $ 21,255 | $ 225,303 | $ 14,148 | $ 29.42 | $ 7.00 |
| CR-86 | Current | Ditch Maintenance | Yes | 255 | - | 0.6 | - | - | 116 | - | $ 514 | $ 625 | $ 514 | $ 1,653 | - | - | $ 0.71 |
| CR-87 | Current | Ditch Maintenance | Yes | 25 | - | 0.1 | - | - | 11 | - | $ 50 | $ 625 | $ 50 | $ 725 | - | - | $ 3.21 |
| CR-88 | Current | Ditch Maintenance | Yes | 371 | - | 0.8 | - | - | 169 | - | $ 748 | $ 625 | $ 748 | $ 2,121 | - | - | $ 0.63 |
| KM-1 | Kaministiquia | Pond | No | 64 | 78 | 4.6 | 0.57 | 183 | 281 | $ 10,133 | $ 54,259 | $ 10,852 | $ 2,442 | $ 67,553 | $ 5,884 | $ 18.46 | $ 12.03 |
| KM-2 | Kaministiquia | Ravine Stabilization | No | 368 | - | - | - | - | - | $ 52,500 | $ 250,000 | $ 50,000 | $ 50,000 | $ 350,000 | - | - | - |
| KM-4 | Kaministiquia | Biofiltration | Yes | 474 | 216 | 74.7 | 1.92 | 519 | 15,528 | - | $ 121,680 | $ 24,336 | $ 7,301 | $ 153,317 | $ 3,987 | $ 14.77 | $ 0.49 |
| KM-5 | Kaministiquia | Biofiltration | No | 49 | 22 | 0.3 | 0.20 | 54 | 244 | - | $ 21,432 | $ 4,286 | $ 1,286 | $ 27,004 | $ 6,725 | $ 24.90 | $ 5.54 |
| KM-6 | Kaministiquia | Biofiltration | No | 74 | 34 | 0.5 | 0.30 | 81 | 366 | - | $ 29,283 | $ 5,857 | $ 1,757 | $ 36,897 | $ 6,122 | $ 22.67 | $ 5.04 |
| KM-7 | Kaministiquia | Biofiltration | No | 53 | 24 | 0.4 | 0.22 | 58 | 262 | - | $ 22,658 | $ 4,532 | $ 1,359 | $ 28,549 | $ 6,613 | $ 24.49 | $ 5.45 |
| KM-8 | Kaministiquia | Pond | Yes | 533 | 650 | 11.8 | 3.29 | 1,648 | 1,462 | - | $ 163,683 | $ 32,737 | $ 7,366 | $ 203,786 | $ 3,100 | $ 6.18 | $ 6.97 |
| KM-9 | Kaministiquia | Pond | Yes | 11,695 | 14,259 | 257.9 | 41.73 | 40,457 | 32,080 | $ 152,596 | $ 817,114 | $ 163,423 | $ 36,770 | $ 1,017,307 | $ 1,219 | $ 1.26 | $ 1.59 |
| KM-10 | Kaministiquia | Pond | No | 26,866 | 32,755 | 592.5 | 82.73 | 95,798 | 73,697 | $ 235,286 | $ 1,259,896 | $ 251,979 | $ 56,695 | $ 1,568,571 | $ 948 | $ 0.82 | $ 1.06 |
| KM-11 | Kaministiquia | Pond | No | 98,241 | 119,775 | 2,166.7 | 240.42 | 367,225 | 269,491 | $ 462,111 | $ 2,474,492 | $ 494,898 | $ 111,352 | $ 3,080,743 | $ 641 | $ 0.42 | $ 0.57 |
| KM-14 | Kaministiquia | Pond | Yes | 195 | 238 | 4.3 | 1.43 | 580 | 534 | - | $ 96,881 | $ 19,376 | $ 4,360 | $ 120,617 | $ 4,203 | $ 10.40 | $ 11.30 |
| KM-15 | Kaministiquia | Impervious Removal | Yes | 436 | - | - | 0.02 | 7 | 55 | - | $ 3,812 | $ 1,173 | $ 880 | $ 5,865 | $ 17,653 | $ 42.87 | $ 5.35 |
| KM-16 | Kaministiquia | Sedimentation Basin | Yes | 27 | 16 | 0.2 | 0.13 | 29 | 30 | - | $ 21,592 | $ 4,318 | $ 972 | $ 26,883 | $ 10,046 | $ 46.00 | $ 45.00 |
| KM-17 | Kaministiquia | Biofiltration | Yes | 419 | 191 | 2.8 | 1.70 | 459 | 2,063 | $ 20,918 | $ 110,679 | $ 22,136 | $ 6,641 | $ 139,456 | $ 4,102 | $ 15.19 | $ 3.38 |
| KM-18 | Kaministiquia | OGS | No | 2 | - | - | - | - | - | - | $ 250,000 | $ 50,000 | $ 62,500 | $ 362,500 | - | - | - |
| KM-19 | Kaministiquia | Biofiltration | No | 161 | 73 | 1.1 | 0.65 | 176 | 793 | - | $ 53,093 | $ 10,619 | $ 3,186 | $ 66,897 | $ 5,118 | $ 18.95 | $ 4.22 |
| KM-21 | Kaministiquia | Pond | No | 34,872 | 42,516 | 769.1 | 102.53 | 125,533 | 95,661 | $ 269,508 | $ 1,443,147 | $ 288,629 | $ 64,942 | $ 1,796,718 | $ 876 | $ 0.72 | $ 0.94 |
| KM-22 | Kaministiquia | Pond | No | 1,034 | 1,261 | 22.8 | 5.67 | 3,275 | 2,837 | - | $ 231,133 | $ 46,227 | $ 10,401 | $ 287,761 | $ 2,537 | $ 4.39 | $ 5.07 |
| KM-23 | Kaministiquia | Pond | No | 2,094 | 2,553 | 46.2 | 10.13 | 6,805 | 5,745 | - | $ 333,732 | $ 66,746 | $ 15,018 | $ 415,496 | $ 2,050 | $ 3.05 | $ 3.62 |

| | | | | | | | Benefits | | | | 20-year Present Costs in 2015 Canadian Dollars | | | | Cost-Benefit Analysis | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Watershed | BMP Category | Demonstration / Education? | Footprint Area ($m^2$) | Water Quality Volume ($m^3$) | Drainage Area (ha) | TP Removal (kg/yr) | TSS Removal (kg/yr) | Runoff Volume Reduction ($m^3$/yr) | Feasibility Cost (CAD) | Construction (CAD) | Design (CAD) | O & M (CAD) | Total (CAD) | TP Removal (CAD/kg) | TSS Removal (CAD/kg) | Volume Reduction (CAD/$m^3$) |
| KM-26 | Kaministiquia | Biofiltration | Yes | 152 | 69 | 1.0 | 0.62 | 166 | 748 | - | $ 50,749 | $ 10,150 | $ 3,045 | $ 63,943 | $ 5,188 | $ 19.21 | $ 4.27 |
| KM-27 | Kaministiquia | Impervious Removal | No | 2,062 | - | - | 0.08 | 32 | 259 | - | $ 18,034 | $ 5,549 | $ 4,162 | $ 27,745 | $ 17,653 | $ 42.87 | $ 5.35 |
| KM-28 | Kaministiquia | Parking Lot Retrofit | No | 3,449 | 143 | 2.1 | 0.77 | 370 | 1,550 | - | $ 164,859 | $ 32,972 | $ 20,607 | $ 218,438 | $ 14,247 | $ 29.55 | $ 7.05 |
| KM-29 | Kaministiquia | Parking Lot Retrofit | No | 4,784 | 1,327 | 19.2 | 7.09 | 2,934 | 14,330 | $ 201,713 | $ 1,014,906 | $ 202,981 | $ 126,863 | $ 1,344,750 | $ 9,486 | $ 22.91 | $ 4.69 |
| KM-30 | Kaministiquia | Parking Lot Retrofit | No | 891 | 37 | 0.5 | 0.20 | 105 | 400 | - | $ 54,539 | $ 10,908 | $ 6,817 | $ 72,264 | $ 18,248 | $ 34.50 | $ 9.03 |
| KM-31 | Kaministiquia | Parking Lot Retrofit | No | 444 | 18 | 0.3 | 0.10 | 55 | 199 | - | $ 30,868 | $ 6,174 | $ 3,858 | $ 40,900 | $ 20,728 | $ 37.36 | $ 10.25 |
| KM-32 | Kaministiquia | Parking Lot Retrofit | No | 1,267 | 53 | 0.8 | 0.28 | 145 | 569 | - | $ 72,716 | $ 14,543 | $ 9,090 | $ 96,349 | $ 17,111 | $ 33.14 | $ 8.46 |
| KM-33 | Kaministiquia | Impervious Removal | No | 1,211 | - | - | 0.05 | 19 | 152 | - | $ 10,587 | $ 3,258 | $ 2,443 | $ 16,288 | $ 17,653 | $ 42.87 | $ 5.35 |
| KM-34 | Kaministiquia | Parking Lot Retrofit | No | 2,153 | 90 | 1.3 | 0.48 | 238 | 967 | - | $ 112,145 | $ 22,429 | $ 14,018 | $ 148,591 | $ 15,530 | $ 31.19 | $ 7.68 |
| KM-35 | Kaministiquia | Parking Lot Retrofit | No | 1,885 | 78 | 1.1 | 0.42 | 211 | 847 | - | $ 100,621 | $ 20,124 | $ 12,578 | $ 133,323 | $ 15,911 | $ 31.66 | $ 7.87 |
| KM-36 | Kaministiquia | Parking Lot Retrofit | No | 754 | 31 | 0.5 | 0.17 | 90 | 339 | - | $ 47,572 | $ 9,514 | $ 5,946 | $ 63,032 | $ 18,815 | $ 35.16 | $ 9.31 |
| KM-37 | Kaministiquia | Parking Lot Retrofit | No | 2,310 | 96 | 1.4 | 0.51 | 254 | 1,038 | - | $ 118,824 | $ 23,765 | $ 14,853 | $ 157,442 | $ 15,330 | $ 30.94 | $ 7.58 |
| KM-38 | Kaministiquia | Parking Lot Retrofit | No | 156 | 6 | 0.1 | 0.03 | 21 | 70 | - | $ 13,127 | $ 2,625 | $ 1,641 | $ 17,393 | $ 25,099 | $ 42.11 | $ 12.42 |
| KM-39 | Kaministiquia | Parking Lot Retrofit | No | 2,034 | 85 | 1.2 | 0.45 | 226 | 914 | - | $ 107,072 | $ 21,414 | $ 13,384 | $ 141,870 | $ 15,691 | $ 31.39 | $ 7.76 |
| KM-40 | Kaministiquia | Parking Lot Retrofit | No | 463 | 19 | 0.3 | 0.10 | 57 | 208 | - | $ 31,930 | $ 6,386 | $ 3,991 | $ 42,307 | $ 20,571 | $ 37.18 | $ 10.18 |
| KM-41 | Kaministiquia | Pond | No | 5,498 | 6,703 | 121.3 | 22.42 | 18,505 | 15,081 | $ 103,013 | $ 551,608 | $ 110,322 | $ 24,822 | $ 686,752 | $ 1,531 | $ 1.86 | $ 2.28 |
| KM-42 | Kaministiquia | Pond | Yes | 1,643 | 2,003 | 36.2 | 8.30 | 5,291 | 4,506 | $ 54,923 | $ 294,097 | $ 58,819 | $ 13,234 | $ 366,151 | $ 2,206 | $ 3.46 | $ 4.06 |
| KM-43 | Kaministiquia | Biofiltration | Yes | 829 | 378 | 5.5 | 3.36 | 908 | 4,080 | - | $ 186,949 | $ 37,390 | $ 11,217 | $ 235,556 | $ 3,504 | $ 12.97 | $ 2.89 |
| KM-44 | Kaministiquia | Tree Trench | No | 1,948 | 540 | 7.8 | 2.89 | 1,271 | 5,835 | $ 96,806 | $ 487,075 | $ 97,415 | $ 60,884 | $ 645,374 | $ 11,179 | $ 25.39 | $ 5.53 |
| KM-45 | Kaministiquia | Pond | Yes | 984 | 1,200 | 21.7 | 5.45 | 3,112 | 2,700 | - | $ 225,270 | $ 45,054 | $ 10,137 | $ 280,461 | $ 2,575 | $ 4.51 | $ 5.19 |
| KM-46 | Kaministiquia | Pond | Yes | 1,186 | 1,446 | 26.2 | 6.35 | 3,776 | 3,254 | - | $ 248,237 | $ 49,647 | $ 11,171 | $ 309,055 | $ 2,434 | $ 4.09 | $ 4.75 |
| KM-47 | Kaministiquia | Biofiltration | Yes | 26 | 12 | 0.2 | 0.10 | 28 | 127 | - | $ 12,995 | $ 2,599 | $ 780 | $ 16,374 | $ 7,818 | $ 28.95 | $ 6.44 |
| KM-48 | Kaministiquia | Biofiltration | Yes | 54 | 25 | 0.4 | 0.22 | 59 | 265 | - | $ 22,840 | $ 4,568 | $ 1,370 | $ 28,778 | $ 6,597 | $ 24.43 | $ 5.44 |
| KM-49 | Kaministiquia | Biofiltration | No | 395 | 180 | 2.6 | 1.60 | 433 | 1,944 | - | $ 105,744 | $ 21,149 | $ 6,345 | $ 133,237 | $ 4,159 | $ 15.40 | $ 3.43 |
| KM-50 | Kaministiquia | Pond | No | 1,838 | 2,241 | 40.5 | 9.10 | 5,946 | 5,043 | $ 58,238 | $ 311,850 | $ 62,370 | $ 14,033 | $ 388,253 | $ 2,132 | $ 3.26 | $ 3.85 |
| KM-51 | Kaministiquia | Biofiltration | No | 1,037 | 473 | 6.8 | 4.20 | 1,135 | 5,101 | $ 41,950 | $ 221,958 | $ 44,392 | $ 13,317 | $ 279,667 | $ 3,327 | $ 12.32 | $ 2.74 |
| KM-52 | Kaministiquia | Biofiltration | No | 755 | 344 | 5.0 | 3.06 | 826 | 3,715 | $ 32,876 | $ 173,946 | $ 34,789 | $ 10,437 | $ 219,172 | $ 3,580 | $ 13.26 | $ 2.95 |
| KM-54 | Kaministiquia | Biofiltration | Yes | 1,899 | 865 | 12.5 | 7.70 | 2,079 | 9,345 | - | $ 353,482 | $ 70,696 | $ 21,209 | $ 445,387 | $ 2,892 | $ 10.71 | $ 2.38 |
| KM-56 | Kaministiquia | Pond | Yes | 1,528 | 1,863 | 33.7 | 7.82 | 4,908 | 4,190 | - | $ 283,190 | $ 56,638 | $ 12,744 | $ 352,571 | $ 2,255 | $ 3.59 | $ 4.21 |
| KM-57 | Kaministiquia | Biofiltration | Yes | 323 | 147 | 2.1 | 1.31 | 354 | 1,592 | - | $ 90,691 | $ 18,138 | $ 5,441 | $ 114,271 | $ 4,356 | $ 16.13 | $ 3.59 |
| KM-58 | Kaministiquia | Biofiltration | Yes | 976 | 445 | 3.1 | 3.50 | 1,015 | 1,337 | - | $ 211,981 | $ 42,396 | $ 12,719 | $ 267,097 | $ 3,817 | $ 13.16 | $ 9.99 |
| KM-59 | Kaministiquia | Biofiltration | Yes | 3,099 | 1,412 | 9.9 | 11.10 | 3,220 | 4,242 | $ 97,339 | $ 515,024 | $ 103,005 | $ 30,901 | $ 648,930 | $ 2,922 | $ 10.08 | $ 7.65 |
| KM-60 | Kaministiquia | Tree Trench | Yes | 343 | 95 | 0.7 | 0.51 | 217 | 286 | - | $ 117,903 | $ 23,581 | $ 14,738 | $ 156,222 | $ 15,357 | $ 35.97 | $ 27.31 |
| KM-61 | Kaministiquia | Biofiltration | Yes | 604 | 275 | 1.9 | 2.16 | 628 | 827 | - | $ 146,530 | $ 29,306 | $ 8,792 | $ 184,628 | $ 4,266 | $ 14.71 | $ 11.17 |
| KM-62 | Kaministiquia | Biofiltration | No | 866 | 395 | 5.7 | 3.51 | 948 | 4,262 | - | $ 193,310 | $ 38,662 | $ 11,599 | $ 243,570 | $ 3,468 | $ 12.84 | $ 2.86 |
| KM-63 | Kaministiquia | Biofiltration | Yes | 1,196 | 545 | 3.8 | 4.28 | 1,243 | 1,637 | - | $ 247,728 | $ 49,546 | $ 14,864 | $ 312,137 | $ 3,642 | $ 12.56 | $ 9.53 |
| KM-64 | Kaministiquia | Biofiltration | Yes | 941 | 429 | 3.0 | 3.37 | 978 | 1,289 | - | $ 206,112 | $ 41,222 | $ 12,367 | $ 259,701 | $ 3,850 | $ 13.28 | $ 10.08 |
| KM-65 | Kaministiquia | Biofiltration | Yes | 781 | 356 | 5.2 | 3.17 | 855 | 3,845 | - | $ 178,600 | $ 35,720 | $ 10,716 | $ 225,036 | $ 3,552 | $ 13.15 | $ 2.93 |
| KM-66 | Kaministiquia | Pond | Yes | 1,356 | 1,653 | 29.9 | 7.09 | 4,337 | 3,719 | - | $ 266,138 | $ 53,228 | $ 11,976 | $ 331,342 | $ 2,338 | $ 3.82 | $ 4.45 |
| KM-67 | Kaministiquia | Biofiltration | Yes | 167 | 76 | 1.1 | 0.68 | 183 | 823 | - | $ 54,638 | $ 10,928 | $ 3,278 | $ 68,844 | $ 5,074 | $ 18.79 | $ 4.18 |
| KM-68 | Kaministiquia | Biofiltration | Yes | 975 | 444 | 6.4 | 3.95 | 1,068 | 4,799 | - | $ 211,795 | $ 42,359 | $ 12,708 | $ 266,862 | $ 3,374 | $ 12.50 | $ 2.78 |
| KM-69 | Kaministiquia | Pond | Yes | 25,721 | 31,359 | 607.5 | 79.81 | 91,570 | 43,038 | $ 230,011 | $ 1,231,651 | $ 246,330 | $ 55,424 | $ 1,533,406 | $ 961 | $ 0.84 | $ 1.78 |
| KM-70 | Kaministiquia | Biofiltration | Yes | 950 | 433 | 149.7 | 3.85 | 1,040 | 31,110 | - | $ 207,580 | $ 41,516 | $ 12,455 | $ 261,551 | $ 3,395 | $ 12.57 | $ 0.42 |
| MI-1 | McIntyre | Ditch Maintenance | No | 57 | - | 0.1 | - | - | 26 | - | $ 115 | $ 625 | $ 115 | $ 855 | - | - | $ 1.64 |
| MI-2 | McIntyre | Ditch Maintenance | No | 1,157 | - | 2.6 | - | - | 529 | - | $ 2,335 | $ 625 | $ 2,335 | $ 5,294 | - | - | $ 0.50 |
| MI-3 | McIntyre | Wetland | Yes | 5,497 | 5,026 | 72.7 | 20.13 | 9,202 | 18,094 | - | $ 230,089 | $ 46,018 | $ 4,602 | $ 280,709 | $ 697 | $ 1.53 | $ 0.78 |
| MI-4 | McIntyre | Pond | No | 2,054 | 2,504 | 45.3 | 9.98 | 6,671 | 5,635 | - | $ 330,417 | $ 66,083 | $ 14,869 | $ 411,370 | $ 2,062 | $ 3.08 | $ 3.65 |
| MI-5 | McIntyre | Pond | Yes | 1,277 | 1,557 | 28.2 | 6.74 | 4,074 | 3,502 | - | $ 257,923 | $ 51,585 | $ 11,607 | $ 321,114 | $ 2,381 | $ 3.94 | $ 4.58 |
| MI-6 | McIntyre | Pond | No | 1,613 | 1,967 | 35.6 | 8.18 | 5,194 | 4,426 | - | $ 291,366 | $ 58,273 | $ 13,111 | $ 362,751 | $ 2,218 | $ 3.49 | $ 4.10 |
| MI-7 | McIntyre | Sedimentation Basin | No | 264 | 161 | 2.3 | 0.87 | 308 | 290 | - | $ 70,498 | $ 14,100 | $ 3,172 | $ 87,770 | $ 5,055 | $ 14.24 | $ 15.14 |
| MI-8 | McIntyre | Biofiltration | No | 389 | 177 | 2.6 | 1.58 | 426 | 1,915 | - | $ 104,518 | $ 20,904 | $ 6,271 | $ 131,693 | $ 4,174 | $ 15.46 | $ 3.44 |

| ID | Watershed | BMP Category | Demonstration / Education? | Footprint Area ($m^2$) | Water Quality Volume ($m^3$) | Drainage Area (ha) | Benefits: TP Removal (kg/yr) | Benefits: TSS Removal (kg/yr) | Benefits: Runoff Volume Reduction ($m^3$/yr) | Feasibility Cost (CAD) | 20-year Present Costs in 2015 Canadian Dollars: Construction (CAD) | Design (CAD) | O & M (CAD) | Total (CAD) | Cost-Benefit Analysis: TP Removal (CAD/kg) | TSS Removal (CAD/kg) | Volume Reduction (CAD/$m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MI-9 | McIntyre | Biofiltration | No | 246 | 112 | 1.6 | 1.00 | 270 | 1,212 | - | $ 73,523 | $ 14,705 | $ 4,411 | $ 92,638 | $ 4,640 | $ 17.18 | $ 3.82 |
| MI-10 | McIntyre | Pond Retrofit | No | 925 | 846 | 12.2 | 3.40 | 1,718 | 1,522 | - | $ 167,155 | $ 33,431 | $ 7,522 | $ 208,108 | $ 3,062 | $ 6.06 | $ 6.84 |
| MI-11 | McIntyre | Pond Retrofit | No | 442 | 404 | 5.9 | 1.85 | 800 | 728 | - | $ 113,878 | $ 22,776 | $ 5,125 | $ 141,778 | $ 3,827 | $ 8.86 | $ 9.73 |
| MI-12 | McIntyre | Pond Retrofit | No | 401 | 367 | 5.3 | 1.71 | 723 | 661 | - | $ 108,248 | $ 21,650 | $ 4,871 | $ 134,769 | $ 3,941 | $ 9.31 | $ 10.20 |
| MI-13 | McIntyre | Pond Retrofit | No | 182 | 166 | 2.4 | 0.89 | 320 | 300 | - | $ 71,803 | $ 14,361 | $ 3,231 | $ 89,395 | $ 5,001 | $ 13.99 | $ 14.88 |
| MI-14 | McIntyre | Curb Cut | No | 26 | - | - | - | - | - | - | $ 625 | $ - | $ - | $ 625 | - | - | - |
| MI-15 | McIntyre | Curb Cut | No | 22 | - | - | - | - | - | - | $ 625 | $ - | $ - | $ 625 | - | - | - |
| MI-16 | McIntyre | Curb Cut | No | 28 | - | - | - | - | - | - | $ 625 | $ - | $ - | $ 625 | - | - | - |
| MI-17 | McIntyre | Curb Cut | No | 28 | - | - | - | - | - | - | $ 625 | $ - | $ - | $ 625 | - | - | - |
| MI-18 | McIntyre | Curb Cut | No | 28 | - | - | - | - | - | - | $ 625 | $ - | $ - | $ 625 | - | - | - |
| MI-19 | McIntyre | Curb Cut | No | 30 | - | - | - | - | - | - | $ 625 | $ - | $ - | $ 625 | - | - | - |
| MI-20 | McIntyre | Curb Cut | No | 27 | - | - | - | - | - | - | $ 625 | $ - | $ - | $ 625 | - | - | - |
| MI-21 | McIntyre | Curb Cut | No | 25 | - | - | - | - | - | - | $ 625 | $ - | $ - | $ 625 | - | - | - |
| MI-22 | McIntyre | Curb Cut | No | 24 | - | - | - | - | - | - | $ 625 | $ - | $ - | $ 625 | - | - | - |
| MI-23 | McIntyre | Curb Cut | No | 25 | - | - | - | - | - | - | $ 625 | $ - | $ - | $ 625 | - | - | - |
| MI-24 | McIntyre | Impervious Removal | No | 460 | - | - | 0.02 | 7 | 58 | - | $ 4,019 | $ 1,237 | $ 927 | $ 6,183 | $ 17,653 | $ 42.87 | $ 5.35 |
| MI-25 | McIntyre | Pond | No | 3,299 | 4,022 | 35.3 | 14.73 | 10,898 | 7,552 | $ 78,958 | $ 422,800 | $ 84,560 | $ 19,026 | $ 526,386 | $ 1,787 | $ 2.41 | $ 3.49 |
| MI-26 | McIntyre | Biofiltration | Yes | 1,286 | 586 | 8.5 | 5.22 | 1,408 | 6,331 | - | $ 262,044 | $ 52,409 | $ 15,723 | $ 330,175 | $ 3,165 | $ 11.72 | $ 2.61 |
| MI-27 | McIntyre | Biofiltration | No | 417 | 190 | 2.8 | 1.69 | 457 | 2,054 | - | $ 110,302 | $ 22,060 | $ 6,618 | $ 138,981 | $ 4,107 | $ 15.21 | $ 3.38 |
| MI-28 | McIntyre | Biofiltration | Yes | 588 | 268 | 3.9 | 2.39 | 644 | 2,895 | - | $ 143,610 | $ 28,722 | $ 8,617 | $ 180,949 | $ 3,793 | $ 14.05 | $ 3.13 |
| MI-30 | McIntyre | Check Dam w/IESF | No | 2,536 | - | - | - | - | - | $ 5,625 | $ 25,000 | $ 6,250 | $ 6,250 | $ 37,500 | - | - | - |
| MI-31 | McIntyre | Check Dam w/IESF | No | 3,920 | - | - | - | - | - | $ 5,625 | $ 25,000 | $ 6,250 | $ 6,250 | $ 37,500 | - | - | - |
| MI-32 | McIntyre | Check Dam w/IESF | No | 2,743 | - | - | - | - | - | $ 5,625 | $ 25,000 | $ 6,250 | $ 6,250 | $ 37,500 | - | - | - |
| MI-33 | McIntyre | Check Dam w/IESF | No | 2,368 | - | - | - | - | - | $ 5,625 | $ 25,000 | $ 6,250 | $ 6,250 | $ 37,500 | - | - | - |
| MI-34 | McIntyre | Check Dam w/IESF | Yes | 8,684 | - | - | - | - | - | $ 5,625 | $ 25,000 | $ 6,250 | $ 6,250 | $ 37,500 | - | - | - |
| MI-35 | McIntyre | Biofiltration | Yes | 776 | 354 | 5.1 | 3.15 | 849 | 3,818 | - | $ 177,653 | $ 35,531 | $ 10,659 | $ 223,842 | $ 3,558 | $ 13.18 | $ 2.93 |
| MI-36 | McIntyre | Biofiltration | Yes | 677 | 308 | 4.5 | 2.74 | 741 | 3,332 | - | $ 159,984 | $ 31,997 | $ 9,599 | $ 201,580 | $ 3,672 | $ 13.60 | $ 3.03 |
| MI-37 | McIntyre | Biofiltration | Yes | 617 | 281 | 4.1 | 2.50 | 675 | 3,036 | - | $ 148,950 | $ 29,790 | $ 8,937 | $ 187,677 | $ 3,752 | $ 13.89 | $ 3.09 |
| MI-38 | McIntyre | Pond | No | 5,121 | 6,244 | 112.9 | 21.15 | 17,191 | 14,047 | $ 99,272 | $ 531,575 | $ 106,315 | $ 23,921 | $ 661,811 | $ 1,565 | $ 1.92 | $ 2.36 |
| MI-39 | McIntyre | Pond | No | 3,489 | 4,254 | 76.9 | 15.42 | 11,550 | 9,570 | $ 81,294 | $ 435,307 | $ 87,061 | $ 19,589 | $ 541,957 | $ 1,757 | $ 2.35 | $ 2.83 |
| MI-40 | McIntyre | Ditch Maintenance | Yes | 2,159 | - | 4.8 | - | - | 987 | - | $ 4,357 | $ 625 | $ 4,357 | $ 9,339 | - | - | $ 0.47 |
| MI-41 | McIntyre | Ditch Maintenance | Yes | 5,821 | - | 6.2 | - | - | 2,221 | - | $ 11,748 | $ 625 | $ 11,748 | $ 24,121 | - | - | $ 0.54 |
| MI-42 | McIntyre | Tree Trench | No | 256 | 71 | 1.0 | 0.38 | 192 | 766 | - | $ 92,647 | $ 18,529 | $ 11,581 | $ 122,758 | $ 16,208 | $ 32.03 | $ 8.02 |
| MI-43 | McIntyre | Tree Trench | No | 222 | 62 | 0.9 | 0.33 | 168 | 664 | - | $ 82,474 | $ 16,495 | $ 10,309 | $ 109,278 | $ 16,635 | $ 32.56 | $ 8.23 |
| MI-44 | McIntyre | Biofiltration | Yes | 636 | 290 | 4.2 | 2.58 | 697 | 3,132 | - | $ 152,575 | $ 30,515 | $ 9,154 | $ 192,244 | $ 3,725 | $ 13.79 | $ 3.07 |
| MI-46 | McIntyre | Pond | No | 3,167 | 3,861 | 33.9 | 14.24 | 10,446 | 7,249 | - | $ 413,892 | $ 82,778 | $ 18,625 | $ 515,296 | $ 1,809 | $ 2.47 | $ 3.55 |
| MI-47 | McIntyre | Biofiltration | Yes | 956 | 436 | 6.3 | 3.88 | 1,047 | 4,706 | $ 39,430 | $ 208,624 | $ 41,725 | $ 12,517 | $ 262,867 | $ 3,390 | $ 12.55 | $ 2.79 |
| MI-48 | McIntyre | Pond | No | 2,967 | 3,617 | 31.7 | 13.50 | 9,765 | 6,792 | - | $ 400,101 | $ 80,020 | $ 18,005 | $ 498,125 | $ 1,845 | $ 2.55 | $ 3.67 |
| MI-49 | McIntyre | Pond | Yes | 992 | 1,209 | 10.6 | 5.48 | 3,136 | 2,270 | $ 42,234 | $ 226,154 | $ 45,231 | $ 10,177 | $ 281,562 | $ 2,569 | $ 4.49 | $ 6.20 |
| MI-50 | McIntyre | Biofiltration | Yes | 178 | 81 | 0.6 | 0.64 | 185 | 243 | - | $ 57,255 | $ 11,451 | $ 3,435 | $ 72,141 | $ 5,661 | $ 19.52 | $ 14.82 |
| MI-51 | McIntyre | Pond | No | 5,474 | 6,674 | 120.7 | 22.34 | 18,420 | 15,015 | $ 102,777 | $ 550,345 | $ 110,069 | $ 24,766 | $ 685,179 | $ 1,533 | $ 1.86 | $ 2.28 |
| MI-52 | McIntyre | Pond | No | 6,012 | 7,330 | 132.6 | 24.14 | 20,302 | 16,492 | $ 107,922 | $ 577,896 | $ 115,579 | $ 26,005 | $ 719,481 | $ 1,490 | $ 1.77 | $ 2.18 |
| MI-53 | McIntyre | Wetland | No | 4,741 | 4,335 | 62.7 | 17.36 | 7,943 | 15,608 | $ 38,793 | $ 211,982 | $ 42,396 | $ 4,240 | $ 258,618 | $ 745 | $ 1.63 | $ 0.83 |
| MI-54 | McIntyre | Biofiltration | Yes | 1,752 | 798 | 5.6 | 6.28 | 1,820 | 2,398 | - | $ 332,245 | $ 66,449 | $ 19,935 | $ 418,629 | $ 3,334 | $ 11.50 | $ 8.73 |
| MI-55 | McIntyre | Biofiltration | Yes | 810 | 369 | 5.3 | 3.28 | 887 | 3,985 | - | $ 183,607 | $ 36,721 | $ 11,016 | $ 231,345 | $ 3,523 | $ 13.05 | $ 2.90 |
| MI-56 | McIntyre | Biofiltration | No | 278 | 127 | 1.8 | 1.13 | 304 | 1,367 | - | $ 80,691 | $ 16,138 | $ 4,841 | $ 101,671 | $ 4,512 | $ 16.71 | $ 3.72 |
| MI-57 | McIntyre | Pervious Pavement | No | 231 | 56 | 0.8 | 0.30 | 154 | 607 | - | $ 69,695 | $ 13,939 | $ 8,712 | $ 92,346 | $ 15,372 | $ 29.90 | $ 7.60 |
| MI-58 | McIntyre | Pond | No | 1,685 | 2,054 | 18.0 | 8.48 | 5,434 | 3,859 | - | $ 298,064 | $ 59,613 | $ 13,413 | $ 371,090 | $ 2,189 | $ 3.41 | $ 4.81 |
| MI-59 | McIntyre | Tree Trench | No | 136 | 38 | 0.5 | 0.20 | 106 | 407 | - | $ 55,271 | $ 11,054 | $ 6,909 | $ 73,234 | $ 18,194 | $ 34.43 | $ 9.00 |
| MI-60 | McIntyre | Biofiltration | Yes | 480 | 219 | 3.2 | 1.95 | 525 | 2,361 | - | $ 122,796 | $ 24,559 | $ 7,368 | $ 154,723 | $ 3,976 | $ 14.73 | $ 3.28 |
| MI-61 | McIntyre | Biofiltration | Yes | 1,877 | 855 | 6.0 | 6.72 | 1,950 | 2,569 | - | $ 350,301 | $ 70,060 | $ 21,018 | $ 441,379 | $ 3,282 | $ 11.32 | $ 8.59 |

| ID | Watershed | BMP Category | Demonstration / Education? | Footprint Area ($m^2$) | Water Quality Volume ($m^3$) | Drainage Area (ha) | Benefits: TP Removal (kg/yr) | Benefits: TSS Removal (kg/yr) | Benefits: Runoff Volume Reduction ($m^3$/yr) | Feasibility Cost (CAD) | 20-year Present Costs in 2015 Canadian Dollars: Construction (CAD) | Design (CAD) | O & M (CAD) | Total (CAD) | Cost-Benefit Analysis: TP Removal (CAD/kg) | TSS Removal (CAD/kg) | Volume Reduction (CAD/$m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MI-62 | McIntyre | Biofiltration | Yes | 355 | 162 | 2.3 | 1.44 | 389 | 1,749 | - | $ 97,483 | $ 19,497 | $ 5,849 | $ 122,828 | $ 4,262 | $ 15.78 | $ 3.51 |
| MI-63 | McIntyre | Biofiltration | Yes | 479 | 218 | 3.2 | 1.94 | 525 | 2,359 | - | $ 122,687 | $ 24,537 | $ 7,361 | $ 154,585 | $ 3,977 | $ 14.73 | $ 3.28 |
| MI-64 | McIntyre | Pond | Yes | 1,643 | 2,003 | 17.6 | 8.30 | 5,294 | 3,762 | $ 54,936 | $ 294,166 | $ 58,833 | $ 13,237 | $ 366,237 | $ 2,206 | $ 3.46 | $ 4.87 |
| MI-65 | McIntyre | Pond | Yes | 2,419 | 2,949 | 53.3 | 11.41 | 7,901 | 6,634 | $ 67,177 | $ 359,718 | $ 71,944 | $ 16,187 | $ 447,849 | $ 1,963 | $ 2.83 | $ 3.38 |
| MI-66 | McIntyre | Pond | Yes | 14,240 | 17,361 | 314.1 | 49.07 | 49,618 | 39,063 | $ 169,072 | $ 905,337 | $ 181,067 | $ 40,740 | $ 1,127,144 | $ 1,149 | $ 1.14 | $ 1.44 |
| MI-67 | McIntyre | Pond | Yes | 430 | 524 | 4.6 | 2.75 | 1,319 | 985 | - | $ 146,381 | $ 29,276 | $ 6,587 | $ 182,245 | $ 3,308 | $ 6.91 | $ 9.26 |
| MI-68 | McIntyre | Tree Trench | Yes | 389 | 108 | 0.8 | 0.58 | 246 | 324 | - | $ 130,532 | $ 26,106 | $ 16,317 | $ 172,955 | $ 15,011 | $ 35.16 | $ 26.69 |
| MI-69 | McIntyre | Biofiltration | Yes | 691 | 315 | 2.2 | 2.48 | 718 | 946 | - | $ 162,577 | $ 32,515 | $ 9,755 | $ 204,847 | $ 4,135 | $ 14.26 | $ 10.82 |
| MI-70 | McIntyre | Biofiltration | No | 559 | 255 | 3.7 | 2.27 | 612 | 2,751 | - | $ 138,069 | $ 27,614 | $ 8,284 | $ 173,967 | $ 3,838 | $ 14.21 | $ 3.16 |
| MI-71 | McIntyre | Parking Lot Retrofit | Yes | 220 | 61 | 0.9 | 0.33 | 166 | 658 | - | $ 81,852 | $ 16,370 | $ 10,232 | $ 108,454 | $ 16,663 | $ 32.59 | $ 8.24 |
| MI-72 | McIntyre | Pond | No | 1,058 | 1,290 | 23.3 | 5.78 | 3,354 | 2,902 | - | $ 233,907 | $ 46,781 | $ 10,526 | $ 291,214 | $ 2,520 | $ 4.34 | $ 5.02 |
| MI-73 | McIntyre | Pond | No | 3,448 | 4,204 | 76.0 | 15.28 | 11,410 | 9,458 | - | $ 432,656 | $ 86,531 | $ 19,470 | $ 538,657 | $ 1,763 | $ 2.36 | $ 2.85 |
| MI-74 | McIntyre | Biofiltration | No | 1,369 | 624 | 9.0 | 5.55 | 1,499 | 6,739 | - | $ 274,939 | $ 54,988 | $ 16,496 | $ 346,423 | $ 3,120 | $ 11.55 | $ 2.57 |
| MI-75 | McIntyre | Parking Lot Retrofit | Yes | 9,252 | 2,566 | 37.1 | 13.71 | 5,425 | 27,716 | $ 345,803 | $ 1,739,887 | $ 347,977 | $ 217,486 | $ 2,305,350 | $ 8,408 | $ 21.25 | $ 4.16 |
| MI-76 | McIntyre | Pond | Yes | 5,717 | 6,970 | 126.1 | 23.16 | 19,271 | 15,683 | $ 105,133 | $ 562,962 | $ 112,592 | $ 25,333 | $ 700,888 | $ 1,513 | $ 1.82 | $ 2.23 |
| MI-77 | McIntyre | Biofiltration | Yes | 401 | 183 | 2.6 | 1.63 | 440 | 1,976 | - | $ 107,060 | $ 21,412 | $ 6,424 | $ 134,896 | $ 4,144 | $ 15.35 | $ 3.41 |
| MI-78 | McIntyre | Pond | Yes | 273 | 333 | 6.0 | 1.90 | 825 | 750 | $ 21,595 | $ 115,633 | $ 23,127 | $ 5,203 | $ 143,963 | $ 3,793 | $ 8.72 | $ 9.60 |
| MI-79 | McIntyre | Pond | Yes | 3,291 | 4,012 | 72.6 | 14.70 | 10,871 | 9,027 | - | $ 422,266 | $ 84,453 | $ 19,002 | $ 525,722 | $ 1,788 | $ 2.42 | $ 2.91 |
| MI-80 | McIntyre | Pond | Yes | 6,956 | 8,481 | 74.4 | 27.21 | 23,613 | 15,924 | $ 116,433 | $ 623,470 | $ 124,694 | $ 28,056 | $ 776,220 | $ 1,426 | $ 1.64 | $ 2.44 |
| MI-81 | McIntyre | Parking Lot Retrofit | Yes | 126 | 35 | 0.2 | 0.19 | 80 | 105 | - | $ 51,880 | $ 10,376 | $ 6,485 | $ 68,741 | $ 18,454 | $ 43.23 | $ 32.81 |
| MI-82 | McIntyre | Parking Lot Retrofit | No | 143 | 40 | 0.3 | 0.21 | 91 | 120 | - | $ 57,791 | $ 11,558 | $ 7,224 | $ 76,573 | $ 18,013 | $ 42.20 | $ 32.03 |
| MI-83 | McIntyre | Parking Lot Retrofit | No | 108 | 30 | 0.2 | 0.16 | 68 | 90 | - | $ 45,846 | $ 9,169 | $ 5,731 | $ 60,746 | $ 18,972 | $ 44.44 | $ 33.73 |
| MI-84 | McIntyre | Parking Lot Retrofit | No | 98 | 27 | 0.2 | 0.15 | 62 | 82 | - | $ 42,402 | $ 8,480 | $ 5,300 | $ 56,182 | $ 19,306 | $ 45.23 | $ 34.33 |
| MI-85 | McIntyre | Parking Lot Retrofit | No | 89 | 25 | 0.4 | 0.13 | 72 | 266 | - | $ 39,028 | $ 7,806 | $ 4,878 | $ 51,712 | $ 19,668 | $ 36.15 | $ 9.73 |
| MI-86 | McIntyre | Parking Lot Retrofit | No | 67 | 19 | 0.3 | 0.10 | 55 | 200 | - | $ 30,949 | $ 6,190 | $ 3,869 | $ 41,007 | $ 20,715 | $ 37.35 | $ 10.25 |
| MI-87 | McIntyre | Parking Lot Retrofit | No | 36 | 10 | 0.1 | 0.05 | 31 | 109 | - | $ 18,853 | $ 3,771 | $ 2,357 | $ 24,980 | $ 23,146 | $ 40.03 | $ 11.45 |
| MI-88 | McIntyre | Biofiltration | No | 482 | 220 | 1.5 | 1.73 | 500 | 659 | - | $ 123,125 | $ 24,625 | $ 7,388 | $ 155,138 | $ 4,496 | $ 15.50 | $ 11.77 |
| MI-89 | McIntyre | Pond | No | 2,877 | 3,508 | 63.5 | 13.16 | 9,459 | 7,893 | - | $ 393,754 | $ 78,751 | $ 17,719 | $ 490,224 | $ 1,862 | $ 2.59 | $ 3.11 |
| MI-90 | McIntyre | Pond | No | 4,801 | 5,853 | 51.3 | 20.06 | 16,079 | 10,991 | $ 95,994 | $ 514,021 | $ 102,804 | $ 23,131 | $ 639,957 | $ 1,595 | $ 1.99 | $ 2.91 |
| MI-91 | McIntyre | Pond | No | 9,108 | 11,104 | 97.4 | 33.97 | 31,225 | 20,852 | $ 133,979 | $ 717,423 | $ 143,485 | $ 32,284 | $ 893,191 | $ 1,315 | $ 1.43 | $ 2.14 |
| MI-92 | McIntyre | Pond | No | 4,774 | 5,820 | 51.0 | 19.96 | 15,986 | 10,929 | $ 95,714 | $ 512,523 | $ 102,505 | $ 23,064 | $ 638,091 | $ 1,598 | $ 2.00 | $ 2.92 |
| MI-93 | McIntyre | Pond | No | 3,600 | 4,389 | 38.5 | 15.83 | 11,933 | 8,242 | - | $ 442,506 | $ 88,501 | $ 19,913 | $ 550,920 | $ 1,740 | $ 2.31 | $ 3.34 |
| MI-94 | McIntyre | Pond | No | 8,001 | 9,755 | 85.5 | 30.54 | 27,301 | 18,317 | $ 125,237 | $ 670,611 | $ 134,122 | $ 30,178 | $ 834,911 | $ 1,367 | $ 1.53 | $ 2.28 |
| MI-95 | McIntyre | Pervious Pavement | No | 2,474 | 603 | 4.2 | 3.22 | 1,376 | 1,813 | $ 96,313 | $ 484,596 | $ 96,919 | $ 60,574 | $ 642,090 | $ 9,960 | $ 23.33 | $ 17.71 |
| MI-96 | McIntyre | Pervious Pavement | No | 2,521 | 615 | 4.3 | 3.28 | 1,402 | 1,847 | $ 97,791 | $ 492,032 | $ 98,406 | $ 61,504 | $ 651,942 | $ 9,926 | $ 23.25 | $ 17.65 |
| MI-97 | McIntyre | Pervious Pavement | No | 571 | 139 | 1.0 | 0.74 | 318 | 418 | - | $ 146,251 | $ 29,250 | $ 18,281 | $ 193,782 | $ 13,023 | $ 30.51 | $ 23.16 |
| MI-98 | McIntyre | Biofiltration | No | 488 | 222 | 1.6 | 1.75 | 508 | 669 | - | $ 124,492 | $ 24,898 | $ 7,470 | $ 156,860 | $ 4,481 | $ 15.45 | $ 11.73 |
| MI-99 | McIntyre | Biofiltration | No | 1,306 | 595 | 4.2 | 4.68 | 1,358 | 1,789 | - | $ 265,180 | $ 53,036 | $ 15,911 | $ 334,127 | $ 3,569 | $ 12.31 | $ 9.34 |
| MI-100 | McIntyre | Pond | Yes | 1,350 | 1,646 | 14.4 | 7.06 | 4,316 | 3,090 | - | $ 265,501 | $ 53,100 | $ 11,948 | $ 330,549 | $ 2,341 | $ 3.83 | $ 5.35 |
| MI-101 | McIntyre | Wetland | Yes | 40,263 | 36,816 | 258.3 | 147.44 | 66,728 | 110,611 | $ 127,042 | $ 694,218 | $ 138,844 | $ 13,884 | $ 846,946 | $ 287 | $ 0.63 | $ 0.38 |
| MI-102 | McIntyre | Biofiltration | No | 804 | 366 | 2.6 | 2.88 | 836 | 1,101 | - | $ 182,603 | $ 36,521 | $ 10,956 | $ 230,080 | $ 3,993 | $ 13.77 | $ 10.45 |
| MI-103 | McIntyre | Biofiltration | No | 1,348 | 614 | 4.3 | 4.83 | 1,400 | 1,845 | - | $ 271,578 | $ 54,316 | $ 16,295 | $ 342,188 | $ 3,543 | $ 12.22 | $ 9.27 |
| MI-104 | McIntyre | Biofiltration | No | 427 | 195 | 1.4 | 1.53 | 443 | 584 | - | $ 112,203 | $ 22,441 | $ 6,732 | $ 141,376 | $ 4,623 | $ 15.94 | $ 12.10 |
| MI-105 | McIntyre | Pond | No | 21,262 | 25,923 | 227.3 | 68.24 | 73,895 | 48,676 | $ 208,308 | $ 1,115,436 | $ 223,087 | $ 50,195 | $ 1,388,718 | $ 1,018 | $ 0.94 | $ 1.43 |
| MI-106 | McIntyre | Pond | Yes | 5,407 | 6,592 | 57.8 | 22.12 | 18,186 | 12,377 | $ 102,118 | $ 546,818 | $ 109,364 | $ 24,607 | $ 680,789 | $ 1,539 | $ 1.87 | $ 2.75 |
| MI-107 | McIntyre | Biofiltration | No | 1,849 | 843 | 5.9 | 6.63 | 1,922 | 2,532 | - | $ 346,349 | $ 69,270 | $ 20,781 | $ 436,399 | $ 3,293 | $ 11.35 | $ 8.62 |
| MI-108 | McIntyre | Wetland | No | 399 | 365 | 2.6 | 1.46 | 677 | 1,096 | - | $ 53,733 | $ 10,747 | $ 1,075 | $ 65,554 | $ 2,243 | $ 4.84 | $ 2.99 |
| MI-109 | McIntyre | Pond | No | 936 | 1,141 | 10.0 | 5.23 | 2,955 | 2,144 | - | $ 219,490 | $ 43,898 | $ 9,877 | $ 273,265 | $ 2,614 | $ 4.62 | $ 6.37 |
| MI-110 | McIntyre | Subsurface Storage | No | 2,588 | 3,155 | 22.1 | 10.04 | 6,726 | 4,741 | - | $ 331,782 | $ 66,356 | $ 14,930 | $ 413,069 | $ 2,057 | $ 3.07 | $ 4.36 |
| MI-111 | McIntyre | Tree Trench | No | 407 | 113 | 0.8 | 0.60 | 257 | 339 | - | $ 135,481 | $ 27,096 | $ 16,935 | $ 179,513 | $ 14,886 | $ 34.87 | $ 26.47 |
| MI-112 | McIntyre | Biofiltration | No | 57 | 26 | 0.2 | 0.21 | 59 | 78 | - | $ 23,954 | $ 4,791 | $ 1,437 | $ 30,182 | $ 7,359 | $ 25.38 | $ 19.26 |

| ID | Watershed | BMP Category | Demonstration / Education? | Footprint Area | Water Quality | Drainage Area | Benefits | | | Feasibility Cost | 20-year Present Costs in 2015 Canadian Dollars | | | | Cost-Benefit Analysis | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | TP Removal | TSS Removal | Runoff Volume | | Construction | Design | O & M | Total | TP Removal | TSS Removal | Volume Reduction |
| | | | | ($m^2$) | Volume ($m^3$) | (ha) | (kg/yr) | (kg/yr) | Reduction ($m^3$/yr) | (CAD) | (CAD) | (CAD) | (CAD) | (CAD) | (CAD/kg) | (CAD/kg) | (CAD/$m^3$) |
| MI-113 | McIntyre | Biofiltration | No | 60 | 27 | 0.2 | 0.21 | 62 | 82 | - | $ 24,697 | $ 4,939 | $ 1,482 | $ 31,119 | $ 7,292 | $ 25.14 | $ 19.09 |
| MI-114 | McIntyre | Tree Trench | No | 3,942 | 1,093 | 7.7 | 5.84 | 2,450 | 3,285 | $ 172,203 | $ 866,428 | $ 173,286 | $ 108,303 | $ 1,148,017 | $ 9,827 | $ 23.43 | $ 17.47 |
| MI-115 | McIntyre | Biofiltration | No | 658 | 300 | 2.1 | 2.36 | 684 | 901 | - | $ 156,514 | $ 31,303 | $ 9,391 | $ 197,207 | $ 4,182 | $ 14.42 | $ 10.95 |
| MI-116 | McIntyre | Tree Trench | No | 558 | 155 | 1.1 | 0.83 | 353 | 465 | - | $ 175,331 | $ 35,066 | $ 21,916 | $ 232,313 | $ 14,052 | $ 32.92 | $ 24.99 |
| MI-117 | McIntyre | Tree Trench | No | 566 | 157 | 1.1 | 0.84 | 358 | 472 | - | $ 177,380 | $ 35,476 | $ 22,172 | $ 235,028 | $ 14,015 | $ 32.83 | $ 24.92 |
| MI-118 | McIntyre | Biofiltration | No | 733 | 334 | 4.8 | 2.97 | 802 | 3,605 | - | $ 169,999 | $ 34,000 | $ 10,200 | $ 214,199 | $ 3,605 | $ 13.35 | $ 2.97 |
| MI-119 | McIntyre | Biofiltration | No | 111 | 51 | 0.4 | 0.40 | 115 | 152 | - | $ 39,838 | $ 7,968 | $ 2,390 | $ 50,195 | $ 6,314 | $ 21.77 | $ 16.53 |
| MI-120 | McIntyre | Biofiltration | No | 522 | 238 | 1.7 | 1.87 | 542 | 714 | - | $ 130,921 | $ 26,184 | $ 7,855 | $ 164,961 | $ 4,413 | $ 15.22 | $ 11.55 |
| MI-121 | McIntyre | Biofiltration | No | 588 | 268 | 1.9 | 2.11 | 611 | 805 | - | $ 143,541 | $ 28,708 | $ 8,612 | $ 180,861 | $ 4,293 | $ 14.80 | $ 11.24 |
| MI-122 | McIntyre | Biofiltration | No | 989 | 451 | 3.2 | 3.55 | 1,028 | 1,354 | - | $ 214,149 | $ 42,830 | $ 12,849 | $ 269,827 | $ 3,806 | $ 13.12 | $ 9.96 |
| MI-123 | McIntyre | Biofiltration | No | 195 | 89 | 0.6 | 0.70 | 203 | 267 | - | $ 61,508 | $ 12,302 | $ 3,690 | $ 77,499 | $ 5,540 | $ 19.10 | $ 14.50 |
| MI-124 | McIntyre | Biofiltration | No | 181 | 82 | 0.6 | 0.65 | 188 | 248 | - | $ 58,081 | $ 11,616 | $ 3,485 | $ 73,182 | $ 5,637 | $ 19.44 | $ 14.75 |
| MI-125 | McIntyre | Biofiltration | No | 754 | 344 | 2.4 | 2.70 | 783 | 1,032 | - | $ 173,715 | $ 34,743 | $ 10,423 | $ 218,881 | $ 4,053 | $ 13.98 | $ 10.61 |
| MI-126 | McIntyre | Biofiltration | No | 46 | 21 | 0.1 | 0.17 | 48 | 63 | - | $ 20,310 | $ 4,062 | $ 1,219 | $ 25,591 | $ 7,734 | $ 26.67 | $ 20.24 |
| MI-127 | McIntyre | Pond | Yes | 1,774 | 2,163 | 19.0 | 8.84 | 5,729 | 4,061 | - | $ 306,091 | $ 61,218 | $ 13,774 | $ 381,083 | $ 2,155 | $ 3.33 | $ 4.69 |
| MI-128 | McIntyre | Pond | Yes | 1,526 | 1,860 | 16.3 | 7.81 | 4,902 | 3,493 | - | $ 283,020 | $ 56,604 | $ 12,736 | $ 352,359 | $ 2,256 | $ 3.59 | $ 5.04 |
| MI-129 | McIntyre | Pond | Yes | 4,543 | 5,539 | 48.6 | 19.17 | 15,186 | 10,401 | - | $ 499,472 | $ 99,894 | $ 22,476 | $ 621,842 | $ 1,622 | $ 2.05 | $ 2.99 |
| MI-130 | McIntyre | Pond | No | 1,544 | 1,882 | 16.5 | 7.89 | 4,963 | 3,535 | - | $ 284,800 | $ 56,960 | $ 12,816 | $ 354,576 | $ 2,248 | $ 3.57 | $ 5.01 |
| MI-131 | McIntyre | Pond | No | 640 | 780 | 6.8 | 3.82 | 1,992 | 1,465 | - | $ 180,044 | $ 36,009 | $ 8,102 | $ 224,155 | $ 2,933 | $ 5.63 | $ 7.65 |
| MI-132 | McIntyre | Biofiltration | No | 771 | 351 | 5.1 | 3.13 | 844 | 3,794 | - | $ 176,802 | $ 35,360 | $ 10,608 | $ 222,770 | $ 3,563 | $ 13.19 | $ 2.94 |
| MI-133 | McIntyre | Pond | No | 1,534 | 1,870 | 16.4 | 7.85 | 4,930 | 3,512 | - | $ 283,826 | $ 56,765 | $ 12,772 | $ 353,363 | $ 2,252 | $ 3.58 | $ 5.03 |
| MI-134 | McIntyre | Biofiltration | Yes | 396 | 180 | 1.3 | 1.42 | 411 | 542 | - | $ 105,877 | $ 21,175 | $ 6,353 | $ 133,406 | $ 4,705 | $ 16.22 | $ 12.31 |
| MI-135 | McIntyre | Biofiltration | Yes | 118 | 54 | 0.4 | 0.42 | 123 | 162 | - | $ 41,823 | $ 8,365 | $ 2,509 | $ 52,697 | $ 6,222 | $ 21.46 | $ 16.29 |
| MI-136 | McIntyre | Biofiltration | Yes | 585 | 267 | 1.9 | 2.09 | 607 | 800 | - | $ 142,912 | $ 28,582 | $ 8,575 | $ 180,070 | $ 4,298 | $ 14.82 | $ 11.25 |
| MI-137 | McIntyre | Tree Trench | No | 160 | 44 | 0.3 | 0.24 | 101 | 133 | - | $ 63,030 | $ 12,606 | $ 7,879 | $ 83,515 | $ 17,667 | $ 41.39 | $ 31.41 |
| MI-138 | McIntyre | Pond | No | 638 | 778 | 6.8 | 3.81 | 1,986 | 1,461 | - | $ 179,772 | $ 35,954 | $ 8,090 | $ 223,816 | $ 2,936 | $ 5.63 | $ 7.66 |
| MV-1 | McVicar | Biofiltration | No | 79 | 36 | 0.5 | 0.32 | 86 | 389 | - | $ 30,690 | $ 6,138 | $ 1,841 | $ 38,669 | $ 6,036 | $ 22.35 | $ 4.97 |
| MV-2 | McVicar | Biofiltration | No | 112 | 51 | 0.7 | 0.45 | 123 | 551 | - | $ 40,134 | $ 8,027 | $ 2,408 | $ 50,568 | $ 5,568 | $ 20.62 | $ 4.59 |
| MV-3 | McVicar | Biofiltration | No | 149 | 68 | 1.0 | 0.60 | 163 | 733 | - | $ 49,980 | $ 9,996 | $ 2,999 | $ 62,974 | $ 5,212 | $ 19.30 | $ 4.29 |
| MV-4 | McVicar | Sedimentation Basin | No | 11 | 7 | 0.1 | 0.06 | 11 | 12 | - | $ 13,472 | $ 2,694 | $ 606 | $ 16,773 | $ 14,018 | $ 73.40 | $ 69.48 |
| MV-5 | McVicar | Sedimentation Basin | No | 11 | 7 | 0.1 | 0.06 | 11 | 12 | - | $ 13,472 | $ 2,694 | $ 606 | $ 16,773 | $ 14,018 | $ 73.40 | $ 69.48 |
| MV-6 | McVicar | Biofiltration | Yes | 107 | 49 | 0.7 | 0.43 | 117 | 527 | - | $ 38,749 | $ 7,750 | $ 2,325 | $ 48,824 | $ 5,627 | $ 20.84 | $ 4.64 |
| MV-7 | McVicar | Biofiltration | No | 41 | 19 | 0.3 | 0.17 | 45 | 202 | - | $ 18,538 | $ 3,708 | $ 1,112 | $ 23,358 | $ 7,025 | $ 26.02 | $ 5.79 |
| MV-8 | McVicar | Biofiltration | Yes | 20 | 9 | 0.1 | 0.08 | 22 | 98 | - | $ 10,677 | $ 2,135 | $ 641 | $ 13,453 | $ 8,294 | $ 30.72 | $ 6.83 |
| MV-9 | McVicar | Biofiltration | Yes | 81 | 37 | 0.5 | 0.33 | 89 | 399 | - | $ 31,285 | $ 6,257 | $ 1,877 | $ 39,419 | $ 6,001 | $ 22.22 | $ 4.94 |
| MV-10 | McVicar | Biofiltration | Yes | 164 | 75 | 1.1 | 0.66 | 180 | 807 | - | $ 53,804 | $ 10,761 | $ 3,228 | $ 67,793 | $ 5,097 | $ 18.88 | $ 4.20 |
| MV-11 | McVicar | Biofiltration | Yes | 135 | 62 | 0.9 | 0.55 | 148 | 664 | - | $ 46,329 | $ 9,266 | $ 2,780 | $ 58,375 | $ 5,332 | $ 19.75 | $ 4.39 |
| MV-12 | McVicar | Biofiltration | Yes | 340 | 155 | 2.2 | 1.38 | 372 | 1,673 | - | $ 94,229 | $ 18,846 | $ 5,654 | $ 118,728 | $ 4,306 | $ 15.95 | $ 3.55 |
| MV-13 | McVicar | Biofiltration | Yes | 118 | 54 | 0.8 | 0.48 | 129 | 581 | - | $ 41,776 | $ 8,355 | $ 2,507 | $ 52,638 | $ 5,501 | $ 20.37 | $ 4.53 |
| MV-14 | McVicar | Biofiltration | Yes | 236 | 108 | 1.6 | 0.96 | 258 | 1,161 | - | $ 71,171 | $ 14,234 | $ 4,270 | $ 89,676 | $ 4,686 | $ 17.35 | $ 3.86 |
| MV-15 | McVicar | Biofiltration | Yes | 218 | 99 | 1.4 | 0.88 | 239 | 1,073 | - | $ 66,961 | $ 13,392 | $ 4,018 | $ 84,371 | $ 4,772 | $ 17.67 | $ 3.93 |
| MV-16 | McVicar | Biofiltration | No | 37 | 17 | 0.2 | 0.15 | 41 | 182 | - | $ 17,131 | $ 3,426 | $ 1,028 | $ 21,585 | $ 7,194 | $ 26.64 | $ 5.93 |
| MV-17 | McVicar | Biofiltration | Yes | 156 | 71 | 1.0 | 0.63 | 171 | 768 | - | $ 51,775 | $ 10,355 | $ 3,106 | $ 65,236 | $ 5,157 | $ 19.10 | $ 4.25 |
| MV-18 | McVicar | Biofiltration | Yes | 167 | 76 | 1.1 | 0.68 | 183 | 822 | - | $ 54,558 | $ 10,912 | $ 3,274 | $ 68,744 | $ 5,076 | $ 18.80 | $ 4.18 |
| MV-19 | McVicar | Biofiltration | No | 62 | 28 | 0.4 | 0.25 | 68 | 305 | - | $ 25,475 | $ 5,095 | $ 1,528 | $ 32,098 | $ 6,384 | $ 23.64 | $ 5.26 |
| MV-20 | McVicar | Biofiltration | Yes | 62 | 28 | 0.4 | 0.25 | 68 | 305 | - | $ 25,475 | $ 5,095 | $ 1,528 | $ 32,098 | $ 6,384 | $ 23.64 | $ 5.26 |
| MV-21 | McVicar | Biofiltration | Yes | 340 | 155 | 2.2 | 1.38 | 372 | 1,673 | - | $ 94,229 | $ 18,846 | $ 5,654 | $ 118,728 | $ 4,306 | $ 15.95 | $ 3.55 |
| MV-22 | McVicar | Biofiltration | Yes | 175 | 80 | 1.2 | 0.71 | 192 | 861 | - | $ 56,556 | $ 11,311 | $ 3,393 | $ 71,261 | $ 5,021 | $ 18.60 | $ 4.14 |
| MV-23 | McVicar | Biofiltration | Yes | 270 | 123 | 1.8 | 1.09 | 296 | 1,329 | - | $ 78,928 | $ 15,786 | $ 4,736 | $ 99,450 | $ 4,542 | $ 16.82 | $ 3.74 |
| MV-24 | McVicar | Wetland | Yes | 625 | 572 | 8.3 | 2.29 | 1,058 | 2,057 | - | $ 68,907 | $ 13,781 | $ 1,378 | $ 84,067 | $ 1,837 | $ 3.97 | $ 2.04 |
| MV-25 | McVicar | Biofiltration | No | 106 | 48 | 0.7 | 0.43 | 116 | 522 | - | $ 38,471 | $ 7,694 | $ 2,308 | $ 48,473 | $ 5,639 | $ 20.88 | $ 4.65 |

| ID | Watershed | BMP Category | Demonstration / Education? | Footprint Area ($m^2$) | Water Quality Volume ($m^3$) | Drainage Area (ha) | Benefits: TP Removal (kg/yr) | Benefits: TSS Removal (kg/yr) | Benefits: Runoff Volume Reduction ($m^3$/yr) | Feasibility Cost (CAD) | 20-year Present Costs in 2015 Canadian Dollars: Construction (CAD) | Design (CAD) | O & M (CAD) | Total (CAD) | Cost-Benefit Analysis: TP Removal (CAD/kg) | TSS Removal (CAD/kg) | Volume Reduction (CAD/$m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MV-26 | McVicar | Biofiltration | Yes | 115 | 52 | 0.8 | 0.47 | 126 | 566 | - | $ 40,957 | $ 8,191 | $ 2,457 | $ 51,606 | $ 5,534 | $ 20.49 | $ 4.56 |
| MV-27 | McVicar | Biofiltration | Yes | 218 | 99 | 1.4 | 0.88 | 239 | 1,073 | - | $ 66,961 | $ 13,392 | $ 4,018 | $ 84,371 | $ 4,772 | $ 17.67 | $ 3.93 |
| MS-1 | Mosquito | Parking Lot Retrofit | Yes | 740 | 31 | 1.4 | 0.16 | 88 | 177 | - | $ 46,856 | $ 9,371 | $ 5,857 | $ 62,085 | $ 18,879 | $ 35.24 | $ 17.50 |
| MS-2 | Mosquito | Parking Lot Retrofit | No | 1,811 | 75 | 3.5 | 0.40 | 203 | 434 | - | $ 97,392 | $ 19,478 | $ 12,174 | $ 129,045 | $ 16,028 | $ 31.81 | $ 14.85 |
| MS-3 | Mosquito | Biofiltration | No | 48 | 22 | 1.0 | 0.19 | 52 | 126 | - | $ 20,873 | $ 4,175 | $ 1,252 | $ 26,301 | $ 6,779 | $ 25.10 | $ 10.46 |
| MS-4 | Mosquito | Ditch Maintenance | No | 1,273 | - | 9.1 | - | - | 932 | - | $ 2,569 | $ 625 | $ 2,569 | $ 5,763 | - | - | $ 0.31 |
| MS-5 | Mosquito | Biofiltration | Yes | 218 | 99 | 4.7 | 0.88 | 239 | 572 | - | $ 66,949 | $ 13,390 | $ 4,017 | $ 84,356 | $ 4,773 | $ 17.68 | $ 7.37 |
| MS-6 | Mosquito | Curb Cut | Yes | 1 | - | - | - | - | - | - | $ 625 | $ - | $ - | $ 625 | - | - | - |
| MS-7 | Mosquito | Biofiltration | Yes | 19 | 9 | 0.1 | 0.08 | 21 | 19 | - | $ 10,437 | $ 2,087 | $ 626 | $ 13,150 | $ 8,351 | $ 30.93 | $ 33.84 |
| MS-8 | Mosquito | Biofiltration | Yes | 21 | 10 | 0.1 | 0.09 | 23 | 21 | - | $ 11,158 | $ 2,232 | $ 670 | $ 14,060 | $ 8,185 | $ 30.31 | $ 33.17 |
| MS-9 | Mosquito | Biofiltration | No | 17 | 8 | 0.1 | 0.07 | 19 | 17 | - | $ 9,621 | $ 1,924 | $ 577 | $ 12,122 | $ 8,559 | $ 31.70 | $ 34.68 |
| MS-10 | Mosquito | Ditch Maintenance | No | 2,094 | - | 15.0 | - | - | 1,533 | - | $ 4,226 | $ 625 | $ 4,226 | $ 9,078 | - | - | $ 0.30 |
| MS-11 | Mosquito | Ditch Maintenance | No | 950 | - | 6.8 | - | - | 696 | - | $ 1,918 | $ 625 | $ 1,918 | $ 4,461 | - | - | $ 0.32 |
| MS-12 | Mosquito | Ditch Maintenance | No | 4,555 | - | 32.6 | - | - | 3,335 | - | $ 9,194 | $ 625 | $ 9,194 | $ 19,012 | - | - | $ 0.29 |
| MS-13 | Mosquito | Ditch Maintenance | No | 1,920 | - | 13.7 | - | - | 1,405 | - | $ 3,874 | $ 625 | $ 3,874 | $ 8,373 | - | - | $ 0.30 |
| MS-14 | Mosquito | Ditch Maintenance | Yes | 2,598 | - | 18.6 | - | - | 1,902 | - | $ 5,243 | $ 625 | $ 5,243 | $ 11,112 | - | - | $ 0.29 |
| MS-15 | Mosquito | Biofiltration | Yes | 180 | 82 | 1.3 | 0.73 | 197 | 180 | - | $ 57,668 | $ 11,534 | $ 3,460 | $ 72,662 | $ 4,992 | $ 18.49 | $ 20.23 |
| MS-17 | Mosquito | Biofiltration | Yes | 328 | 149 | 7.0 | 1.33 | 360 | 863 | - | $ 91,750 | $ 18,350 | $ 5,505 | $ 115,606 | $ 4,341 | $ 16.08 | $ 6.70 |
| MS-18 | Mosquito | Biofiltration | No | 144 | 66 | 3.1 | 0.58 | 158 | 378 | - | $ 48,709 | $ 9,742 | $ 2,923 | $ 61,374 | $ 5,252 | $ 19.45 | $ 8.11 |
| NB-1 | Neebing | Subsurface Storage | Yes | 2,544 | 3,102 | 44.9 | 9.90 | 6,607 | 33,497 | - | $ 328,807 | $ 65,761 | $ 14,796 | $ 409,364 | $ 2,068 | $ 3.10 | $ 0.61 |
| NB-2 | Neebing | Biofiltration | Yes | 76 | 35 | 0.5 | 0.31 | 83 | 375 | - | $ 29,844 | $ 5,969 | $ 1,791 | $ 37,604 | $ 6,087 | $ 22.54 | $ 5.02 |
| NB-3 | Neebing | Pond | No | 6,580 | 8,022 | 145.1 | 26.00 | 22,292 | 18,050 | $ 113,114 | $ 605,696 | $ 121,139 | $ 27,256 | $ 754,092 | $ 1,450 | $ 1.69 | $ 2.09 |
| NB-4 | Neebing | Tree Trench | No | 370 | 103 | 1.5 | 0.55 | 270 | 1,108 | - | $ 125,361 | $ 25,072 | $ 15,670 | $ 166,103 | $ 15,147 | $ 30.70 | $ 7.49 |
| NB-5 | Neebing | Tree Trench | No | 381 | 106 | 1.5 | 0.56 | 278 | 1,140 | - | $ 128,311 | $ 25,662 | $ 16,039 | $ 170,012 | $ 15,069 | $ 30.60 | $ 7.45 |
| NB-6 | Neebing | Tree Trench | No | 606 | 168 | 2.4 | 0.90 | 429 | 1,817 | - | $ 187,712 | $ 37,542 | $ 23,464 | $ 248,719 | $ 13,839 | $ 29.02 | $ 6.85 |
| NB-7 | Neebing | Tree Trench | No | 562 | 156 | 2.3 | 0.83 | 399 | 1,683 | - | $ 176,380 | $ 35,276 | $ 22,047 | $ 233,703 | $ 14,033 | $ 29.27 | $ 6.94 |
| NB-8 | Neebing | Tree Trench | No | 824 | 229 | 3.3 | 1.22 | 570 | 2,467 | - | $ 241,018 | $ 48,204 | $ 30,127 | $ 319,348 | $ 13,086 | $ 28.02 | $ 6.47 |
| NB-9 | Neebing | Tree Trench | No | 788 | 219 | 3.2 | 1.17 | 547 | 2,359 | - | $ 232,407 | $ 46,481 | $ 29,051 | $ 307,939 | $ 13,193 | $ 28.16 | $ 6.53 |
| NB-10 | Neebing | Tree Trench | No | 713 | 198 | 2.9 | 1.06 | 498 | 2,137 | - | $ 214,326 | $ 42,865 | $ 26,791 | $ 283,982 | $ 13,434 | $ 28.48 | $ 6.65 |
| NB-11 | Neebing | Tree Trench | No | 673 | 187 | 2.7 | 1.00 | 472 | 2,016 | - | $ 204,397 | $ 40,879 | $ 25,550 | $ 270,826 | $ 13,577 | $ 28.67 | $ 6.72 |
| NB-12 | Neebing | Tree Trench | No | 700 | 194 | 2.8 | 1.04 | 490 | 2,098 | - | $ 211,104 | $ 42,221 | $ 26,388 | $ 279,713 | $ 13,480 | $ 28.54 | $ 6.67 |
| NB-13 | Neebing | Tree Trench | No | 306 | 85 | 1.2 | 0.45 | 227 | 917 | - | $ 107,339 | $ 21,468 | $ 13,417 | $ 142,225 | $ 15,683 | $ 31.38 | $ 7.76 |
| NB-15 | Neebing | Biofiltration | Yes | 200 | 91 | 1.3 | 0.81 | 219 | 984 | - | $ 62,652 | $ 12,530 | $ 3,759 | $ 78,941 | $ 4,869 | $ 18.03 | $ 4.01 |
| NB-16 | Neebing | Pond | No | 248 | 302 | 5.5 | 1.75 | 746 | 681 | - | $ 109,962 | $ 21,992 | $ 4,948 | $ 136,902 | $ 3,905 | $ 9.17 | $ 10.05 |
| NB-17 | Neebing | Pond | No | 56 | 68 | 1.2 | 0.51 | 158 | 152 | - | $ 50,440 | $ 10,088 | $ 2,270 | $ 62,798 | $ 6,139 | $ 19.85 | $ 20.60 |
| NB-18 | Neebing | Pond | Yes | 1,728 | 2,107 | 38.1 | 8.65 | 5,578 | 4,741 | - | $ 302,001 | $ 60,400 | $ 13,590 | $ 375,991 | $ 2,172 | $ 3.37 | $ 3.96 |
| NB-19 | Neebing | Pond | Yes | 4,176 | 5,091 | 92.1 | 17.88 | 13,917 | 11,457 | - | $ 478,050 | $ 95,610 | $ 21,512 | $ 595,173 | $ 1,664 | $ 2.14 | $ 2.60 |
| NB-20 | Neebing | Biofiltration | Yes | 1,581 | 720 | 10.4 | 6.41 | 1,731 | 7,779 | - | $ 306,992 | $ 61,398 | $ 18,420 | $ 386,810 | $ 3,018 | $ 11.18 | $ 2.49 |
| NB-21 | Neebing | Biofiltration | Yes | 824 | 375 | 5.4 | 3.34 | 903 | 4,057 | - | $ 186,128 | $ 37,226 | $ 11,168 | $ 234,521 | $ 3,508 | $ 12.99 | $ 2.89 |
| NB-22 | Neebing | Biofiltration | Yes | 727 | 331 | 4.8 | 2.95 | 796 | 3,579 | - | $ 169,054 | $ 33,811 | $ 10,143 | $ 213,008 | $ 3,611 | $ 13.37 | $ 2.98 |
| NB-23 | Neebing | Pond | Yes | 3,205 | 3,908 | 70.7 | 14.39 | 10,579 | 8,793 | $ 77,786 | $ 416,527 | $ 83,305 | $ 18,744 | $ 518,576 | $ 1,802 | $ 2.45 | $ 2.95 |
| NB-24 | Neebing | Pond | Yes | 2,522 | 3,075 | 55.6 | 11.81 | 8,250 | 6,917 | $ 68,651 | $ 367,609 | $ 73,522 | $ 16,542 | $ 457,673 | $ 1,938 | $ 2.77 | $ 3.31 |
| NB-26 | Neebing | Wetland | No | 4,301 | 3,933 | 1,359.9 | 15.75 | 7,208 | 94,202 | - | $ 200,818 | $ 40,164 | $ 4,016 | $ 244,998 | $ 778 | $ 1.70 | $ 0.13 |
| NB-27 | Neebing | Wetland | No | 2,642 | 2,416 | 835.4 | 9.67 | 4,439 | 57,870 | - | $ 153,268 | $ 30,654 | $ 3,065 | $ 186,987 | $ 966 | $ 2.11 | $ 0.16 |
| NB-28 | Neebing | Biofiltration | Yes | 253 | 115 | 39.8 | 1.02 | 276 | 8,269 | - | $ 74,968 | $ 14,994 | $ 4,498 | $ 94,460 | $ 4,613 | $ 17.08 | $ 0.57 |
| NB-29 | Neebing | Tree Trench | Yes | 258 | 72 | 24.7 | 0.38 | 193 | 5,135 | - | $ 93,252 | $ 18,650 | $ 11,657 | $ 123,559 | $ 16,184 | $ 32.00 | $ 1.20 |
| NB-30 | Neebing | Biofiltration | Yes | 127 | 58 | 19.9 | 0.51 | 139 | 4,144 | - | $ 44,079 | $ 8,816 | $ 2,645 | $ 55,540 | $ 5,413 | $ 20.04 | $ 0.67 |
| NB-31 | Neebing | Ravine Stabilization | Yes | 76 | - | - | - | - | - | - | $ 125,000 | $ 25,000 | $ 25,000 | $ 175,000 | - | - | - |
| NB-32 | Neebing | Ravine Stabilization | Yes | 1,903 | - | - | - | - | - | $ 26,250 | $ 125,000 | $ 25,000 | $ 25,000 | $ 175,000 | - | - | - |
| NB-33 | Neebing | Pond | Yes | 1,272 | 1,551 | 28.1 | 6.73 | 4,060 | 3,490 | $ 48,081 | $ 257,463 | $ 51,493 | $ 11,586 | $ 320,542 | $ 2,383 | $ 3.95 | $ 4.59 |
| NB-34 | Neebing | Biofiltration | No | 161 | 73 | 0.5 | 0.58 | 167 | 220 | - | $ 53,046 | $ 10,609 | $ 3,183 | $ 66,838 | $ 5,793 | $ 19.97 | $ 15.16 |

| ID | Watershed | BMP Category | Demonstration / Education? | Footprint Area ($m^2$) | Water Quality Volume ($m^3$) | Drainage Area (ha) | Benefits: TP Removal (kg/yr) | Benefits: TSS Removal (kg/yr) | Benefits: Runoff Volume Reduction ($m^3$/yr) | Feasibility Cost (CAD) | 20-year Present Costs in 2015 Canadian Dollars: Construction (CAD) | Design (CAD) | O & M (CAD) | Total (CAD) | Cost-Benefit Analysis: TP Removal (CAD/kg) | TSS Removal (CAD/kg) | Volume Reduction (CAD/$m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NB-35 | Neebing | Biofiltration | No | 145 | 66 | 0.5 | 0.52 | 151 | 199 | - | $ 49,047 | $ 9,809 | $ 2,943 | $ 61,799 | $ 5,931 | $ 20.45 | $ 15.52 |
| NB-36 | Neebing | Biofiltration | Yes | 58 | 26 | 0.4 | 0.23 | 63 | 285 | - | $ 24,163 | $ 4,833 | $ 1,450 | $ 30,445 | $ 6,486 | $ 24.02 | $ 5.34 |
| NB-37 | Neebing | Biofiltration | Yes | 69 | 31 | 0.5 | 0.28 | 76 | 342 | - | $ 27,780 | $ 5,556 | $ 1,667 | $ 35,003 | $ 6,220 | $ 23.03 | $ 5.12 |
| NB-38 | Neebing | Biofiltration | Yes | 263 | 120 | 1.7 | 1.07 | 288 | 1,296 | - | $ 77,437 | $ 15,487 | $ 4,646 | $ 97,570 | $ 4,568 | $ 16.92 | $ 3.76 |
| NB-39 | Neebing | Biofiltration | Yes | 488 | 222 | 3.2 | 1.98 | 534 | 2,401 | - | $ 124,383 | $ 24,877 | $ 7,463 | $ 156,723 | $ 3,961 | $ 14.67 | $ 3.26 |
| NB-40 | Neebing | Tree Trench | No | 286 | 79 | 1.2 | 0.42 | 213 | 858 | - | $ 101,714 | $ 20,343 | $ 12,714 | $ 134,771 | $ 15,873 | $ 31.62 | $ 7.85 |
| NB-41 | Neebing | Biofiltration | Yes | 292 | 133 | 1.9 | 1.18 | 320 | 1,437 | - | $ 83,846 | $ 16,769 | $ 5,031 | $ 105,645 | $ 4,460 | $ 16.52 | $ 3.67 |
| NB-42 | Neebing | Biofiltration | Yes | 738 | 336 | 4.9 | 2.99 | 808 | 3,631 | - | $ 170,926 | $ 34,185 | $ 10,256 | $ 215,367 | $ 3,599 | $ 13.33 | $ 2.97 |
| NB-43 | Neebing | Biofiltration | Yes | 441 | 201 | 2.9 | 1.79 | 483 | 2,172 | - | $ 115,140 | $ 23,028 | $ 6,908 | $ 145,076 | $ 4,054 | $ 15.01 | $ 3.34 |
| NB-44 | Neebing | Pond | No | 8,772 | 10,695 | 207.2 | 32.93 | 30,030 | 14,678 | $ 131,377 | $ 703,492 | $ 140,698 | $ 31,657 | $ 875,848 | $ 1,330 | $ 1.46 | $ 2.98 |
| NB-45 | Neebing | Pond | No | 18,544 | 22,609 | 438.0 | 60.98 | 65,238 | 31,029 | $ 193,990 | $ 1,038,770 | $ 207,754 | $ 46,745 | $ 1,293,268 | $ 1,060 | $ 0.99 | $ 2.08 |
| NB-46 | Neebing | Biofiltration | No | 4,536 | 2,067 | 29.9 | 18.39 | 4,967 | 22,324 | $ 130,470 | $ 690,319 | $ 138,064 | $ 41,419 | $ 869,802 | $ 2,364 | $ 8.76 | $ 1.95 |
| NB-47 | Neebing | Tree Trench | No | 387 | 107 | 1.6 | 0.57 | 282 | 1,159 | - | $ 129,997 | $ 25,999 | $ 16,250 | $ 172,246 | $ 15,025 | $ 30.55 | $ 7.43 |
| NB-48 | Neebing | Tree Trench | No | 342 | 95 | 1.4 | 0.51 | 251 | 1,025 | - | $ 117,591 | $ 23,518 | $ 14,699 | $ 155,807 | $ 15,366 | $ 30.98 | $ 7.60 |
| NB-49 | Neebing | Tree Trench | No | 352 | 98 | 1.4 | 0.52 | 258 | 1,054 | - | $ 120,349 | $ 24,070 | $ 15,044 | $ 159,462 | $ 15,286 | $ 30.88 | $ 7.56 |
| NB-50 | Neebing | Tree Trench | No | 1,018 | 282 | 4.1 | 1.51 | 694 | 3,048 | - | $ 286,514 | $ 57,303 | $ 35,814 | $ 379,631 | $ 12,589 | $ 27.35 | $ 6.23 |
| NB-51 | Neebing | Subsurface Storage | Yes | 18,419 | 22,456 | 325.0 | 50.47 | 51,406 | 242,525 | $ 172,106 | $ 921,584 | $ 184,317 | $ 41,471 | $ 1,147,372 | $ 1,137 | $ 1.12 | $ 0.24 |
| NB-52 | Neebing | Pond | Yes | 1,915 | 2,335 | 42.2 | 9.42 | 6,204 | 5,254 | - | $ 318,569 | $ 63,714 | $ 14,336 | $ 396,618 | $ 2,106 | $ 3.20 | $ 3.77 |
| NB-53 | Neebing | Biofiltration | No | 182 | 83 | 1.2 | 0.74 | 200 | 897 | - | $ 58,355 | $ 11,671 | $ 3,501 | $ 73,528 | $ 4,974 | $ 18.42 | $ 4.10 |
| NB-54 | Neebing | Pervious Pavement | Yes | 404 | 99 | 1.4 | 0.53 | 260 | 1,063 | - | $ 110,154 | $ 22,031 | $ 13,769 | $ 145,955 | $ 13,875 | $ 28.05 | $ 6.86 |
| NB-55 | Neebing | Pervious Pavement | Yes | 422 | 103 | 1.5 | 0.55 | 271 | 1,110 | - | $ 114,136 | $ 22,827 | $ 14,267 | $ 151,230 | $ 13,766 | $ 27.91 | $ 6.81 |
| NB-56 | Neebing | Tree Trench | Yes | 1,084 | 301 | 4.4 | 1.61 | 736 | 3,247 | - | $ 301,666 | $ 60,333 | $ 37,708 | $ 399,707 | $ 12,445 | $ 27.15 | $ 6.16 |
| NB-57 | Neebing | Ditch Maintenance | Yes | 61 | - | 0.1 | - | - | 28 | - | $ 124 | $ 625 | $ 124 | $ 873 | - | - | $ 1.55 |
| NB-58 | Neebing | Biofiltration | Yes | 254 | 116 | 1.7 | 1.03 | 278 | 1,250 | - | $ 75,307 | $ 15,061 | $ 4,518 | $ 94,887 | $ 4,607 | $ 17.06 | $ 3.80 |
| NB-59 | Neebing | Biofiltration | Yes | 263 | 120 | 1.7 | 1.07 | 288 | 1,293 | - | $ 77,311 | $ 15,462 | $ 4,639 | $ 97,411 | $ 4,570 | $ 16.93 | $ 3.77 |
| NB-60 | Neebing | Pervious Pavement | Yes | 217 | 53 | 0.8 | 0.28 | 146 | 571 | - | $ 66,304 | $ 13,261 | $ 8,288 | $ 87,852 | $ 15,545 | $ 30.11 | $ 7.69 |
| NB-61 | Neebing | Biofiltration | Yes | 205 | 93 | 1.4 | 0.83 | 224 | 1,009 | - | $ 63,879 | $ 12,776 | $ 3,833 | $ 80,488 | $ 4,841 | $ 17.93 | $ 3.99 |
| NB-62 | Neebing | Biofiltration | Yes | 115 | 52 | 0.8 | 0.47 | 126 | 566 | - | $ 40,987 | $ 8,197 | $ 2,459 | $ 51,643 | $ 5,532 | $ 20.49 | $ 4.56 |
| NB-63 | Neebing | Biofiltration | Yes | 345 | 157 | 2.3 | 1.40 | 378 | 1,699 | - | $ 95,340 | $ 19,068 | $ 5,720 | $ 120,129 | $ 4,291 | $ 15.89 | $ 3.54 |
| NB-64 | Neebing | Pervious Pavement | No | 744 | 181 | 2.6 | 0.97 | 460 | 1,959 | - | $ 181,527 | $ 36,305 | $ 22,691 | $ 240,523 | $ 12,408 | $ 26.15 | $ 6.14 |
| NB-65 | Neebing | Biofiltration | Yes | 498 | 227 | 3.3 | 2.02 | 545 | 2,450 | - | $ 126,308 | $ 25,262 | $ 7,578 | $ 159,148 | $ 3,943 | $ 14.60 | $ 3.25 |
| NB-66 | Neebing | Biofiltration | No | 351 | 160 | 2.3 | 1.43 | 385 | 1,730 | - | $ 96,659 | $ 19,332 | $ 5,800 | $ 121,790 | $ 4,273 | $ 15.83 | $ 3.52 |
| NB-67 | Neebing | Biofiltration | No | 688 | 314 | 4.5 | 2.79 | 754 | 3,388 | - | $ 162,056 | $ 32,411 | $ 9,723 | $ 204,190 | $ 3,658 | $ 13.55 | $ 3.01 |
| NB-68 | Neebing | Biofiltration | Yes | 158 | 72 | 1.0 | 0.64 | 173 | 777 | - | $ 52,244 | $ 10,449 | $ 3,135 | $ 65,827 | $ 5,143 | $ 19.05 | $ 4.24 |
| NB-69 | Neebing | Pervious Pavement | No | 184 | 45 | 0.7 | 0.24 | 125 | 485 | - | $ 58,016 | $ 11,603 | $ 7,252 | $ 76,872 | $ 16,016 | $ 30.68 | $ 7.92 |
| NB-70 | Neebing | Biofiltration | No | 94 | 43 | 0.6 | 0.38 | 102 | 460 | - | $ 34,949 | $ 6,990 | $ 2,097 | $ 44,036 | $ 5,804 | $ 21.50 | $ 4.78 |
| NB-71 | Neebing | Biofiltration | No | 21 | 10 | 0.1 | 0.08 | 23 | 101 | - | $ 10,932 | $ 2,186 | $ 656 | $ 13,774 | $ 8,236 | $ 30.50 | $ 6.79 |
| NB-72 | Neebing | Parking Lot Retrofit | Yes | 264 | 11 | 0.2 | 0.06 | 34 | 119 | - | $ 20,196 | $ 4,039 | $ 2,525 | $ 26,760 | $ 22,792 | $ 39.64 | $ 11.27 |
| NB-73 | Neebing | Parking Lot Retrofit | No | 1,322 | 55 | 0.8 | 0.29 | 151 | 594 | - | $ 75,316 | $ 15,063 | $ 9,415 | $ 99,794 | $ 16,977 | $ 32.97 | $ 8.40 |
| NB-74 | Neebing | Parking Lot Retrofit | No | 1,877 | 78 | 1.1 | 0.42 | 210 | 843 | - | $ 100,261 | $ 20,052 | $ 12,533 | $ 132,845 | $ 15,924 | $ 31.68 | $ 7.88 |
| NB-75 | Neebing | Biofiltration | Yes | 1,090 | 497 | 7.2 | 4.42 | 1,193 | 5,363 | - | $ 230,684 | $ 46,137 | $ 13,841 | $ 290,662 | $ 3,289 | $ 12.18 | $ 2.71 |
| NB-76 | Neebing | Pervious Pavement | No | 576 | 140 | 2.0 | 0.75 | 363 | 1,518 | - | $ 147,358 | $ 29,472 | $ 18,420 | $ 195,249 | $ 13,001 | $ 26.93 | $ 6.43 |
| NB-77 | Neebing | Biofiltration | No | 873 | 398 | 5.8 | 3.54 | 956 | 4,296 | - | $ 194,520 | $ 38,904 | $ 11,671 | $ 245,095 | $ 3,462 | $ 12.82 | $ 2.85 |
| NB-78 | Neebing | Biofiltration | No | 324 | 148 | 2.1 | 1.31 | 355 | 1,594 | - | $ 90,771 | $ 18,154 | $ 5,446 | $ 114,372 | $ 4,355 | $ 16.13 | $ 3.59 |
| NB-79 | Neebing | Biofiltration | Yes | 136 | 62 | 0.9 | 0.55 | 148 | 667 | - | $ 46,473 | $ 9,295 | $ 2,788 | $ 58,556 | $ 5,327 | $ 19.73 | $ 4.39 |
| NB-80 | Neebing | Biofiltration | No | 18 | 8 | 0.1 | 0.07 | 19 | 87 | - | $ 9,739 | $ 1,948 | $ 584 | $ 12,271 | $ 8,527 | $ 31.58 | $ 7.03 |
| NB-81 | Neebing | Biofiltration | No | 136 | 62 | 0.9 | 0.55 | 148 | 667 | - | $ 46,473 | $ 9,295 | $ 2,788 | $ 58,556 | $ 5,327 | $ 19.73 | $ 4.39 |
| NB-82 | Neebing | Biofiltration | No | 52 | 24 | 0.3 | 0.21 | 57 | 256 | - | $ 22,231 | $ 4,446 | $ 1,334 | $ 28,011 | $ 6,651 | $ 24.63 | $ 5.48 |
| NB-83 | Neebing | Parking Lot Retrofit | No | 97 | 4 | 0.1 | 0.02 | 13 | 44 | - | $ 8,928 | $ 1,786 | $ 1,116 | $ 11,830 | $ 27,360 | $ 44.44 | $ 13.53 |
| NB-84 | Neebing | Biofiltration | No | 52 | 24 | 0.3 | 0.21 | 57 | 254 | - | $ 22,139 | $ 4,428 | $ 1,328 | $ 27,896 | $ 6,659 | $ 24.66 | $ 5.49 |
| NB-85 | Neebing | Ditch Maintenance | Yes | 4,418 | - | 9.7 | - | - | 2,020 | - | $ 8,917 | $ 625 | $ 8,917 | $ 18,459 | - | - | $ 0.46 |

| ID | Watershed | BMP Category | Demonstration / Education? | Footprint Area ($m^2$) | Water Quality Volume ($m^3$) | Drainage Area (ha) | Benefits: TP Removal (kg/yr) | Benefits: TSS Removal (kg/yr) | Benefits: Runoff Volume Reduction ($m^3$/yr) | Feasibility Cost (CAD) | 20-year Present Costs in 2015 Canadian Dollars: Construction (CAD) | Design (CAD) | O & M (CAD) | Total (CAD) | Cost-Benefit Analysis: TP Removal (CAD/kg) | TSS Removal (CAD/kg) | Volume Reduction (CAD/$m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NB-86 | Neebing | Ditch Maintenance | Yes | 1,126 | - | 2.5 | - | - | 515 | - | $ 2,273 | $ 625 | $ 2,273 | $ 5,170 | - | - | $ 0.50 |
| NB-87 | Neebing | Ditch Maintenance | No | 918 | - | 2.0 | - | - | 420 | - | $ 1,852 | $ 625 | $ 1,852 | $ 4,329 | - | - | $ 0.52 |
| NB-88 | Neebing | Wetland Protection | No | 629,783 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| NB-89 | Neebing | Wetland Protection | No | 101,748 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| NB-90 | Neebing | Sedimentation Basin | Yes | 135 | 82 | 3.9 | 0.50 | 154 | 237 | - | $ 49,715 | $ 9,943 | $ 2,237 | $ 61,895 | $ 6,191 | $ 20.13 | $ 13.04 |
| NB-91 | Neebing | Pond | No | 1,756 | 2,141 | 18.8 | 8.77 | 5,670 | 4,020 | - | $ 304,501 | $ 60,900 | $ 13,703 | $ 379,104 | $ 2,162 | $ 3.34 | $ 4.71 |
| NB-92 | Neebing | Biofiltration | No | 438 | 200 | 2.9 | 1.78 | 479 | 2,155 | - | $ 114,450 | $ 22,890 | $ 6,867 | $ 144,207 | $ 4,061 | $ 15.04 | $ 3.35 |
| NB-93 | Neebing | Biofiltration | No | 242 | 110 | 0.8 | 0.87 | 252 | 331 | - | $ 72,582 | $ 14,516 | $ 4,355 | $ 91,454 | $ 5,271 | $ 18.18 | $ 13.80 |
| NB-94 | Neebing | Biofiltration | No | 254 | 116 | 0.8 | 0.91 | 263 | 347 | - | $ 75,201 | $ 15,040 | $ 4,512 | $ 94,754 | $ 5,215 | $ 17.98 | $ 13.65 |
| NB-95 | Neebing | Biofiltration | No | 250 | 114 | 1.6 | 1.01 | 273 | 1,228 | - | $ 74,310 | $ 14,862 | $ 4,459 | $ 93,631 | $ 4,625 | $ 17.13 | $ 3.81 |
| NB-96 | Neebing | Biofiltration | No | 289 | 132 | 1.9 | 1.17 | 316 | 1,422 | - | $ 83,168 | $ 16,634 | $ 4,990 | $ 104,792 | $ 4,471 | $ 16.56 | $ 3.68 |
| NB-97 | Neebing | Biofiltration | No | 661 | 301 | 2.1 | 2.37 | 687 | 905 | - | $ 157,074 | $ 31,415 | $ 9,424 | $ 197,913 | $ 4,178 | $ 14.41 | $ 10.94 |
| NB-98 | Neebing | Biofiltration | No | 237 | 108 | 0.8 | 0.85 | 246 | 324 | - | $ 71,402 | $ 14,280 | $ 4,284 | $ 89,967 | $ 5,297 | $ 18.27 | $ 13.86 |
| NB-99 | Neebing | Biofiltration | No | 222 | 101 | 0.7 | 0.79 | 230 | 304 | - | $ 67,847 | $ 13,569 | $ 4,071 | $ 85,487 | $ 5,379 | $ 18.55 | $ 14.08 |
| NB-100 | Neebing | Biofiltration | No | 387 | 176 | 2.6 | 1.57 | 424 | 1,905 | - | $ 104,115 | $ 20,823 | $ 6,247 | $ 131,185 | $ 4,179 | $ 15.48 | $ 3.44 |
| NB-103 | Neebing | Biofiltration | No | 189 | 86 | 1.2 | 0.77 | 207 | 931 | - | $ 60,062 | $ 12,012 | $ 3,604 | $ 75,678 | $ 4,931 | $ 18.26 | $ 4.06 |
| NB-104 | Neebing | Ditch Maintenance | No | 1,243 | - | 2.7 | - | - | 568 | - | $ 2,509 | $ 625 | $ 2,509 | $ 5,644 | - | - | $ 0.50 |
| NB-105 | Neebing | Subsurface Storage | Yes | 1,747 | 2,130 | 30.8 | 7.27 | 4,477 | 23,010 | - | $ 270,416 | $ 54,083 | $ 12,169 | $ 336,669 | $ 2,316 | $ 3.76 | $ 0.73 |
| NB-106 | Neebing | Biofiltration | No | 89 | 41 | 0.6 | 0.36 | 97 | 438 | - | $ 33,607 | $ 6,721 | $ 2,016 | $ 42,345 | $ 5,873 | $ 21.75 | $ 4.84 |
| NB-107 | Neebing | Biofiltration | No | 35 | 16 | 0.2 | 0.14 | 38 | 171 | - | $ 16,357 | $ 3,271 | $ 981 | $ 20,610 | $ 7,295 | $ 27.02 | $ 6.01 |
| NB-108 | Neebing | Biofiltration | No | 44 | 20 | 0.3 | 0.18 | 48 | 218 | - | $ 19,648 | $ 3,930 | $ 1,179 | $ 24,756 | $ 6,903 | $ 25.56 | $ 5.69 |
| NB-109 | Neebing | Biofiltration | No | 41 | 19 | 0.3 | 0.16 | 44 | 199 | - | $ 18,366 | $ 3,673 | $ 1,102 | $ 23,141 | $ 7,045 | $ 26.09 | $ 5.80 |
| NB-110 | Neebing | Biofiltration | No | 308 | 140 | 2.0 | 1.25 | 337 | 1,517 | - | $ 87,370 | $ 17,474 | $ 5,242 | $ 110,086 | $ 4,405 | $ 16.31 | $ 3.63 |
| NB-111 | Neebing | Biofiltration | No | 420 | 191 | 2.8 | 1.70 | 460 | 2,067 | - | $ 110,830 | $ 22,166 | $ 6,650 | $ 139,646 | $ 4,101 | $ 15.19 | $ 3.38 |
| NB-112 | Neebing | Biofiltration | No | 170 | 77 | 1.1 | 0.69 | 186 | 837 | - | $ 55,337 | $ 11,067 | $ 3,320 | $ 69,724 | $ 5,054 | $ 18.72 | $ 4.16 |
| NB-113 | Neebing | Biofiltration | No | 98 | 45 | 0.6 | 0.40 | 107 | 482 | - | $ 36,222 | $ 7,244 | $ 2,173 | $ 45,640 | $ 5,742 | $ 21.27 | $ 4.73 |
| NB-114 | Neebing | Biofiltration | Yes | 133 | 61 | 0.9 | 0.54 | 146 | 655 | - | $ 45,811 | $ 9,162 | $ 2,749 | $ 57,721 | $ 5,350 | $ 19.81 | $ 4.41 |
| NB-115 | Neebing | Biofiltration | No | 498 | 227 | 3.3 | 2.02 | 545 | 2,449 | - | $ 126,290 | $ 25,258 | $ 7,577 | $ 159,125 | $ 3,943 | $ 14.60 | $ 3.25 |
| NB-116 | Neebing | Biofiltration | Yes | 906 | 413 | 6.0 | 3.68 | 992 | 4,460 | - | $ 200,207 | $ 40,041 | $ 12,012 | $ 252,261 | $ 3,432 | $ 12.71 | $ 2.83 |
| NB-117 | Neebing | Biofiltration | Yes | 171 | 78 | 1.1 | 0.69 | 187 | 840 | - | $ 55,499 | $ 11,100 | $ 3,330 | $ 69,929 | $ 5,050 | $ 18.70 | $ 4.16 |
| NB-118 | Neebing | Tree Trench | No | 720 | 200 | 2.9 | 1.07 | 503 | 2,157 | - | $ 215,967 | $ 43,193 | $ 26,996 | $ 286,156 | $ 13,411 | $ 28.45 | $ 6.63 |
| NB-119 | Neebing | Biofiltration | Yes | 57 | 26 | 0.4 | 0.23 | 62 | 280 | - | $ 23,864 | $ 4,773 | $ 1,432 | $ 30,069 | $ 6,511 | $ 24.11 | $ 5.36 |
| NB-120 | Neebing | Biofiltration | Yes | 44 | 20 | 0.3 | 0.18 | 49 | 219 | - | $ 19,711 | $ 3,942 | $ 1,183 | $ 24,836 | $ 6,896 | $ 25.54 | $ 5.68 |
| NB-121 | Neebing | Biofiltration | No | 23 | 10 | 0.2 | 0.09 | 25 | 113 | - | $ 11,866 | $ 2,373 | $ 712 | $ 14,952 | $ 8,035 | $ 29.76 | $ 6.62 |
| NB-122 | Neebing | Biofiltration | No | 31 | 14 | 0.2 | 0.13 | 34 | 155 | - | $ 15,102 | $ 3,020 | $ 906 | $ 19,028 | $ 7,472 | $ 27.67 | $ 6.16 |
| NB-123 | Neebing | Biofiltration | Yes | 96 | 44 | 0.6 | 0.39 | 105 | 471 | - | $ 35,561 | $ 7,112 | $ 2,134 | $ 44,807 | $ 5,774 | $ 21.38 | $ 4.76 |
| NB-124 | Neebing | Ditch Maintenance | Yes | 44 | - | 0.1 | - | - | 20 | - | $ 89 | $ 625 | $ 89 | $ 803 | - | - | $ 1.99 |
| NB-125 | Neebing | Control Structure | Yes | 37 | - | - | - | - | - | - | $ 2,500 | $ - | $ - | $ 2,500 | - | - | - |
| NB-126 | Neebing | Control Structure | Yes | 25 | - | - | - | - | - | - | $ 2,500 | $ - | $ - | $ 2,500 | - | - | - |
| NB-127 | Neebing | Biofiltration | Yes | 582 | 265 | 3.8 | 2.36 | 638 | 2,866 | - | $ 142,511 | $ 28,502 | $ 8,551 | $ 179,564 | $ 3,802 | $ 14.08 | $ 3.13 |
| NB-128 | Neebing | Biofiltration | No | 619 | 282 | 2.0 | 2.22 | 643 | 847 | - | $ 149,243 | $ 29,849 | $ 8,955 | $ 188,046 | $ 4,243 | $ 14.63 | $ 11.10 |
| NB-129 | Neebing | Biofiltration | No | 584 | 266 | 1.9 | 2.09 | 607 | 800 | - | $ 142,860 | $ 28,572 | $ 8,572 | $ 180,004 | $ 4,299 | $ 14.82 | $ 11.25 |
| NB-130 | Neebing | Biofiltration | No | 64 | 29 | 0.2 | 0.23 | 67 | 88 | - | $ 26,194 | $ 5,239 | $ 1,572 | $ 33,005 | $ 7,164 | $ 24.70 | $ 18.75 |
| NB-131 | Neebing | Biofiltration | No | 61 | 28 | 0.2 | 0.22 | 63 | 83 | - | $ 25,111 | $ 5,022 | $ 1,507 | $ 31,640 | $ 7,255 | $ 25.02 | $ 18.99 |
| NB-132 | Neebing | Biofiltration | No | 645 | 294 | 2.1 | 2.31 | 670 | 883 | - | $ 154,147 | $ 30,829 | $ 9,249 | $ 194,225 | $ 4,202 | $ 14.49 | $ 11.00 |
| NB-133 | Neebing | Pond | Yes | 197 | 240 | 2.1 | 1.45 | 586 | 450 | - | $ 97,361 | $ 19,472 | $ 4,381 | $ 121,215 | $ 4,191 | $ 10.35 | $ 13.47 |
| NB-134 | Neebing | Tree Trench | No | 2,047 | 568 | 4.0 | 3.03 | 1,295 | 1,706 | $ 100,794 | $ 507,142 | $ 101,428 | $ 63,393 | $ 671,963 | $ 11,079 | $ 25.95 | $ 19.70 |
| NB-135 | Neebing | Tree Trench | No | 457 | 127 | 0.9 | 0.68 | 289 | 381 | - | $ 148,934 | $ 29,787 | $ 18,617 | $ 197,337 | $ 14,574 | $ 34.14 | $ 25.91 |
| NB-136 | Neebing | Biofiltration | Yes | 198 | 90 | 0.6 | 0.71 | 205 | 271 | - | $ 62,114 | $ 12,423 | $ 3,727 | $ 78,264 | $ 5,524 | $ 19.05 | $ 14.46 |
| NB-137 | Neebing | Biofiltration | Yes | 132 | 60 | 0.4 | 0.47 | 137 | 180 | - | $ 45,392 | $ 9,078 | $ 2,724 | $ 57,194 | $ 6,071 | $ 20.93 | $ 15.89 |
| NB-138 | Neebing | Biofiltration | Yes | 154 | 70 | 0.5 | 0.55 | 160 | 211 | - | $ 51,296 | $ 10,259 | $ 3,078 | $ 64,633 | $ 5,852 | $ 20.18 | $ 15.32 |

| | | | | | | | Benefits | | | | 20-year Present Costs in 2015 Canadian Dollars | | | | Cost-Benefit Analysis | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Watershed | BMP Category | Demonstration / Education? | Footprint Area ($m^2$) | Water Quality Volume ($m^3$) | Drainage Area (ha) | TP Removal (kg/yr) | TSS Removal (kg/yr) | Runoff Volume Reduction ($m^3$/yr) | Feasibility Cost (CAD) | Construction (CAD) | Design (CAD) | O & M (CAD) | Total (CAD) | TP Removal (CAD/kg) | TSS Removal (CAD/kg) | Volume Reduction (CAD/$m^3$) |
| NB-139 | Neebing | Biofiltration | Yes | 76 | 35 | 0.2 | 0.27 | 79 | 104 | - | $ 29,872 | $ 5,974 | $ 1,792 | $ 37,639 | $ 6,886 | $ 23.74 | $ 18.02 |
| NB-140 | Neebing | Subsurface Storage | Yes | 5,727 | 6,982 | 49.0 | 19.30 | 15,320 | 10,490 | - | $ 501,684 | $ 100,337 | $ 22,576 | $ 624,597 | $ 1,618 | $ 2.04 | $ 2.98 |
| NB-141 | Neebing | Biofiltration | Yes | 377 | 172 | 1.2 | 1.35 | 392 | 516 | - | $ 102,035 | $ 20,407 | $ 6,122 | $ 128,564 | $ 4,757 | $ 16.40 | $ 12.45 |
| NB-142 | Neebing | Biofiltration | Yes | 790 | 360 | 2.5 | 2.83 | 821 | 1,081 | - | $ 180,133 | $ 36,027 | $ 10,808 | $ 226,967 | $ 4,009 | $ 13.82 | $ 10.49 |
| NB-143 | Neebing | Ditch Maintenance | Yes | 2,678 | - | 2.9 | - | - | 1,022 | - | $ 5,404 | $ 625 | $ 5,404 | $ 11,433 | - | - | $ 0.56 |
| NB-144 | Neebing | Biofiltration | Yes | 598 | 272 | 1.9 | 2.14 | 622 | 819 | - | $ 145,472 | $ 29,094 | $ 8,728 | $ 183,295 | $ 4,276 | $ 14.74 | $ 11.19 |
| NB-145 | Neebing | Ditch Maintenance | Yes | 818 | - | 0.9 | - | - | 312 | - | $ 1,651 | $ 625 | $ 1,651 | $ 3,927 | - | - | $ 0.63 |
| NB-146 | Neebing | Biofiltration | Yes | 169 | 77 | 0.5 | 0.60 | 175 | 231 | - | $ 54,988 | $ 10,998 | $ 3,299 | $ 69,285 | $ 5,730 | $ 19.76 | $ 15.00 |
| NB-147 | Neebing | Biofiltration | Yes | 132 | 60 | 0.4 | 0.47 | 137 | 180 | - | $ 45,466 | $ 9,093 | $ 2,728 | $ 57,287 | $ 6,068 | $ 20.92 | $ 15.88 |
| NB-148 | Neebing | Pond | Yes | 1,323 | 1,613 | 14.2 | 6.95 | 4,230 | 3,030 | - | $ 262,815 | $ 52,563 | $ 11,827 | $ 327,205 | $ 2,355 | $ 3.87 | $ 5.40 |
| NB-149 | Neebing | Pond | No | 723 | 881 | 7.7 | 4.23 | 2,261 | 1,656 | - | $ 191,878 | $ 38,376 | $ 8,634 | $ 238,887 | $ 2,827 | $ 5.28 | $ 7.21 |
| NB-150 | Neebing | Tree Trench | No | 514 | 143 | 1.0 | 0.76 | 325 | 428 | - | $ 163,962 | $ 32,792 | $ 20,495 | $ 217,250 | $ 14,264 | $ 33.41 | $ 25.36 |
| NB-151 | Neebing | Biofiltration | Yes | 284 | 129 | 0.9 | 1.02 | 296 | 389 | - | $ 82,160 | $ 16,432 | $ 4,930 | $ 103,521 | $ 5,078 | $ 17.51 | $ 13.29 |
| NB-152 | Neebing | Biofiltration | Yes | 577 | 263 | 1.8 | 2.07 | 600 | 791 | - | $ 141,584 | $ 28,317 | $ 8,495 | $ 178,396 | $ 4,311 | $ 14.86 | $ 11.28 |
| NB-153 | Neebing | Biofiltration | Yes | 187 | 85 | 0.6 | 0.67 | 194 | 255 | - | $ 59,404 | $ 11,881 | $ 3,564 | $ 74,849 | $ 5,599 | $ 19.31 | $ 14.65 |
| NB-154 | Neebing | Biofiltration | Yes | 90 | 41 | 0.3 | 0.32 | 94 | 123 | - | $ 33,985 | $ 6,797 | $ 2,039 | $ 42,821 | $ 6,624 | $ 22.84 | $ 17.34 |
| NB-155 | Neebing | Tree Trench | No | 7,451 | 2,067 | 14.5 | 11.04 | 4,434 | 6,209 | $ 289,737 | $ 1,457,795 | $ 291,559 | $ 182,224 | $ 1,931,578 | $ 8,747 | $ 21.78 | $ 15.55 |
| NB-156 | Neebing | Tree Trench | No | 754 | 209 | 1.5 | 1.12 | 477 | 628 | - | $ 224,288 | $ 44,858 | $ 28,036 | $ 297,182 | $ 13,298 | $ 31.15 | $ 23.65 |
| NB-157 | Neebing | Tree Trench | No | 294 | 82 | 0.6 | 0.44 | 186 | 245 | - | $ 103,946 | $ 20,789 | $ 12,993 | $ 137,728 | $ 15,796 | $ 37.00 | $ 28.09 |
| NB-158 | Neebing | Biofiltration | Yes | 479 | 218 | 1.5 | 1.72 | 498 | 656 | - | $ 122,632 | $ 24,526 | $ 7,358 | $ 154,516 | $ 4,501 | $ 15.52 | $ 11.78 |
| NB-159 | Neebing | Pond | Yes | 1,342 | 1,636 | 14.3 | 7.03 | 4,291 | 3,072 | - | $ 264,729 | $ 52,946 | $ 11,913 | $ 329,588 | $ 2,345 | $ 3.84 | $ 5.36 |
| NB-160 | Neebing | Pond | Yes | 1,461 | 1,781 | 15.6 | 7.54 | 4,688 | 3,346 | - | $ 276,738 | $ 55,348 | $ 12,453 | $ 344,539 | $ 2,285 | $ 3.68 | $ 5.15 |
| NB-161 | Neebing | Pond | Yes | 2,861 | 3,488 | 30.6 | 13.10 | 9,402 | 6,549 | - | $ 392,567 | $ 78,513 | $ 17,666 | $ 488,746 | $ 1,866 | $ 2.60 | $ 3.73 |
| NB-162 | Neebing | Tree Trench | No | 1,268 | 352 | 2.5 | 1.88 | 802 | 1,057 | - | $ 342,996 | $ 68,599 | $ 42,874 | $ 454,469 | $ 12,092 | $ 28.33 | $ 21.50 |
| NB-163 | Neebing | Biofiltration | Yes | 657 | 299 | 2.1 | 2.35 | 682 | 899 | - | $ 156,259 | $ 31,252 | $ 9,376 | $ 196,886 | $ 4,184 | $ 14.43 | $ 10.95 |
| NB-164 | Neebing | Biofiltration | Yes | 386 | 176 | 1.2 | 1.38 | 401 | 528 | - | $ 103,846 | $ 20,769 | $ 6,231 | $ 130,846 | $ 4,732 | $ 16.32 | $ 12.39 |
| NB-165 | Neebing | Parking Lot Retrofit | No | 134 | 6 | 0.0 | 0.03 | 13 | 17 | $ 2,306 | $ 11,604 | $ 2,321 | $ 1,451 | $ 15,375 | $ 25,801 | $ 60.44 | $ 45.88 |
| PN-1 | Pennock | Sedimentation Basin | No | 496 | 302 | 104.5 | 1.46 | 591 | 3,620 | - | $ 97,825 | $ 19,565 | $ 4,402 | $ 121,792 | $ 4,179 | $ 10.30 | $ 1.68 |
| PN-2 | Pennock | Sedimentation Basin | No | 347 | 212 | 73.1 | 1.09 | 408 | 2,531 | - | $ 81,199 | $ 16,240 | $ 3,654 | $ 101,093 | $ 4,657 | $ 12.38 | $ 2.00 |
| PN-3 | Pennock | Sedimentation Basin | Yes | 218 | 133 | 46.0 | 0.74 | 253 | 1,594 | - | $ 63,832 | $ 12,766 | $ 2,872 | $ 79,470 | $ 5,355 | $ 15.72 | $ 2.49 |
| PN-5 | Pennock | Biofiltration | Yes | 18 | 8 | 2.9 | 0.07 | 20 | 602 | - | $ 10,012 | $ 2,002 | $ 601 | $ 12,615 | $ 8,457 | $ 31.32 | $ 1.05 |
| PN-6 | Pennock | Wetland Protection | No | 4,648 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| PN-7 | Pennock | Ravine Stabilization | Yes | 379 | - | - | - | - | - | $ 39,375 | $ 187,500 | $ 37,500 | $ 37,500 | $ 262,500 | - | - | - |
| PN-8 | Pennock | Ravine Stabilization | Yes | 359 | - | - | - | - | - | $ 39,375 | $ 187,500 | $ 37,500 | $ 37,500 | $ 262,500 | - | - | - |
| PN-9 | Pennock | Ravine Stabilization | Yes | 618 | - | - | - | - | - | $ 52,500 | $ 250,000 | $ 50,000 | $ 50,000 | $ 350,000 | - | - | - |
| PN-10 | Pennock | Ravine Stabilization | Yes | 192 | - | - | - | - | - | - | $ 125,000 | $ 25,000 | $ 25,000 | $ 175,000 | - | - | - |
| WF-1 | Waterfront | Biofiltration | Yes | 3,011 | 1,372 | 19.9 | 12.21 | 3,297 | 14,819 | $ 95,222 | $ 503,819 | $ 100,764 | $ 30,229 | $ 634,811 | $ 2,600 | $ 9.63 | $ 2.14 |
| WF-2 | Waterfront | Biofiltration | Yes | 1,085 | 494 | 7.2 | 4.40 | 1,188 | 5,341 | - | $ 229,958 | $ 45,992 | $ 13,797 | $ 289,747 | $ 3,292 | $ 12.19 | $ 2.71 |
| WF-3 | Waterfront | Parking Lot Retrofit | No | 2,125 | 88 | 1.3 | 0.47 | 235 | 955 | - | $ 110,988 | $ 22,198 | $ 13,874 | $ 147,059 | $ 15,566 | $ 31.23 | $ 7.70 |
| WF-4 | Waterfront | Biofiltration | No | 1,619 | 738 | 10.7 | 6.56 | 1,772 | 7,966 | - | $ 312,649 | $ 62,530 | $ 18,759 | $ 393,938 | $ 3,001 | $ 11.11 | $ 2.47 |
| WF-5 | Waterfront | Parking Lot Retrofit | No | 1,085 | 45 | 0.7 | 0.24 | 126 | 488 | - | $ 64,078 | $ 12,816 | $ 8,010 | $ 84,904 | $ 17,602 | $ 33.73 | $ 8.71 |
| WF-6 | Waterfront | Biofiltration | No | 480 | 219 | 3.2 | 1.95 | 525 | 2,361 | - | $ 122,778 | $ 24,556 | $ 7,367 | $ 154,700 | $ 3,976 | $ 14.73 | $ 3.28 |
| WF-7 | Waterfront | Pond | No | 4,174 | 5,089 | 92.1 | 17.88 | 13,910 | 11,451 | - | $ 477,923 | $ 95,585 | $ 21,507 | $ 595,014 | $ 1,664 | $ 2.14 | $ 2.60 |
| WF-8 | Waterfront | Pond | No | 2,426 | 2,958 | 53.5 | 11.44 | 7,925 | 6,654 | - | $ 360,279 | $ 72,056 | $ 16,213 | $ 448,547 | $ 1,961 | $ 2.83 | $ 3.37 |
| WF-9 | Waterfront | Biofiltration | No | 804 | 366 | 5.3 | 3.26 | 880 | 3,955 | - | $ 182,522 | $ 36,504 | $ 10,951 | $ 229,977 | $ 3,529 | $ 13.07 | $ 2.91 |
| WF-10 | Waterfront | Biofiltration | Yes | 860 | 392 | 5.7 | 3.49 | 942 | 4,233 | - | $ 192,321 | $ 38,464 | $ 11,539 | $ 242,324 | $ 3,474 | $ 12.86 | $ 2.86 |
| WF-11 | Waterfront | Biofiltration | Yes | 538 | 245 | 3.5 | 2.18 | 589 | 2,649 | - | $ 134,136 | $ 26,827 | $ 8,048 | $ 169,011 | $ 3,872 | $ 14.34 | $ 3.19 |
| WF-12 | Waterfront | Biofiltration | Yes | 430 | 196 | 2.8 | 1.74 | 470 | 2,115 | - | $ 112,804 | $ 22,561 | $ 6,768 | $ 142,133 | $ 4,079 | $ 15.11 | $ 3.36 |
| WF-13 | Waterfront | Tree Trench | Yes | 88 | 24 | 0.4 | 0.13 | 71 | 262 | - | $ 38,626 | $ 7,725 | $ 4,828 | $ 51,180 | $ 19,713 | $ 36.20 | $ 9.75 |
| WF-14 | Waterfront | Tree Trench | Yes | 41 | 11 | 0.2 | 0.06 | 35 | 123 | - | $ 20,796 | $ 4,159 | $ 2,599 | $ 27,554 | $ 22,643 | $ 39.48 | $ 11.20 |
| WF-15 | Waterfront | Tree Trench | Yes | 61 | 17 | 0.2 | 0.09 | 50 | 182 | - | $ 28,643 | $ 5,729 | $ 3,580 | $ 37,952 | $ 21,078 | $ 37.75 | $ 10.43 |

| ID | Watershed | BMP Category | Demonstration / Education? | Footprint Area ($m^2$) | Water Quality Volume ($m^3$) | Drainage Area (ha) | Benefits: TP Removal (kg/yr) | Benefits: TSS Removal (kg/yr) | Benefits: Runoff Volume Reduction ($m^3$/yr) | Feasibility Cost (CAD) | 20-year Present Costs in 2015 Canadian Dollars: Construction (CAD) | Design (CAD) | O & M (CAD) | Total (CAD) | Cost-Benefit Analysis: TP Removal (CAD/kg) | TSS Removal (CAD/kg) | Volume Reduction (CAD/$m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WF-16 | Waterfront | Biofiltration | Yes | 497 | 226 | 3.3 | 2.02 | 544 | 2,447 | - | $ 126,199 | $ 25,240 | $ 7,572 | $ 159,011 | $ 3,944 | $ 14.60 | $ 3.25 |
| WF-17 | Waterfront | Parking Lot Retrofit | No | 938 | 39 | 0.6 | 0.21 | 110 | 421 | - | $ 56,875 | $ 11,375 | $ 7,109 | $ 75,359 | $ 18,078 | $ 34.30 | $ 8.94 |
| WF-18 | Waterfront | Pond | Yes | 668 | 814 | 14.7 | 3.96 | 2,081 | 1,831 | $ 34,370 | $ 184,044 | $ 36,809 | $ 8,282 | $ 229,135 | $ 2,896 | $ 5.51 | $ 6.26 |
| WF-19 | Waterfront | Biofiltration | No | 373 | 170 | 2.5 | 1.51 | 408 | 1,836 | - | $ 101,184 | $ 20,237 | $ 6,071 | $ 127,491 | $ 4,215 | $ 15.61 | $ 3.47 |
| WF-20 | Waterfront | Biofiltration | No | 1,565 | 713 | 10.3 | 6.35 | 1,713 | 7,701 | - | $ 304,632 | $ 60,926 | $ 18,278 | $ 383,836 | $ 3,025 | $ 11.20 | $ 2.49 |
| WF-21 | Waterfront | Biofiltration | Yes | 426 | 194 | 2.8 | 1.73 | 467 | 2,098 | - | $ 112,109 | $ 22,422 | $ 6,727 | $ 141,258 | $ 4,087 | $ 15.13 | $ 3.37 |
| WF-22 | Waterfront | Biofiltration | Yes | 515 | 235 | 3.4 | 2.09 | 564 | 2,536 | - | $ 129,719 | $ 25,944 | $ 7,783 | $ 163,446 | $ 3,911 | $ 14.48 | $ 3.22 |
| WF-23 | Waterfront | Pond | No | 11,625 | 14,173 | 256.4 | 41.52 | 40,209 | 31,890 | $ 152,124 | $ 814,586 | $ 162,917 | $ 36,656 | $ 1,014,159 | $ 1,221 | $ 1.26 | $ 1.59 |
| WF-24 | Waterfront | Biofiltration | No | 381 | 174 | 2.5 | 1.55 | 417 | 1,876 | - | $ 102,884 | $ 20,577 | $ 6,173 | $ 129,634 | $ 4,194 | $ 15.53 | $ 3.46 |
| WF-25 | Waterfront | Biofiltration | No | 1,212 | 552 | 8.0 | 4.92 | 1,327 | 5,966 | - | $ 250,372 | $ 50,074 | $ 15,022 | $ 315,469 | $ 3,209 | $ 11.88 | $ 2.64 |
| WF-26 | Waterfront | Biofiltration | No | 371 | 169 | 2.4 | 1.50 | 406 | 1,823 | - | $ 100,660 | $ 20,132 | $ 6,040 | $ 126,832 | $ 4,221 | $ 15.63 | $ 3.48 |
| WF-27 | Waterfront | Biofiltration | No | 22,240 | 10,134 | 146.7 | 90.18 | 24,350 | 109,448 | $ 442,785 | $ 2,342,776 | $ 468,555 | $ 140,567 | $ 2,951,898 | $ 1,637 | $ 6.06 | $ 1.35 |
| WF-28 | Waterfront | Biofiltration | Yes | 327 | 149 | 2.2 | 1.33 | 358 | 1,609 | - | $ 91,451 | $ 18,290 | $ 5,487 | $ 115,228 | $ 4,345 | $ 16.09 | $ 3.58 |
| WF-29 | Waterfront | Pond | No | 5,442 | 6,635 | 120.0 | 22.24 | 18,311 | 14,929 | $ 102,469 | $ 548,694 | $ 109,739 | $ 24,691 | $ 683,124 | $ 1,536 | $ 1.87 | $ 2.29 |
| WF-30 | Waterfront | Biofiltration | No | 153 | 70 | 1.0 | 0.62 | 167 | 751 | - | $ 50,892 | $ 10,178 | $ 3,053 | $ 64,123 | $ 5,183 | $ 19.20 | $ 4.27 |
| WF-31 | Waterfront | Pond | No | 5,463 | 6,660 | 120.5 | 22.31 | 18,382 | 14,985 | $ 102,670 | $ 549,771 | $ 109,954 | $ 24,740 | $ 684,464 | $ 1,534 | $ 1.86 | $ 2.28 |
| WF-32 | Waterfront | Pond | No | 6,631 | 8,085 | 146.3 | 26.16 | 22,472 | 18,191 | $ 113,572 | $ 608,149 | $ 121,630 | $ 27,367 | $ 757,146 | $ 1,447 | $ 1.68 | $ 2.08 |
| WF-33 | Waterfront | Pervious Pavement | Yes | 787 | 192 | 1.3 | 1.02 | 438 | 576 | - | $ 190,002 | $ 38,000 | $ 23,750 | $ 251,753 | $ 12,282 | $ 28.77 | $ 21.84 |
| WF-34 | Waterfront | Biofiltration | Yes | 117 | 53 | 0.4 | 0.42 | 122 | 160 | - | $ 41,519 | $ 8,304 | $ 2,491 | $ 52,315 | $ 6,236 | $ 21.50 | $ 16.32 |
| WF-35 | Waterfront | Biofiltration | Yes | 134 | 61 | 0.4 | 0.48 | 140 | 184 | - | $ 46,179 | $ 9,236 | $ 2,771 | $ 58,186 | $ 6,040 | $ 20.83 | $ 15.81 |
| WF-36 | Waterfront | Parking Lot Retrofit | Yes | 224 | 62 | 0.4 | 0.33 | 142 | 187 | - | $ 83,321 | $ 16,664 | $ 10,415 | $ 110,400 | $ 16,597 | $ 38.88 | $ 29.51 |
| WF-37 | Waterfront | Biofiltration | Yes | 81 | 37 | 0.3 | 0.29 | 85 | 112 | - | $ 31,426 | $ 6,285 | $ 1,886 | $ 39,597 | $ 6,781 | $ 23.38 | $ 17.75 |
| WF-38 | Waterfront | Biofiltration | Yes | 99 | 45 | 0.3 | 0.36 | 103 | 136 | - | $ 36,539 | $ 7,308 | $ 2,192 | $ 46,039 | $ 6,481 | $ 22.35 | $ 16.96 |
| WF-39 | Waterfront | Parking Lot Retrofit | Yes | 2,090 | 87 | 1.3 | 0.46 | 232 | 939 | - | $ 109,460 | $ 21,892 | $ 13,682 | $ 145,034 | $ 15,614 | $ 31.29 | $ 7.72 |
| WF-40 | Waterfront | Biofiltration | Yes | 244 | 111 | 0.8 | 0.87 | 253 | 334 | - | $ 72,989 | $ 14,598 | $ 4,379 | $ 91,966 | $ 5,262 | $ 18.15 | $ 13.77 |
| WF-41 | Waterfront | Parking Lot Retrofit | Yes | 4,696 | 195 | 2.8 | 1.04 | 493 | 2,110 | - | $ 212,121 | $ 42,424 | $ 26,515 | $ 281,060 | $ 13,465 | $ 28.53 | $ 6.66 |
| WF-42 | Waterfront | Biofiltration | Yes | 100 | 46 | 0.7 | 0.41 | 110 | 100 | - | $ 36,880 | $ 7,376 | $ 2,213 | $ 46,469 | $ 5,711 | $ 21.15 | $ 23.14 |
| WF-43 | Waterfront | Biofiltration | Yes | 29 | 13 | 4.5 | 0.12 | 31 | 937 | - | $ 14,060 | $ 2,812 | $ 844 | $ 17,716 | $ 7,635 | $ 28.27 | $ 0.95 |
| WF-44 | Waterfront | Biofiltration | Yes | 29 | 13 | 4.5 | 0.12 | 32 | 943 | - | $ 14,130 | $ 2,826 | $ 848 | $ 17,804 | $ 7,623 | $ 28.23 | $ 0.94 |
| WF-45 | Waterfront | Wetland | Yes | 31 | 28 | 9.8 | 0.11 | 53 | 680 | - | $ 13,033 | $ 2,607 | $ 261 | $ 15,900 | $ 6,997 | $ 14.91 | $ 1.17 |
| WF-46 | Waterfront | Biofiltration | No | 49 | 22 | 0.3 | 0.20 | 54 | 49 | - | $ 21,277 | $ 4,255 | $ 1,277 | $ 26,809 | $ 6,740 | $ 24.96 | $ 27.31 |
| WF-47 | Waterfront | Biofiltration | Yes | 187 | 85 | 29.4 | 0.76 | 204 | 6,109 | - | $ 59,404 | $ 11,881 | $ 3,564 | $ 74,849 | $ 4,948 | $ 18.32 | $ 0.61 |
| WF-48 | Waterfront | Biofiltration | Yes | 125 | 57 | 19.8 | 0.51 | 137 | 4,110 | - | $ 43,806 | $ 8,761 | $ 2,628 | $ 55,195 | $ 5,423 | $ 20.08 | $ 0.67 |
| WF-49 | Waterfront | Biofiltration | Yes | 103 | 47 | 16.2 | 0.42 | 112 | 3,359 | - | $ 37,509 | $ 7,502 | $ 2,251 | $ 47,261 | $ 5,682 | $ 21.04 | $ 0.70 |
| WF-50 | Waterfront | Biofiltration | No | 27 | 12 | 0.2 | 0.11 | 30 | 27 | - | $ 13,531 | $ 2,706 | $ 812 | $ 17,049 | $ 7,723 | $ 28.60 | $ 31.30 |
| WF-51 | Waterfront | Biofiltration | Yes | 66 | 30 | 0.5 | 0.27 | 72 | 66 | - | $ 26,630 | $ 5,326 | $ 1,598 | $ 33,553 | $ 6,299 | $ 23.33 | $ 25.53 |
| WF-52 | Waterfront | Wetland | Yes | 379 | 347 | 119.8 | 1.39 | 643 | 8,301 | - | $ 52,210 | $ 10,442 | $ 1,044 | $ 63,697 | $ 2,295 | $ 4.95 | $ 0.38 |
| WF-53 | Waterfront | Shoreline Stabilization | Yes | 888 | - | - | - | - | - | - | $ 37,500 | $ 7,500 | $ 7,500 | $ 52,500 | - | - | - |
| WF-54 | Waterfront | Shoreline Stabilization | Yes | 628 | - | - | - | - | - | - | $ 12,500 | $ 2,500 | $ 2,500 | $ 17,500 | - | - | - |
| WF-55 | Waterfront | Biofiltration | Yes | 561 | 256 | 88.4 | 2.27 | 614 | 18,366 | - | $ 138,439 | $ 27,688 | $ 8,306 | $ 174,434 | $ 3,835 | $ 14.20 | $ 0.47 |
| WF-56 | Waterfront | Biofiltration | Yes | 532 | 242 | 83.8 | 2.16 | 583 | 17,423 | - | $ 132,942 | $ 26,588 | $ 7,977 | $ 167,507 | $ 3,882 | $ 14.38 | $ 0.48 |
| WF-57 | Waterfront | Biofiltration | Yes | 206 | 94 | 32.4 | 0.83 | 225 | 6,742 | - | $ 64,079 | $ 12,816 | $ 3,845 | $ 80,740 | $ 4,836 | $ 17.91 | $ 0.60 |