Barrie

STORMWATER INFRASTRUCTURE DESIGN STANDARD

FINAL

Updated June 2023

FOREWORD

This document was prepared under the direction of the Technical Review Committee assembled by the City of Barrie and consisting of the following members:

Mr. Mike Nugent, C.E.T.	- Policy and Standards Supervisor, Chairperson
Ms. Kelly Oakley, P.Eng.	- Infrastructure Program Engineer (City of Barrie)
Mr. Lorran Cooney, C.E.T.	- Senior Infrastructure Planning Technologist (City of Barrie)
Mr. Jeff Capling, P.Eng.	- Project Engineer (City of Barrie)
Dr. Shah Alamgir, Ph.D., P.Eng.	- Infrastructure Planning Engineer (City of Barrie)
Mr. Dave Caspick, C.E.T.	- Manager of Development, Policy and Standards (City of Barrie)
Mr. Geoff Mitchinson	- Technical Operations Supervisor (City of Barrie)
Mr. Craig Morton, C.E.T., PMP	- Manager of Roads and Parks Operations
Mr. Tom Hogenbirk, P.Eng.	- Manager of Engineering and Technical Services (LSRCA)
Mr. Glenn Switzer, P.Eng.	- Director of Engineering and Technical Services (NVCA)
Mr. Yousry Hamdy, M.Sc., P.Eng.	- SENES Consultants Limited
Mr. Brian Greck, P.Eng.	- Greck and Associates Limited
Mr. Bill Coffey, M.Sc., P.Eng.	- Valdor Engineering Inc.

This document was prepared by Valdor Engineering Inc. in association with SENES Consultants Limited and Greck and Associates Limited.

This updated manual replaces the previous City of Barrie *Drainage & Storm Sewage Policies & Criteria* prepared in 1983. The updated document was prepared to reflect current accepted design practices and the evolving requirements of the City regarding storm drainage and stormwater management in 2009 as well as the current municipal, regional, provincial and federal legislation, guidelines, policies and criteria. Over time it will be necessary to update the manual as the regulations, design practices and technologies continue to evolve and change.

A number of revisions were completed for the updated manual since the previous policies and criteria document was prepared in 1983. The key revisions include the following:

- A summary of current applicable regulations and legislation at the municipal, regional, provincial, and federal levels.

- Updated policies and guidelines for storm drainage and stormwater management based on current industry standard practices and the specific needs and requirements of the City of Barrie. The guidelines and information provided in this document are consistent with standard guidelines provided in the MOE *Stormwater Management Planning and Design Manual* (2003), the MTO *Drainage Management Manual* (1997), the *Lake Simcoe Protection Plan* (2009), and the LSRCA *Watershed Development Policies* (2007) and the NVCA *Development Review Guidelines* (2006).
- The policies and guidelines provided in this document have been endorsed by the Lake Simcoe Region Conservation Authority (LSRCA) and the Nottawasaga Valley Conservation Authority (NVCA).
- Updated IDF data based on 1979 to 2003 rainfall records from the WPCC located in the City of Barrie including an adjustment factor to account for climate change based on a review of climate change literature. The previous IDF data used was from the Orillia climate station.
- Return period design storm files for the City of Barrie adjusted to account for climate change.
- Recent changes in legislation regarding phosphorus loads and the protection of Lake Simcoe (Ontario Regulation 219/09 and the Lake Simcoe Protection Plan).
- New and updated City of Barrie Standard drawings using current design guidelines.
- A summary of recommendations from approved Master Drainage Plans for City of Barrie Watersheds.
- Assumption protocol for storm sewers and stormwater management facilities.
- Guidelines for completing hydrologic and hydraulic analyses and reports associated with storm drainage and stormwater management submissions.
- Sample problems and calculations.
- Stormwater management pond planting guidelines.
- A summary of key emerging technologies in stormwater management.

Copies of the *Stormwater Infrastructure Standard* and subsequent updates may be obtained from the City of Barrie Corporate Asset Management Group.

RECEIVED
OCT 07 2009
THE CITY OF BARRIE
ENGINEERING DEPARTMENT

Via Facsimile 705-739-4247

October 7, 2009

IMS Number: RDACC1

Mike Nugent, Policy and Standards Supervisor
City of Barrie
70 Collier Street,
Barrie, ON L4M 4T5

:l: 905-895-1281
1-800-465-0437
ıx: 905-853-5881
·Mail: info@lsrca.on.ca
eb: www.lsrca.on.ca

0 Bayview Parkway
ox 282
ewmarket, Ontario
3Y 4X1

Dear Sir:

Re: **Storm Drainage and Stormwater Management Policies and Design Guidelines City of Barrie**

On behalf of the LSRCA, we acknowledge and appreciate the invitation by the City of Barrie to participate on the Technical Review Committee and to provide as-required comments and review of the City's updated Storm Drainage and Stormwater Management Policies and Design Guidelines.

We trust that our comments and discussions regarding any issues or concerns throughout the extensive review process will enable a more efficient application review process. Significant efforts have been made by the City to provide updated guidelines that are generally consistent with our current Watershed Development Policies.

Yours truly,

Tom Hogenbirk, CMM, P.Eng.
Manager, Engineering and Technical Services

S:\Tom\RBAR SWM Guide LTR.wpd

A Watershed for Life

Via E-mail, mnugent@city.barrie.on.ca
Original to follow

October 19, 2009

Mike Nugent, Policy and Standards Supervisor
City of Barrie
70 Collier Street,
Barrie, ON
L4M 4T5

Dear Mr. Nugent:

Re: **Storm Drainage and Stormwater Management, Policies and Design Guidelines, City of Barrie**

Staff at the NVCA have participated with the technical review committee in the development of the Storm Drainage and Stormwater Management Policies and Design Guidelines for the City of Barrie. The Draft Final (Revised) Guidelines dated 31 August 2009 generally reflect the current NVCA Stormwater Management Guidelines.

Application of the updated City of Barrie guidelines should provide clear, uniform direction for the preparation of stormwater management reports and streamline the development approvals through our two agencies.

The NVCA appreciates the efforts of the City of Barrie in the preparation of these guidelines and will continue to work with the City in the protection of the environment.

Yours truly,

Glenn Switzer, P. Eng.,
Director of Engineering
and Technical Services

Member Municipalities

Adjala-Tosorontio
Amaranth
Barrie
The Blue Mountains
Bradford-West Gwillimbury
Clearview
Collingwood
Essa
Innisfil
Melancthon
Mono
Mulmur
New Tecumseth
Oro-Medonte
Grey Highlands
Shelburne
Springwater
Wasaga Beach

Watershed Counties

Simcoe
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Member of Conservation ONTARIO

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Telephone: 705.424.1479 • Fax: 705.424.2115 • Web: www.nvca.on.ca • Email: admin@nvca.on.ca

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1.0 INTRODUCTION

1.1 Purpose

The City of Barrie storm drainage and stormwater management policies and design guidelines presented herein are intended as a guide to provide a solid engineering basis for storm drainage and stormwater management design, to establish uniform guidelines of minimum standards, and to improve processing of site plan and plan of subdivision applications for approval in the City.

The development review process involves a number of review agencies each of which has guidelines, policies and criteria that should be followed when completing the storm drainage and stormwater management design for site plans and plans of subdivision. In an effort to maintain some consistency and to streamline the development review process, a review of guidelines, policies and criteria from various governing review agencies was completed while preparing the policies and guidelines included in this document. While best efforts were made to minimize discrepancies between the City's guidelines and those from various agencies, it was not possible to do so in all cases while meeting the City's requirements. Where a discrepancy between the policies and guidelines presented in this document and other agency guidelines exists, the policies and guidelines in this document will govern in completing the City's review of development applications. Otherwise, the guidelines, policies and criteria of other review agencies such as the LSRCA, the NVCA and the MOE will govern.

Technological or economical deviations which improve or maintain the quality of the design will be considered and must be approved by the City. Changes and revisions may be made to these policies and guidelines from time to time and it is the responsibility of the Developer or the Developer's Consulting Engineer to obtain and make use of the latest version available at the time of engineering design.

This document does not provide guidance on the selection of storm drainage or management technologies required to meet specific drainage or environmental objectives.

1.2 Environmental and Municipal Land Use Planning

The Environmental and Municipal Land Use Planning Process has evolved over time to enable a streamlined review process and to ensure that qualified input and representation from the agencies, public and consultants is provided at the appropriate time. A flow chart illustrating the Environmental Planning Process for the City of Barrie is provided in **Figure 1.1**. The flow chart shows the different stages of the planning process, the interrelation between the Environmental Planning Process and the Municipal Land Use Planning Process, and the input from the public and approval agencies. The following sections describe the Urban Drainage/Environmental Plans that are required at different stages of the overall planning process. A list of approved subwatershed and master drainage plans within the City including key recommendations is provided in **Appendix D**.

1.2.1 Watershed Plan

Planning at the watershed level has become an accepted practice, as it integrates resource management, land use planning and land management practices. The typical drainage area associated with a watershed plan is in the order of 1,000 km^2. The watershed consists of an area of land that drains to a major river, lake or stream and represents a complex ecosystem that is influenced by processes associated with the natural environment and human activities. The watershed plan addresses environmental issues associated with studies at the Official Plan level and sets the stage for determining the effects of existing and proposed land use practices on the resources within the watershed. Watershed plan recommendations typically identify at the macro level how land use changes should proceed while minimizing impacts to the watershed resources. Recommendations from the watershed plan are often used to focus and direct further investigations at the subwatershed level.

1.2.2 Subwatershed Plan

The existing environmental conditions within the subwatershed are identified and defined through a series of technical studies including surface water resources, hydrogeology, fluvial geomorphology, surface water quality, terrestrial resources and aquatic resources. Form, function and linkages of natural systems are identified and constraints to development are delineated based on establishing the environmental goals and objectives for the subwatershed. Alternative subwatershed management strategies are developed and evaluated to determine the preferred strategy to implement in terms of achieving the established goals and objectives. Based on the preferred alternative, recommendations are prepared that will specify areas for protection, restoration and/or enhancement. Regarding stormwater management, recommendations are typically made in terms of the level of controls required for water quality, erosion and quantity control (flood protection). Finally, a plan is proposed that will ensure that the recommendations are implemented. Environmentally sound land use designations and development policies are ensured as the information from the subwatershed plan is incorporated into the planning documents. The land area associated with a subwatershed plan is typically in the order of 50 km^2 to 200 km^2.

1.2.3 Master Drainage Plan

The Master Drainage or Environmental Management Plan takes the form of a variety of studies referred to as a Master Drainage Plan (MDP), Environmental Implementation Report (EIR), or Master Environmental Servicing Plan (MESP) and is typically carried out prior to consideration for Draft Plan Approval. This level of study typically deals with lands in the order of 2 km2 to 10 km2 in area; the details provided are sufficient to enable the preparation of block plans. The Master Drainage or Environmental Management Plan demonstrates how development can proceed in accordance with the requirements and criteria established in the Subwatershed Plan. Details provided in the plan include a review of existing information and existing environmental conditions, the establishment of constraint and opportunity mapping, and the development of a preferred environmental and stormwater management strategy for the lands within the plan study area. A sufficient level of detail is provided to enable the preparation of the preliminary or conceptual Stormwater Management Plan for all lands within the block plan.

1.2.4 Stormwater Management Plan (Preliminary/Conceptual Design)

The Stormwater Management Plan prepared at the preliminary or conceptual design stage is typically completed as a Preliminary SWM Report, a Functional SWM Report, or Functional Servicing Report (FSR). A Functional Servicing Report describes the proposed water supply, sanitary servicing, storm sewer drainage system, and stormwater quality and quantity control facilities and how the servicing and development will proceed in accordance with the Master Drainage or Environmental Management Plan recommendations. A Preliminary or Functional SWM Report focuses on the storm drainage system and the proposed stormwater quality and control facilities alone without discussing the additional servicing. The Stormwater Management Plan at the preliminary/conceptual stage provides guidelines for the Draft Plan Approval process and lays the groundwork for the detailed design stage.

1.2.5 Stormwater Management Plan (Detailed Design)

The Stormwater Management Plan prepared at the detailed design stage is referred to as a Stormwater Management Report. The Stormwater Management Report provides details and supporting calculations associated with the detailed design of the minor and major drainage system and the required source, conveyance and end-of-pipe controls (i.e. SWM facilities) to achieve the criteria established in the Master Drainage or Environmental Management Plan. The Stormwater Management Report is typically prepared following issuance of Draft Plan Conditions and is required for Plan of Subdivision Approval and Registration.

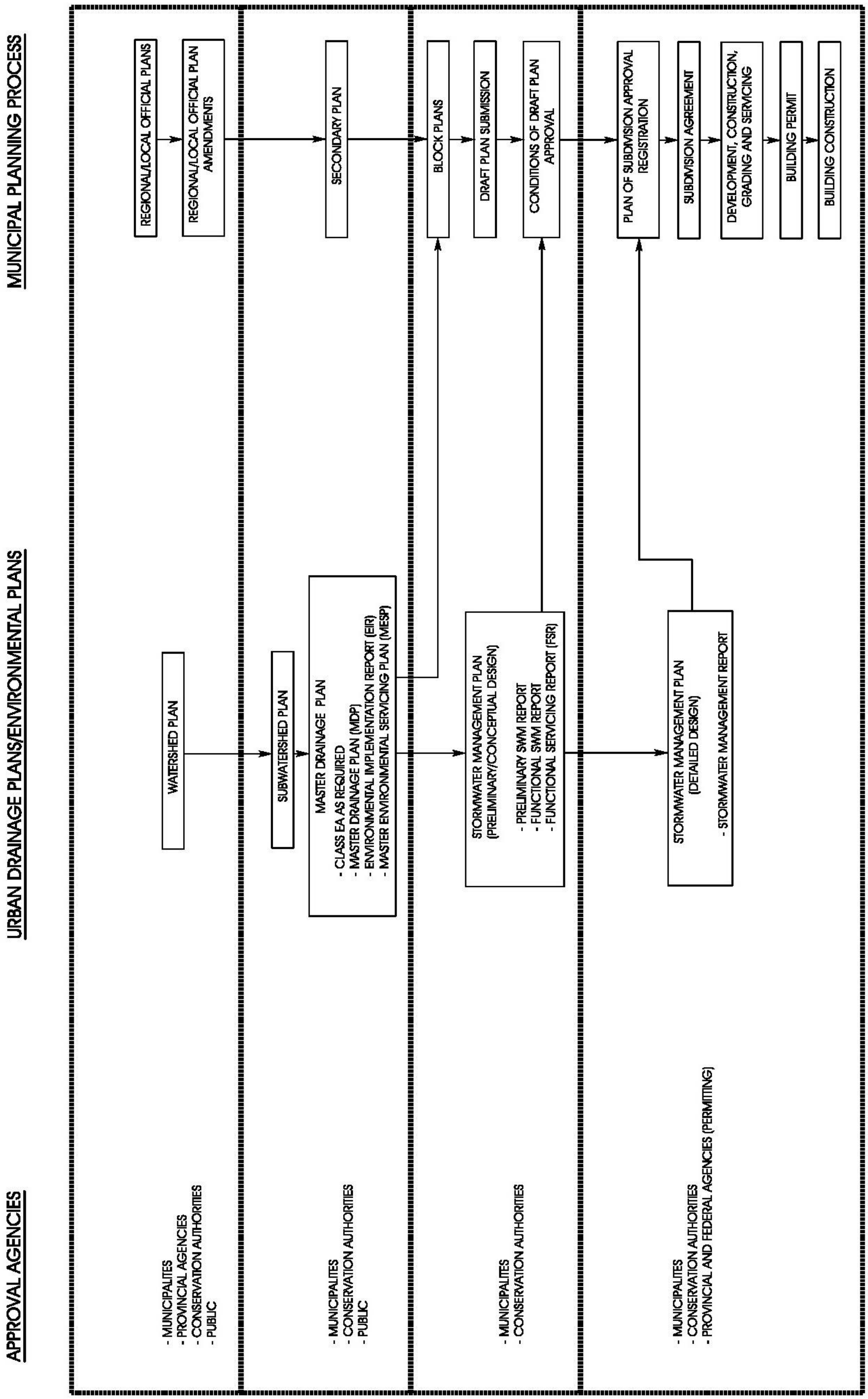


FIGURE 1.1 - CITY OF BARRIE ENVIRONMENTAL PLANNING PROCESS

1.2.6 Municipal Class Environmental Assessment

The Municipal Class EA applies to municipal infrastructure projects including roads, water and wastewater projects. Depending on the potential environmental impact of projects undertaken by the municipality, the project is classified according to the following schedules that must be adhered to as part of the Municipal Class EA process:

Schedule A Generally includes normal or emergency operational and maintenance activities. The environmental effects of these activities are usually minimal and, therefore, these projects are pre-approved.

Schedule A$^+$ These projects are pre-approved, however, the public is to be advised prior to project implementation. The manner in which the public is advised is to be determined by the proponent.

Schedule B Generally includes improvements and minor expansions to existing facilities. There is the potential for some adverse environmental impacts and, therefore, the proponent is required to proceed through a screening process including consultation with those who may be affected.

Schedule C Generally includes the construction of new facilities and major expansions to existing facilities. These projects proceed through the environmental assessment planning process outlined in the Municipal Class EA document (MEA, September 2007).

1.3 Format of Document

The document is organized into 9 sections with the intent to provide the reader with a comprehensive set of policies and guidelines regarding storm drainage and stormwater management design to be followed when submitting site plans and plans of subdivision to the City for approval.

***Section 2** - Legislation, Acts and Regulations* **–** This section provides a review of current legislation, acts and regulations that form the basis for most of the existing municipal, regional, provincial and federal guidelines, policies and criteria.

***Section 3** - Stormwater Drainage System Polices and Design Guidelines* **–** All of the municipal policies and design guidelines regarding the major and minor storm drainage system are provided in this section.

***Section 4** - Stormwater Management Policies and Design Guidelines* **–** The municipal policies and design guidelines regarding stormwater management are provided in this section including source, conveyance and end-of-pipe controls, planting guidelines and density requirements.

***Section 5** - Requirements for Erosion and Sediment Control During Construction* **–** This section provides the municipal requirements that must be followed when designing and implementing erosion and sediment control measures during construction.

***Section 6** - Assumption Protocol for Storm Sewers and Stormwater Management Ponds* – The protocol that must be followed when completing performance evaluations for storm sewers and SWM ponds is included in this section.

***Section 7** - Guidelines for Hydrologic and Hydraulic Analyses* – In this section a number of guidelines are provided for completing various hydrologic and hydraulic analyses including rainfall data, runoff and flow calculations, hydraulic calculations and water balance.

***Section 8** - Engineering Submission and Reporting Requirements (Drainage Designs / SWM Reports)* – An outline of the miscellaneous requirements for storm drainage and stormwater management details to be included in development submissions is provided in this section.

***Section 9** - References* – References for information cited and included in this document are provided in this section.

Appendices – A collection of detailed information related to the municipal policies and guidelines is provided in a series of appendices at the back of this document.

2.0 LEGISLATION – ACTS AND REGULATIONS

Stormwater management policies and design guidelines provided in this document were developed based on legislation and acts for:

- Watercourses and Existing Infrastructure (i.e., Culverts and Bridges, Roads)
- Erosion and Sediment Control
- Flood Damage Control
- Pollution Prevention
- Fisheries

Appendix E provides a summary of the legislations and acts that may influence drainage and stormwater management for the City of Barrie.

3.0 STORMWATER DRAINAGE SYSTEM POLICIES AND DESIGN GUIDELINES

This section discusses the policies and design guidelines applicable to the storm drainage system including foundation drains, the minor system (storm sewers), the major system (roads and swales), bridges and culverts, watercourses, and easements and buffers. When constructing on private property, construction materials and practices must be in accordance with the Ontario Building Code (OBC), the City of Barrie Standards and the City's *Lot Grading Criteria and Drainage Control Procedures*. A number of relevant sample problems and storm drainage calculations are provided in **Appendix C**.

3 .1 Foundation Drain Collector Outlet System

Foundation drain collector systems shall be designed on the basis of a continuous flow rate of 0.075 liters per second per residential lot plus infiltration. The minimum foundation drain collector diameter shall be 200 mm. Material and bedding standards applicable to foundation drain collectors shall be in accordance with Barrie Standard Drawings.

3.1.1 Foundation Drains

In order to minimize the flow rate from foundation drains, piezometer tests will be completed prior to design and construction to determine the seasonal high water level. Foundation elevations should then be set 0.5 m higher than the water table or as high as is practical. Where the anticipated flow from sump pumps will be considered a nuisance as deemed by the City, the City may request that Options 2 and 3 be implemented. Foundation drains shall have an accessible outlet for maintenance/cleanout.

Foundation drains shall not be connected to the storm sewer system unless as identified in the options below. The City will allow for an approved outlet which could include the storm sewer system. The following alternatives are acceptable to the City:

1. *Option 1 – Sump pump with discharge of foundation drain flow to ground surface.* Flow collecting in the foundation drain shall be pumped to the surface using a sump pump and then conveyed overland via lot drainage to the street or surface drain as per Infrastructure Standard D776 (see **Appendix A**).
2. *Option 2 – Sump pump with discharge of foundation drain flow to storm sewer extension at surface or subsurface.* Lots shall be constructed with a storm sewer extension extending from the storm sewer to the surface or subsurface adjacent the building as per D774 **or** D775, respectively (see **Appendix A**). Flow collecting in the foundation drain shall be pumped to the surface (or subsurface) using a sump pump and into the storm sewer extension and then conveyed to the storm sewer. A benefit of this configuration is the ability to discharge flow from foundation drains to the storm sewer while eliminating the risk of basement flooding and avoiding surface discharge and nuisance flooding.

3. *Option 3 – Gravity drain or sump pump with discharge to third pipe (foundation drain collector - FDC).* A third pipe (FDC) shall be constructed in the right-of-way (ROW) to collect foundation drain flow by gravity (or using a sump pump if grades do not permit) and to convey the flow to a nearby watercourse or other acceptable receiving body. Similar to the option above, an FDC eliminates the risk of basement flooding and surface discharge and nuisance flooding.
4. *Option 4 – Sump pump discharge piping in boulevard (retrofit option only).* In the event of overactive sump pump activity, a 150 mm diameter PVC DR-28 sewer may be installed, when so directed by the City, along the frontages of designated lots, with an offset of 0.6 m from back of curb. This sewer is to have a cleanout at the upstream end and is to outlet into the nearest catchbasin downstream. The depth of sewer is to be equal to the subdrain depth. The discharge piping shall not be directly connected to the foundation drains.

3.2 Minor System

Storm sewers shall be provided on all roads with curb and gutter. Storm sewers shall be designed to convey, as a minimum, the 1:5 year design storm.

3.2.1 Service Area

The drainage system shall be designed to accommodate all upstream drainage areas plus any external area tributary to the system for the existing, interim and ultimate development conditions, as determined by the delineation of appropriate topographic mapping and the preparation of drainage plans.

3.2.2 Design Flow

Storm sewer systems with a drainage area ≤ 50 ha shall be designed to convey the 1:5 year (minimum) design storm using the Rational Method and the City's IDF regression equation for rainfall intensity unless otherwise approved or directed by the City. Storm sewer systems with a drainage area > 50 ha shall be designed using an approved computer program and verified with the Rational Method. The storm sewer design shall be based on the larger of the two flows calculated using the computer model and the Rational Method. Under no circumstances shall the storm system be designed in a surcharged condition.

The design of the storm sewers shall be computed using the City of Barrie's Storm Sewer Design Sheet as provided on the City of Barrie Website under the Stormwater category**.**

All storm sewers shall be designed according to the Rational Formula where:

$$Q = \frac{(C)(i)(A)}{360}$$

where,

Q = the design flow in (m^3/s)

C = the site specific runoff coefficient

A = the drainage area (ha)

i = rainfall intensity (mm/hr)

The rainfall intensity shall be calculated in accordance with the following table and equation:

Table 3.1: Barrie WPCC IDF Curve Parameters - Adjusted to Account for Climate Change

Parameter	Return Period					
	2-Yr	**5-Yr**	**10-Yr**	**25-Yr**	**50-Yr**	**100-Yr**
A	675.586	843.019	976.898	1133.123	1251.473	1383.628
B	4.681	4.582	4.745	4.734	4.847	4.905
C	0.780	0.763	0.760	0.756	0.753	0.754

Rainfall Intensity, I (mm/hr) = $A/(t+B)^C$, where t is time duration in minutes

Parameters based on rain gauge data for the period 1979 – 2003 for the Barrie WPCC Station #6110557

Based on a review of the literature, the IDF intensity values for Barrie WPCC Station were increased by 15% before calculating a, b, c values to account for climate change.

$$i = \frac{A}{(t_d + B)^C}$$

where,

i = the rainfall intensity (mm/hr)

t_d = the storm duration (minutes)

A, B, C = a function of the local intensity-duration data.

The storm duration is set to the time of concentration (i.e. the sewer inlet time plus the time of travel in the pipe or channel) for the total cumulative drainage area to the node of interest. The maximum inlet time for the first pipe of a storm sewer system is 10 minutes.

The runoff coefficient shall be calculated in accordance with the following table:

Table 3.2: Runoff Coefficients (Rational C) (5-yr to 10-yr) Based on Hydrologic Soil Group

Land Use	Runoff Coefficient "C"		
	A-AB	**B-BC**	**C-D**
Cultivated Land, 0 - 5% grade	0.22	0.35	0.55
Cultivated Land, 5 - 10% grade	0.30	0.45	0.60
Cultivated Land, 10 - 30% grade	0.40	0.65	0.70
Pasture Land, 0 - 5% grade	0.10	0.28	0.40
Pasture Land, 5 - 10% grade	0.15	0.35	0.45
Pasture Land, 10 - 30% grade	0.22	0.40	0.55
Woodlot or Cutover, 0 – 5% grade	0.08	0.25	0.35
Woodlot or Cutover, 5 - 10% grade	0.12	0.30	0.42
Woodlot or Cutover, 10 - 30% grade	0.18	0.35	0.52
Lakes and Wetlands	0.05	0.05	0.05
Impervious Area (i.e., buildings, roads, parking lots, etc.)	0.95	0.95	0.95
Gravel (not to be used for proposed parking or storage areas)	0.40	0.50	0.60
Residential – Single Family	0.30	0.40	0.50
Residential – Multiple (i.e., semi, townhouse, apartment)	0.50	0.60	0.70
Industrial – light	0.55	0.65	0.75
Industrial – heavy	0.65	0.75	0.85
Commercial	0.60	0.70	0.80
Unimproved Areas	0.10	0.20	0.30
Lawn, < 2% grade	0.05	0.11	0.17
Lawn, 2 - 7% grade	0.10	0.16	0.22
Lawn, > 7% grade	0.15	0.25	0.35

Adapted from Design Chart 1.07, Ontario Ministry of Transportation, "MTO Drainage Management Manual," MTO. (1997)

An approximation of the runoff coefficient can be calculated based on the following relationship with: $c = (0.7)(TIMP) + 0.2$

where,

c = the runoff coefficient

TIMP = total impervious fraction (dimensionless)

The runoff coefficient shall be adjusted for return period events greater than the 10-yr storm per the following table:

Table 3.3: Runoff Coefficient Adjustment for 25-yr to 100-yr Storms

Return Period	Runoff Coefficient "C"
25 years	$C_{25} = 1.1*C_5$
50 years	$C_{50} = 1.2*C_5$
100 years	$C_{100} = 1.25*C_5$

Adapted from Design Chart 1.07, Ontario Ministry of Transportation,"MTO Drainage Management Manual," MTO. (1997).

Note: When applying the runoff coefficient adjustment, the maximum c-value should not exceed 1.0.

Given that the direct connection of foundation drains to the storm sewer is not permitted, a detailed HGL analysis is typically not required unless deemed otherwise by the City due to special circumstances. Refer to **Section 7.3** for details regarding HGL analysis requirements.

The calculation of total percent impervious (TIMP) values for modeling shall be in accordance with **Section 7.2.5** (**Table 7.6**).

3.2.3 Pipe Capacity and Size

The storm sewer capacity shall be calculated using the Manning's equation assuming the pipe is flowing full as follows:

$$Q=\left[\frac{1}{n}\right]A(R)^{\frac{2}{3}}(S)^{\frac{1}{2}}$$

where,

Q = the pipe capacity (m3/s)

n = the Manning roughness value

R = the hydraulic radius (m)

S = the sewer pipe slope (m/m).

A maximum inlet time of 10 minutes shall be used for the first pipe of a storm sewer system.

The velocity of flow in the storm sewer (assuming pipe flowing full) shall be calculated as follows:

$$v=\left[\frac{Q}{A}\right]$$

where,

Q = flow in the pipe when flowing full (m3/s)

A = cross sectional area of the pipe (m2)

The appropriate roughness coefficients shall be used as identified in **Table 3.4**.

The minimum size for a storm sewer (within a street) shall be 300 mm in diameter. No decrease of pipe size from a larger size upstream to a smaller size downstream shall be allowed regardless of the increase in grade.

3.2.4 Roughness Coefficients

The following roughness coefficients shall be used for hydraulic calculations of storm sewers:

Table 3.4: Sewer Pipe Manning's Coefficient

Material	Manning's "n"
Concrete, PVC, Profile Rib Pipe	0.013
Corrugated Metal with 25% Paved Invert	0.021
Corrugated Metal 68 x 13 mm Corrugations	0.024

3.2.5 Flow Velocity

The minimum flow velocity in the storm sewer shall be 0.75 m/s (full flow conditions).

The maximum flow velocity in the storm sewer shall be 4.0 m/s (full flow conditions).

3.2.6 Minimum Slope

The minimum storm sewer slope shall be not less than 0.5% unless specifically approved by the Director of Infrastructure.

3.2.7 Sewer Alignment

The storm sewers shall be laid as per City standard drawingsin a straight line between maintenance holes unless radius pipe has been designed.

3.2.8 Curved Sewers (radius pipe)

Curved pipe (radius pipe) shall be allowed for storm sewers 1200 mm in diameter and larger. The minimum center line radius allowable shall be in accordance with the minimum radii table as provided by the manufacturer.

3.2.9 Depth of Storm Sewers

A minimum 1.5 m cover below the centerline of road to obvert shall be provided for storm sewers. Under certain conditions where sufficient cover is not feasible, shallow insulated pipes may be permitted subject to review by the City.

3.2.10 Pipe Crossing and Clearance

A minimum clearance of 500 mm between the obvert of the sanitary sewer and the invert of the storm sewer shall be provided if the sanitary sewer connections are required to go under the storm sewer.

The minimum horizontal clearance between the outside wall of the adjacent sewer pipes shall be 800 millimeters. On crescent roads or roads with numerous bends, the sewer position may generally follow the same relative side of the road allowance.

The minimum clearance from a sewer to a watermain shall be 2.5 m horizontally and 0.5 m vertically.

3.2.11 Sewer Bedding

The type and classification of the storm sewer pipe and the sewer bedding type shall be clearly indicated on all profile drawings for each sewer length.

Bedding type selection shall be based on the depth of sewer, sewer material, trench width and configuration and soil conditions. Pipe loading calculations shall accompany the design submission. Storm sewers shall be constructed with bedding as per the current Ontario Provincial Standard Drawings (OPSD) (Gran. “A” embedment material) for flexible pipes and Class B (Gran. “A” bedding material) for rigid pipe unless otherwise approved by the Director of Infrastructure.

All pipe bedding must conform to OPSD, maximum cover table. No flexible pipe sewers will be installed with a depth of cover greater than 6 m unless specifically approved by the Director of Infrastructure.

3.2.12 Joints

All concrete and PVC pipes shall have rubber gasket joints.

3.2.13 Maintenance Holes

Maintenance holes shall be provided at each top end or dead end of a sewer line, change in alignment, grade, material, and at all junctions except where radius pipe is used in sizes 1200 mm and larger.

A self-levelling frame and cover shall be used for all new maintenance holes that are within an asphalt roadway.

Maintenance holes shall be located 3.0 m off the road centre line as per City Standards.

Maintenance holes shall be located, whenever possible, with a minimum of 1.5 m clearance away from the face of curb and/or any other service.

Full height benching within maintenance holes shall be completed per current OPSD.

The maximum maintenance hole spacing shall be 100 m for a pipe diameter less than 1200 mm and 150 m for pipe diameter 1200 mm or larger.

The maximum change in direction is 90 degrees for pipes 900 mm and smaller and 45 degrees for pipes over 900 mm.

The minimum allowances for hydraulic losses incurred at maintenance holes shall be as follows:

Table 3.5: Required Pipe Elevation Drop in Maintenance Holes

Change in Direction	Minimum Required Drops
0 degrees	30 mm
>0 – 45 degrees	80 mm
46 – 90 degrees	150 mm

Where the difference in elevation between the obvert of the inlet and outlet pipes exceed 0.9 m, a drop structure shall be designed in accordance with current City standards. Obverts of inlet pipes shall not be lower than obverts of outlet pipes.

3.2.14 Catch Basins (REVISED)

Catch basins shall be located upstream of pedestrian crossings, at street intersections such as to avoid driveways, sidewalks, and walkways and, where possible, to outlet into maintenance holes.

Type:

The single (CB) and double (DCB) catch basin types shall be designed based on OPSDs, using precast concrete and amended to provide a minimum of 900mm sump. CB and DCB types that are located on arterial and collector roadways shall be curb inlet style per OPSD 400.082 and shall meet the requirements of OPSD 401.080 (fish type cover), except where high flow covers are required. All local roadways shall have catch basins with flat square frames and fish type covers as per OPSD 400.050, except where high flow covers are required.

Due to maintenance issues, RLCB's are typically not permitted by the City except when other options are not feasible. Wherever possible, site grading should be designed in such a way that RLCB's are not required.

Capacity Design:

DCB's are to be installed at the low point of any road where drainage is collected from 2 or more directions. CB's may be acceptable at low points approaching intersections where drainage is mostly from one direction.

The maximum spacing shall be in accordance with the following:

Table 3.6: CB Spacing

Road Pavement Width	Slope	Maximum Spacing
≥10 m	> 4.5%	60 m
	≤ 4.5%	75 m

< 10m	> 4.5%	75 m
	≤ 4.5%	90 m

The maximum drainage area for any catchbasin shall be 2000 m^2 of paved area or 5000 m^2 of grassed area. Additional catch basins may be required at road intersections, elbows, and cul-de-sacs to facilitate satisfactory drainage.

Leads:

The lead size for catch basins shall be as follows:

- 250 mm diameter with a 2% minimum slope for single CB’s
- 300 mm diameter with a 2% minimum slope for DCB’s; and
- 250 mm diameter with a minimum 0.5 % slope for RLCB’s.

ICDs

Inlet control devices (ICD’s) shall be installed where the inlet capacity must be regulated. Inlet Control Devices such as orifice plates or other flow control devices are to be permanently attached to the storm structure in parking lots.

3.2.15 Sewer Materials and Maintenance Hole Types (REVISED)

Sewer Material Specifications:

Polyvinyl Chloride (PVC) specifications: can be used for either residential or industrial use conforming to CSA Standard B182.1, ASTM D3034 for pipe size 100 millimeter to 150 millimeter diameters, CSA Standard B182.2, ASTM D3034 for pipe size 200 millimeter to 375 millimeter diameter and CSA Standard 182.4, ASTM F-794 for pipe size greater than 450 millimeter diameter or current edition only as approved by the City.

Concrete Pipe specifications: complying with CSA Standard A257.1 (concrete sewer, storm drain and culvert pipe), CSA Standard A257.2 (reinforced concrete culvert storm drain and sewer pipe), and CSA Standard A257.3 (joints for concrete sewer and culvert pipe using flexible water tight rubber gaskets), ASTM C14, C76, C655.

Profile Rib Pipe specifications: For 250 mm to 450 mm (inclusive), pipe to be manufactured to the latest edition of CSA Standard B-182.2 (ASTM Specification F-794) with rubber gasketed bell and spigot joints. Pipe and fittings shall have a maximum Standard Dimension Ratio of 35 (SDR-35) and a minimum pipe stiffness of 320 kPa, or higher strength as may be required by the design.

Maintenance Hole Material and Type:

The minimum size for a MH shall be 1200 mm in diameter or 1200 mm x 1200 mm precast or poured in place concrete with precast or poured concrete bases in accordance with the OPSD drawings.

3.2.16 Storm Sewer Connections

The connection of sanitary sewers and foundation drains to the storm sewer is *strictly prohibited.* Options for foundation drain discharge are provided in **Section 3.1**.

3.3 Major System

The major system shall be designed to safely convey flow in excess of the minor system including the larger of the 100-yr storm and Hurricane Hazel via streets, open channels, storm sewers, walkways, and approved drainage easements to a safe outlet without flooding private property.

3.3.1 Drainage Area

The drainage area shall include all upstream drainage areas for the interim and ultimate conditions including any external area tributary to the system, as determined by suitable topographic mapping, site survey, and drainage plans.

3.3.2 External Drainage

All external tributary areas not accounted for in adjacent storm drainage areas, as well as other areas which may become tributary due to re-grading, shall be included in the site drainage plans.

3.3.3 Design Flow

The major system shall be designed to safely convey the Regulatory storm (*i.e.* larger of the 100-yr or Hurricane Hazel) (less minor system flow) through the road network without flooding private property and/or drainage easements.

3.3.4 Lot Grading and Drainage

The minimum lot grading around houses and buildings shall be 2%. The minimum grades for side lot swales and rear lot swales shall be 2%. All grading design shall be completed in accordance with the governing guidelines which are currently documented in the City's *Lot Grading Policy Manual* (1997). Where applicable, side and rear lot swales shall be located on the low side of the property line.

3.3.5 Overland Flow Routes

An overland flow route must be established to safely convey runoff from the Regulatory storm (in excess of the design capacity of the minor system) within the road right-of-way or easements to the nearest major open channel.

3.3.6 Roughness Coefficients

The tables below should be consulted in completing channel and overland flow calculations. The equation for Manning's Overland flow (assuming a wide plane with shallow flows such that R is approximately equal to the channel bottom width) is:

$$q_o = \left[\frac{1}{n}\right](S_o)^{\frac{1}{2}}(y_o)^{\frac{5}{3}}$$

where,

q_o = the overland flow per unit width of overland flow (m^3/s/m)

n = the Manning roughness value for overland flow

S_o = the average overland flow slope (m/m)

y_o = the mean depth of overland flow (m).

The Manning's equation for channel flow is:

$$Q = \left[\frac{1}{n}\right](A)(R)^{\frac{2}{3}}(S_o)^{\frac{1}{2}}$$

where,

Q = the channel flow (m^3/s)

n = the Manning roughness value for channel routing

R = the hydraulic radius (area/wetted perimeter)(m)

S_o = the channel slope (m/m).

and

$$V = \left[\frac{1}{n}\right](R)^{\frac{2}{3}}(S)^{\frac{1}{2}}$$

where,

V = the channel velocity (m/s)

n = the Manning roughness value for channel routing

R = the hydraulic radius (area/wetted perimeter)(m)

S_o = the channel slope (m/m).

Table 3.7: Manning's Roughness Coefficients - for Channel Routing

Location	Cover	Manning's "n"
Over bank	Woods	0.080 - 0.120
	Meadows	0.055 – 0.070
	Lawns	0.035 - 0.050
Channel	Natural	0.030 – 0.080
	Grass	0.030 - 0.050
	Natural Rock	0.030
	Armour Stone	0.025
	Concrete/asphalt	0.015
	Articulated Block e.g. Terrafix	0.020
	Gabions	0.025
	Wood	0.015
	Corrugated Steel Pipe - 3"x1"	0.024
	Structural Plate Corrugated Steel Pipe - 6"x2"	0.032

Adapted from Design Chart 2.01, Ontario Ministry of Transportation, "MTO Drainage Management Manual," MTO. (1997)

Table 3.8: Manning's Roughness Coefficients - for Overland Flow

Cover	Manning's "n"
Impervious Areas	0.013
Woods	
---- with light underbrush	0.400
---- with dense underbrush	0.800
Lawn	
---- short grass	0.150
---- dense grass	0.240
Agriculture	0.050-0.170

Adapted from Soil Conservation Service, Urban Hydrology for Small Watersheds,

U.S. Dept. of Agriculture, Soil Conservation Service, Engineering Division, Technical Release 55, June 1986

3.3.7 Roads

Road grading must direct flows from the right-of-way to a safe outlet at specified low points. Outlets can be walkways or open sections of road leading to open spaces or river valleys. Roads may be used for major system overland flow conveyance during the Regulatory (*i.e.* the larger of the 100-yr storm and Hurricane Hazel) storm subject to the following depth constraints:

Table 3.9: Maximum Allowable Flow Depth for Roads

Location	Maximum Ponding Depth
Local Road	0.20 m above crown of road
Collector and Industrial Road	0.10 m above crown of road
Arterial Roads	Single lane to remain open

Adapted from City of Vaughan Design Criteria, 2004

3.3.8 Channels

Overland flow channels shall be designed to convey the Regulatory storm peak flow without flooding adjacent private properties. Appropriate stabilization shall be provided to protect against velocity conditions experienced during the Regulatory storm and calculations shall be provided to the City for review and approval. The maximum velocities during the 1:5 year and Regulatory storms shall be 1.5 m/s and 2.5 m/s, respectively for sod lined channels. Channels expected to experience higher flow velocities shall be stabilized using other measures approved by the City, such as soil reinforcement or stone lining. Calculations, using the Maximum Permissible Tractive Force method (*MTO Drainage Management Manual*, Section 5), shall be provided to the City and Conservation Authority for review.

3.3.9 Total Capture Inlets

Total capture inlet grates shall be sized with a minimum 2.0 factor of safety (*i.e.* assume 50% blockage). Inlet grates shall be designed as per OPS drawings.

3.3.10 Conveyance of Flow from Road to SWM Facility or Channel

The Consultant must demonstrate that overland flows during the Regulatory storm can be safely conveyed from the road allowance to a SWM facility or open channel without flooding adjacent private properties. Overland flows may be routed as follows:

- Overland flow may be routed over the curb and boulevard. The Consultant must demonstrate that sufficient hydraulic capacity exists using the broad-crested weir equation. The flow route from the boulevard into the SWM facility or open channel must be stabilized to prevent slope erosion.
- Overland flow must be contained within publicly owned lands.
- Overland flow must be captured and piped at the major system low point(s) on the roadway unless the Consultant can demonstrate that the flow can be conveyed by other means to the satisfaction of the City.
- The Consultant must demonstrate that the inlet grates required to capture the major system flow have sufficient hydraulic capacity assuming 50% bar area and blockage of opening.

3.3.11 Outfall Channels (REVISED)

<u>General</u>

The following general principles are to be applied when designing storm sewer or FDC outfalls to a natural watercourse:

- Headwall designs shall conform to OPSD 804.030 for pipe less than 900mm in diameter

- Headwall designs shall conform to OPSD 804.040 for sewer or concrete pipe outlet
- Pipes 900mm in diameter or greater shall be complemented by wing walls
- Headwall grates shall be specified for all headwalls as per OPSD 804.050
- Where a headwall is greater than 600mm, a handrailing shall be installed
- Handrailing shall be designed as per OPSD 980.101 and affixed to headwall and wingwall structures
- Handrailing shall be hot dip galvanized steel, rounded pipe.
- Outfall inverts are to be located at or above the 1:2 year storm flood level in the receiving watercourse.
- All exposed concrete faces and surface treatment shall conform with City Standards
- All outfalls to a watercourse require a permit from the Conservation Authority.

Hydraulics

The following hydraulic considerations are to be incorporated to all outfall channel designs:

- To minimize erosion, outfall channels shall be extended from the headwall to the natural watercourse. The outfall channel shall be designed, where possible, such that flow in the outlet channel is tangential to the flow in the natural watercourse at the confluence. The outfall channel shall tie into the natural watercourse at or above the natural water level in the watercourse.
- Discharge onto steep slopes is not permitted.
- Outfall channels shall be designed to withstand the erosive forces experienced under the design storm event. Calculations, using the Maximum Permissible Tractive Force method (*MTO Drainage Management Manual*, Section 5), shall be provided to the City and Conservation Authority for review.
- Tailwater impacts of the natural watercourse shall be accounted for in the design of the outfall channel, control structures and upstream storm sewer/FDC systems.

3.4 Bridges and Culverts

Culverts and bridges crossing arterial roads must be designed to prevent overtopping during the 100-yr storm. Under certain circumstances the City may request protection from overtopping for the Regional storm. In addition, bridges and culverts shall be designed so there is no increase in the Regulatory flood conditions of the watercourse.

All culverts shall be supplied with headwall end protection constructed of interlocking wall systems, concrete, armour stone or other material approved by the City.

Corrugated Steel Pipe (CSP) Culvert Specifications

- All CSP to be Aluminized (Type 2) pipe in accordance with CSA Standard G.401.
- For 150 mm to 600 mm (inclusive), pipe to be manufactured with the profile dimensions 68 mm x 13 mm with a minimum wall thickness of 1.6 mm.
- For 700 mm to 1000 mm (inclusive), pipe to be manufactured with the profile dimensions 68 mm x 13 mm with a minimum wall thickness of 2.0 mm.
- For 1200 mm to 2400 mm (inclusive), pipe to be manufactured with the profile dimensions 125 mm x 26 mm with a minimum wall thickness of 2.0 mm.
- For 2700 mm to 3000 mm (inclusive), pipe to be manufactured with the profile dimensions 125 mm x 26 mm with a minimum wall thickness of 2.8 mm.
- For 3300 mm and larger, pipe to be manufactured with the profile dimensions 125 mm x 26 mm with a minimum wall thickness of 3.5 mm.
- All CSP to be manufactured with Annular Corrugated ends to allow for a variety of joints to be utilized for standard pipes and pipe-arches. Three recommended and approved types of coupler are the Hugger band, the Annular corrugated standard bolt and angle coupler, and the Dimpled coupling band.

3.4.1 Road Crossings

For local roads, the maximum allowable overflow depth over the gutter elevation shall be 300 mm and must not cause damage to private property. Road crossing culverts shall be a minimum of 450 mm (2.0 mm CSP gauge) in diameter with headwall.

3.4.2 Roadside Ditches and Culverts

When designing a rural road cross section, the design of roadside ditches shall consider the following:

- Ditch inverts shall be located a minimum of 0.15 m and a maximum of 0.50 m below the roadway subgrade elevation. Where the minimum of 0.15 m cannot be met, a ditch subdrain will be required and shall outlet to the ditch once the minimum depth criterion is met.
- The minimum and maximum ditch gradients shall be 2.0% (wherever possible) and 6.0%, respectively.
- Ditch protection shall consist of 200 mm topsoil and staked sod on the side slopes and bottom of the ditch. In the event that the 1:5 year storm velocity in the ditch exceeds 1.5 m/s, or the Regulatory storm velocity exceeds 2.5 m/s, the ditches shall be stabilized using other measures approved by the City such as soil reinforcement or stone lining.
- All roadside ditches shall transport runoff to a safe outlet, such as a stormwater management facility or natural watercourse, approved by the City.

The design of culverts shall consider the following:

- Entrance or driveway culverts must have a minimum size of 450 mm (1.6 mm CSP gauge) with appropriate end treatment and be sized to convey the 10-yr event (minimum) without overtopping unless otherwise directed by the City.
- A minimum of 300 mm cover shall be provided at the edge of the shoulders.
- End protection shall be provided on all driveway culverts, including metal aprons, concrete, pressure treated timbers, concrete headwalls or precast stones.

3.4.3 Design Flow Capacity

The following design flood frequency shall apply to road crossings unless otherwise directed by the City. Culverts and road elevations shall be designed accordingly to meet the flood design guidelines.

Table 3.10: Flow Design Guidelines for Road Crossing

Road Classification	Design Flood Frequency
Arterial	1:100 Year Regional (Hurricane Hazel) – if directed by the City
Collector	1:50 Year
Urban Local	1:50 Year
Rural Local	1:25 Year
Temporary Detour	1:10 Year
Driveway	1:10 Year

Modified from MTO Directive B-100 and the Highway Drainage Design Standards (MTO, Jan 2008).

3.4.4 Headwalls / Endwalls

Headwall and endwall structures shall conform to the current OPSD and City Standards and be included on the engineering drawings. The details provided shall include the existing topography, proposed grading and the works necessary to protect against erosion.

3.4.5 Fish Passage

Requirements for flow and hydraulic calculations regarding fish passage for bridges and culverts shall be completed in accordance with the Federal Department of Fisheries requirements and the MTO Drainage Management Manual and subject to review by the Conservation Authority. Perched culverts are typically not permitted if they will introduce a barrier to fish movement. Open bottom culverts shall be utilized where possible.

3.4.6 Erosion Protection

Armour stone, river stone and/or concrete shall be provided at all inlets and outlets to protect against erosion of the watercourse and provide embankment stability. The maximum allowable target channel velocity shall be in accordance with the MTO Drainage Management Manual (Section 5). Subject to City approval, gabions may be permitted in certain settings (e.g., industrial). Gabions are not permitted in or adjacent to watercourses and other bodies of water.

3.5 Watercourses

Watercourses and associated flood plains shall be capable of handling the Regulatory flood run-off as determined by the Conservation Authority.

3.5.1 Existing Watercourses

Existing water courses shall be left in their natural state as much as possible.

3.5.2 Natural Channel Design

The criteria for natural channel design shall be determined on a site-specific basis and shall be consistent with accepted natural channel design principles such as those provided in the *Adaptive Management of Stream Corridors in Ontario* (MNR, 2002).

A natural channel shall be designed to have a baseflow channel, a 2-yr conveyance channel and an adjacent floodplain in accordance with natural channel principles. The channel shall be designed for the Regulatory flood run-off with approved lined material within the baseflow and 2-yr conveyance channel and with slopes vegetated to the satisfaction of the City. Maximum side slope shall not exceed 4:1 (H:V).

3.6 Easements and Buffers

The minimum width of easements for storm sewers shall be in accordance with the following guidelines:

Table 3.11: Easement Design Guidelines

Size of Pipe	Depth of Invert	Minimum Width of Easement
250 to 375 mm	3.0 m maximum	3.0 m
450 to 675 mm	3.0 m maximum	5.0 m
750 to 1500 mm	3.0 m maximum	6.0 m
1650 and larger	4.0 m maximum	4.0 m plus 3 times O.D. of pipe

Sewers in easements between houses are to be concrete encased for the full length of the lot and to the back of the street curb.

Easement plans shall be reviewed and approved per the City’s judgment on a case-by-case basis.

3.7 General Maintenance Requirements

In order to ensure the optimal and long term continued operation of the storm drainage system prior to assumption and following assumption, it is important that the storm drainage system be regularly maintained. Some of the key components of an effective maintenance program include:

- Regular street sweeping and catch basin cleaning.
- Regular inspections of the storm sewer system including inlet grates and catch basins and periodic flushing and cleaning as required.
- Regular inspections of the overland drainage system including ditches, culverts and bridges and the removal of accumulated sediment and debris as required.
- Regular inspections of total capture inlet grates and the removal of debris as required.
- Regular inspections of storm drainage system components for structural degradation and repair or replacement of degraded components as required.

4.0 STORMWATER MANAGEMENT POLICIES AND DESIGN GUIDELINES

This section describes the stormwater management policies and design guidelines regarding environmental protection and flood and erosion control. This section provides guidance on the design of stormwater management facilities as they may be applied to traditional urban design, urban design concepts employing principles of low impact development (LID) and redevelopment as infill. The stormwater management guidelines to be applied to proposed site plans are dependent upon the drainage area associated with the proposed development. A flow chart is provided in **Figure 4.2** that identifies the stormwater management requirements for proposed development sites based on drainage areas that are either less than 5 ha or greater than or equal to 5 ha in size.

4.1 Environmental Protection Guidelines

4.1.1 Water Quality and Erosion Control

As per Ontario Regulation 219/09 regarding water quality and phosphorus loading to Lake Simcoe, all new SWM facilities shall provide as a minimum the Enhanced level of protection as specified in the *Stormwater Management Planning and Design Manual* (MOE, 2003). Ontario Regulation 219/09 may not apply to infill developments and the redevelopment of one or more properties if the applicant can demonstrate to the satisfaction of the Director (MOE) that it is impractical to achieve the Enhanced level of protection. In addition, it shall be demonstrated that through an evaluation of anticipated changes in phosphorus loadings between pre-development and post-development conditions how the phosphorus loadings shall be minimized.

Unless otherwise directed by the City or Conservation Authority, or unless otherwise indicated in an approved master drainage plan or watershed plan, developments ≥ 5 ha in drainage area shall require erosion control measures to be implemented whereby the 25 mm 4 hr Chicago storm shall be stored and released over a minimum 24 hour period. Proposed developments < 5 ha may require erosion control measures, depending upon the type of protection provided in any downstream facilities and the potential for downstream erosion. The erosion control requirements for proposed development sites < 5 ha shall be confirmed with the City and Conservation Authority. A summary of recommendations from approved master drainage plans for City of Barrie watersheds is provided in **Appendix D**.

4.1.2 Quantity Control (Flood Protection)

Post-to-pre quantity control shall be provided unless otherwise directed by the City or Conservation Authority, or unless otherwise indicated in an approved master drainage plan or watershed plan. Under certain circumstances where the proposed development is located in close proximity to Lake Simcoe and where there are no downstream land owners, the post-to-pre peak flow control requirements may be waived subject to approval by the City and

Conservation Authority. A summary of recommendations from approved master drainage plans for City of Barrie watersheds is provided in **Appendix D**.

4.1.3 Water Balance

All new developments with a contributing drainage area > 5 ha shall provide post-to-pre infiltration on-site where soils permit and unless otherwise established at the secondary plan stage. The water balance requirements apply to the property limit of the development and do not necessarily need to be achieved on a lot-by-lot basis (*i.e.* "communal" infiltration facilities that service multiple lots may be acceptable). Sites ≤ 5 ha (*e.g.* site plans or infill sites) shall minimize any anticipated changes in the water balance between pre-development and post-development conditions and shall provide a minimum infiltration equivalent to the first 5 mm of any given rainfall event.

4.1.4 Flow Diversions

Unless approved by the City and the Conservation Authority, the re-direction of flow between drainage basins is not permitted.

4.1.5 Receiving Watercourses

It shall be a general requirement that all watercourses remain in their natural state and that base flow and velocity be maintained. Any alterations required must take into consideration the form and function of the watercourse, including requirements to convey water and sediment, and the provision of aquatic habitats.

4.1.6 Lake Simcoe Water Quality

The Lake Simcoe Protection Act provides direction in terms of protecting the water quality of Lake Simcoe. The guidelines regarding water quality and level of treatment required shall be consistent with Ontario Regulation 219/09 as outlined in **Section 4.1.1**.

4.1.7 Wetlands

As per regulations made under the Conservation Authorities Act, proposed development within a wetland is not permitted. Development within a portion of the adjacent buffer area may be permitted subject to an approved Environmental Impact Study.

4.2 Flood and Erosion Protection Guidelines

4.2.1 Flood Standards for River Systems

The flood plain shall be defined as the limit of the water surface elevation associated with the larger of the 100-year or the Regional storm with the exception of Bunker's Creek and Sophia Creek, where the 100-yr flood event standard applies. For purposes of flood plain mapping and associated hydrology models the Timmins storm shall be the Regional storm for Zone 3 and Hurricane Hazel shall be the Regional storm for Zone 1. A map delineating the boundary of the flood hazard criteria zones within the City of Barrie is provided in **Appendix B**. As per regulations made under the Conservation Authorities Act, proposed development within the maximum extent of the flood plain is not permitted, with certain exceptions.

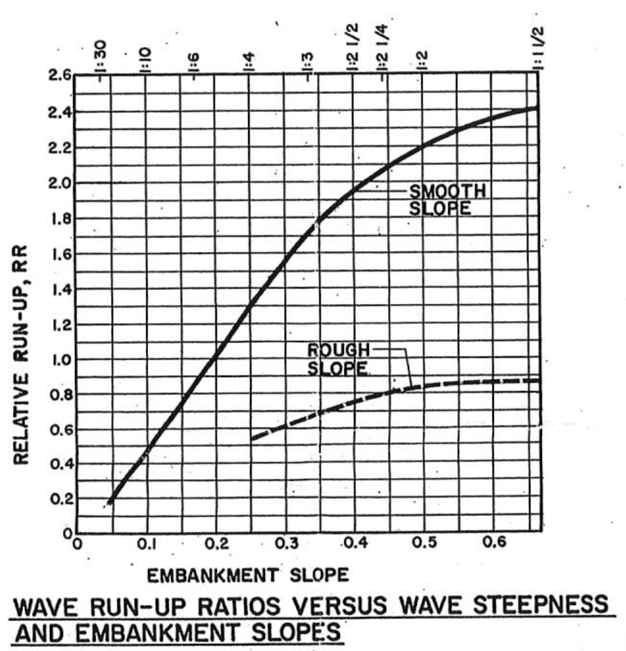
4.2.2 Flood Hazard Limits for Lakes

The flood hazard limit for Lake Simcoe and other inland lakes within the City limits shall be defined as the 100 year flood level, plus the appropriate allowance for wave uprush as calculated by the equations provided in the document entitled *Shoreline Flood Elevation Study, Lake Simcoe, Lake Couchiching* (MNR, April 1981). The 100-yr wave run-up equation for Kempenfelt Bay within City of Barrie limits is:

$$100 - yr\ Wave\ Run - up\ Elevation(m) = (0.945)(RR) + 219.593$$

Where, RR is the relative wave run-up coefficient determined by using the graph below based on the embankment slope (m/m) adjacent the lake and the surface roughness of the embankment.

Figure 4.1: Wave Run-up Ratios Versus Wave Steepness and Embankment Slopes



Source: *Shoreline Flood Elevation Study, Lake Simcoe, Lake Couchiching* (MNR, April 1981)

4.2.3 One and Two Zone Concepts

In areas governed by the One Zone concept, development within the flood plain is prohibited unless, in the opinion of the City and the Conservation Authority, the control and extent of flooding will not be affected by the development. In areas where the Two Zone concept for flood plains is applied, “development and site alteration may be permitted in the flood fringe, subject to appropriate flood proofing to the flooding hazard elevation or another flooding hazard standard approved by the Minister of Natural Resources."

Some development (e.g., parking lots) may be permitted within the flood fringe if it lies within an approved Two Zone Area. Short term parking may be permitted within an approved Two Zone Area subject to a maximum "depth × velocity" criteria (i.e. low risk conditions) whereby the product of flow depth and flow velocity is ≤ 0.4 m^2/s with a maximum allowable depth of 0.8 m and a maximum allowable velocity of 1.7 m/s. No residential or overnight parking (other than seasonal parking associated with recreational campgrounds) facilities shall be permitted within the flood plain.

Any other proposed development within a Two Zone Area is not permitted unless it can be demonstrated that there is no other option to the satisfaction of the City and Conservation Authority, in which case certain criteria regarding flood proofing and maximum depth and flow must be achieved as agreed to by the City and Conservation Authority.

Currently, there are no Two Zone areas in the City of Barrie.

4.2.4 Special Policy Areas

In some areas of the City where historical development has occurred within the flood plain, it may not always be feasible to meet the strict requirements of the Regulatory Flood standard. As such, these areas may be designated a Special Policy Area and may not be subject to the same level of protection as stipulated by the Regulatory Flood standard. Per the *Provincial Policy 2005*, under no circumstances, shall the development of emergency services and vulnerable institutional services be permitted within the flood plain even if designated a Special Policy Area. Special Policy Areas are delineated by detailed studies and are subject to a public process and review and approval by the Province.

Currently, there are no Special Policy areas in the City of Barrie.

4.2.5 Flood Proofing of Buildings

Should approval be granted by the City and Conservation Authority for development or re-development of buildings within the flood plain, the minimum opening elevation into a structure shall be 500 mm greater than the regulatory flood elevation.

4.2.6 Stormwater Management Facilities

The construction of new SWM facilities within the 100-yr flood plain is not permitted. The construction of new SWM facilities within the Regional flood plain is only permitted by the City and Conservation Authorities if it can be demonstrated that there will be no impacts to the Regional water surface elevation or floodplain storage upstream and downstream of the proposed facility and no other reasonable options are available. On-line SWM ponds are not permitted by the City or Conservation Authorities. Existing on-line flow attenuation areas behind railroad/road embankments may be considered at the discretion of the Director of Infrastructure or Conservation Authority.

4.2.7 Retrofit of SWM Facilities

The retrofit of SWM facilities is permitted to enhance the current level of treatment provided, subject to review by the City, Conservation Authority and MOE. Subject to feasibility, the retrofit design shall provide the Enhanced level of protection for water quality per the SWMPD Manual (MOE, 2003). The Enhanced level of protection may not apply to the retrofit of existing SWM facilities if the applicant can demonstrate to the satisfaction of the City, Conservation Authority, and Director (MOE) that it is impractical to achieve the Enhanced level of protection. Typically, the extent of improvements for a pond retrofit is restricted by space limitations (i.e. the pond block cannot usually be expanded due to surrounding development). As such, an analysis of needs and priorities should be completed prior to the retrofit to determine the best allocation of available volume in terms of water quality, erosion, and quantity control to maximize the overall benefit.

4.2.8 Erosion and Sediment Control

Measures shall be implemented to minimize the impact of erosion and sediments from sites to receiving watercourses. Control measures during construction shall be designed in accordance with the City of Barrie *Site Alteration By-Law 2006-101* and the *Erosion and Sediment Control Guidelines for Urban Construction* (GGHA CA's, 2006).

In accordance with the governing guidelines, which are currently documented in the *Stormwater Management Planning and Design Manual* (MOE, 2003), and the NVCA guidelines, and until further erosion studies are completed, erosion control measures must be implemented for stormwater management facilities, requiring the 25 mm 4-hr Chicago storm be stored and released over a 24-hr period.

4.3 Site Plans and Infill Developments (Drainage Area < 5 ha)

Proposed developments with drainage areas less than 5 ha, such as site plans and infill development, shall require the design of water quality and quantity controls based on the existing or proposed quality and quantity facilities provided downstream of the site. Four scenarios have been identified that describe the level of water quality and quantity control provided downstream of the site and are presented below. A flow chart outlining the decision making process is provided in **Figure 4.2**.

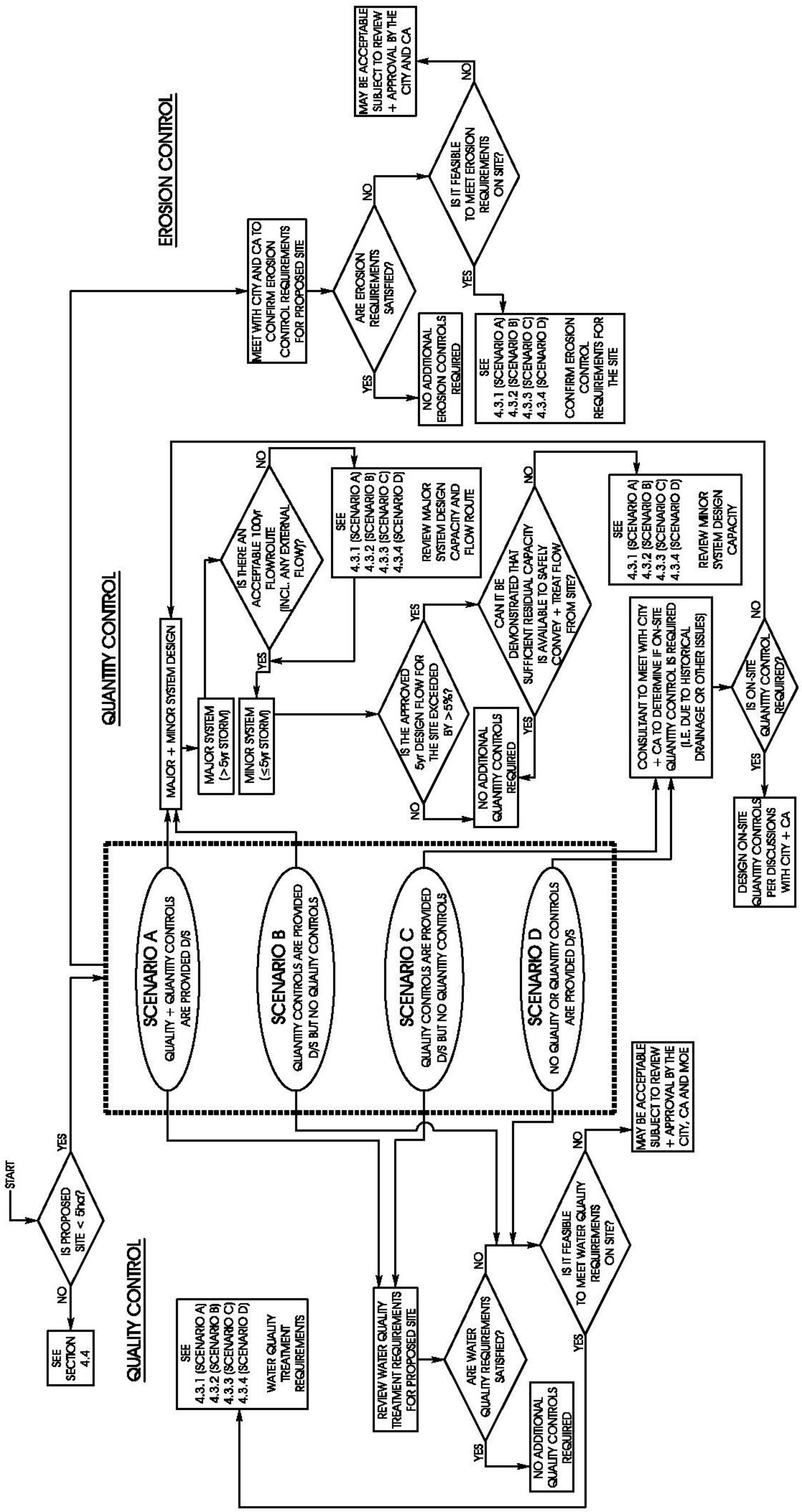


FIGURE 4.2 - CITY OF BARRIE STORMWATER MANAGEMENT POLICIES FLOW CHART

4.3.1 Scenario A – Both Quality and Quantity Controls Provided Downstream

Scenario A defines the case where downstream quality and quantity control facilities are in place or are proposed that service the proposed development site. Depending on the design of the major and minor system downstream of the proposed development, additional on-site quantity controls may be required. The steps identified below shall be followed when completing a site plan or infill development classified as Scenario A.

Step 1 – Review Minor System Design Capacity (≤ 5 Year Event)

The previously approved storm sewer design sheets and storm drainage plans shall be reviewed and compared with the design parameters (i.e. runoff coefficient and contributing drainage area) for the proposed site to confirm that sufficient residual capacity is provided to safely convey the 5-yr design flow from the site. If the proposed 5-yr design flow does not exceed the previously approved design flow from the site by more than 5%, then no additional on-site quantity controls are required. If the proposed 5-yr design flow exceeds the previously approved design flow by more than 5%, then the consultant shall complete one of the following options:

Option 1 – it shall be demonstrated that the there is sufficient residual capacity in the minor system to safely convey the 5-yr flow from the site. The consultant shall assess the ability of the downstream facility to accommodate any additional storm runoff and to maintain the same level of quality and quantity control.

Option 2 – on-site quantity controls (e.g. rooftop, parking, landscape storage and outlet controls) shall be provided for the proposed development such that the 5-year peak flow is reduced to the previously approved peak flow from the site. On-site quantity controls shall adhere to the guidelines provided in **Sections 4.5** and **4.6**.

Step 2 – Review Major System Design Capacity and Flow Route (Regulatory Event)

It shall be demonstrated that the major system flow from the proposed site will be safely conveyed to a previously identified existing R.O.W. or other defined flow route within City property or easement. Drainage to the major system outlet shall not exceed 0.3 m in depth and velocities shall not exceed 0.65 m/s.

Where it is not feasible to safely convey the Regulatory flow from the proposed site to a previously identified overland flow route, an alternate flow route shall be identified within City lands or easement adjacent to the proposed property that is acceptable to the City.

Should there be no feasible overland flow route that is acceptable to the City, or as an alternative to the above option, quantity storage (e.g. rooftop, parking, landscape storage and outlet controls) shall be provided on the proposed site to attenuate the Regulatory peak flow to the capacity of the minor system. On-site quantity controls shall adhere to the guidelines provided in **Section 4.5**.

The proposed major system design for the development site must be designed to convey any existing external flows or future external drainage as identified in approved master drainage or other studies.

Step 3 - Water Quality Treatment Requirements

The current level of water quality protection afforded by the downstream controls shall be reviewed to confirm that the Enhanced level of protection per the governing guidelines which are currently documented in the *Stormwater Management Planning and Design Manual* (MOE, 2003) is provided for the proposed development site. Should it be determined that the required level of water quality control is provided, then no additional water quality controls are required on-site. Should it be determined that the required level of control is not achieved and it is feasible to provide the Enhanced level of protection on-site, then on-site controls shall be provided that achieve the requisite level of water quality protection. If it is not possible to comply with the Enhanced level design standard due to on-site limitations, it must be demonstrated to the satisfaction of the City and the Conservation Authority that the most effective measures possible have been incorporated in the overall design of on-site water quality treatment. Proposed developments that have the potential for contaminant spills as stipulated by the City shall require the installation of an appropriate end-of-pipe treatment such as an oil grit separator.

Step 4 – Confirm Erosion Control Requirements for the Site

Depending upon the type of protection provided in any downstream facilities and the potential for erosion issues along the downstream conveyance route to Lake Simcoe, erosion controls may be required on-site. Erosion and sediment control requirements for the proposed development site shall be confirmed with the City and Conservation Authority. *Site Alteration By-Law 2006-101* regulates placing or dumping of fill, stripping of topsoil and alteration of grade for areas greater than 0.5 ha. Should it be determined that sufficient erosion requirements are provided downstream or that downstream erosion is not an issue, then no additional erosion controls are required on site. Otherwise, the minimum control requirement shall be the runoff associated with the 25 mm 4-hr Chicago storm released over 24 hours. In order to protect or maintain the stability of receiving watercourses under special circumstances, the City and/or Conservation Authority may identify the need for and request a detailed erosion control analysis. Detailed watercourse erosion analyses may be based on continuous modeling and/or field based analyses to determine critical flow thresholds. Field based analyses must be completed by a qualified fluvial geomorphologist. If it can be demonstrated that the required level of erosion control is not feasible due to on-site limitations, then a reduced level of protection may be acceptable, subject to review and approval by the City and Conservation Authority.

4.3.2 Scenario B – Quantity Controls Provided Downstream but No Quality Controls

Scenario B defines the case where quantity facilities are in place or are proposed downstream of the proposed development site, however, no existing or proposed quality facilities are in place. As such, on-site quality controls shall be required. Depending on the design of the major and minor system downstream of the proposed development, additional on-site quantity controls may be required. The steps identified below shall be followed when completing a site plan or infill development classified as Scenario B.

Step 1 – Review Minor System Design Capacity (≤ 5 Year Event)

Refer to **Section 4.3.1** (Step 1).

Step 2 – Review Major System Design Capacity and Flow Route (Regulatory Event)

Refer to **Section 4.3.1** (Step 2).

Step 3 – Water Quality Treatment Requirements

On-site water quality controls shall be provided that achieve the Enhanced level of protection per the governing guidelines which are currently documented in the *Stormwater Management Planning and Design Manual* (MOE, 2003). If it is not possible to comply with the Enhanced level design standard due to on-site limitations, it must be demonstrated to the satisfaction of the City and the Conservation Authority that the most effective measures possible have been incorporated in the overall design of on-site water quality treatment. Proposed developments that have the potential for contaminant spills as stipulated by the City shall require the installation of an appropriate end-of-pipe treatment such as an oil grit separator.

Step 4 – Confirm Erosion Control Requirements for the Site

Refer to **Section 4.3.1** (Step 4).

4.3.3 Scenario C – Quality Controls Provided Downstream but No Quantity Controls

Scenario C defines the case where quality facilities are in place or are proposed downstream of the proposed development site, however, no existing or proposed quantity facilities are in place. Subject to discussions with the City regarding any potential downstream drainage or other issues and depending on the design of the major and minor system downstream of the proposed development, additional on-site quantity controls may be required. The steps identified below shall be followed when completing a site plan or infill development classified as Scenario C.

Step1 - Consultation with City

In the case where downstream quantity controls are not provided or previously required, a consultation with the City is required to determine if on-site quantity controls are required due to downstream drainage or other issues. Subject to clearance by the City in this regard, the following steps shall be taken in completing the site design. Should clearance not be obtained, on-site quantity controls shall be provided per discussions and agreement with the City and Conservation Authority.

Step 2 – Review Minor System Design Capacity (≤ 5 Year Event)

Refer to **Section 4.3.1** (Step 1).

Step 3 – Review Major System Design Capacity and Flow Route (Regulatory Event)

Refer to **Section 4.3.1** (Step 2).

Step 4 - Water Quality Treatment Requirements

Refer to **Section 4.3.1** (Step 3).

Step 5 – Confirm Erosion Control Requirements for the Site

Refer to **Section 4.3.1** (Step 4).

4.3.4 Scenario D – No Quality or Quantity Controls Downstream of Site

Scenario D defines the case where there are no existing or proposed quality or quantity control facilities in place downstream of the proposed development site. Subject to discussions with the City regarding any potential downstream drainage or other issues and depending on the design of the major and minor system downstream of the proposed development, additional on-site quantity controls may be required. Subject to feasibility, on-site water quality controls that meet the Enhanced level of protection shall be provided. The steps identified below shall be followed when completing a site plan or infill development classified as Scenario D.

Step1 - Consultation with City

In the case where downstream quantity controls are not provided or previously required, a consultation with the City is required to determine if on-site quantity controls are required due to downstream drainage or other issues. Subject to clearance by the City in this regard, the following steps shall be taken in completing the site design. Should clearance not be obtained, on-site quantity controls shall be provided per discussions and agreement with the City and Conservation Authority.

Step 2 – Review Minor System Design Capacity (≤ 5 Year Event)

Refer to **Section 4.3.1** (Step 1).

Step 3 – Review Major System Design Capacity and Flow Route (Regulatory Event)

Refer to **Section 4.3.1** (Step 2).

Step 4 - Water Quality Treatment Requirements

Refer to **Section 4.3.2** (Step 3).

Step 5 – Confirm Erosion Control Requirements for the Site

Refer to **Section 4.3.1** (Step 4).

4.3.5 Interim Facilities

In cases where the proposed downstream quality and quantity control facilities have not yet been constructed, the construction of interim site controls may be considered by the City if it can be demonstrated that an acceptable level of control will be provided. The construction of any such interim facilities shall be in accordance with the applicable municipal and provincial guidelines.

4.3.6 Uncontrolled Sewershed Outfalls

Under exceptional circumstances for very small catchments (<0.5 ha) where it is not possible to provide end-of-pipe water quality (incl. oil/grit separators), erosion and quantity controls, measures should be implemented at the sewer outfall to minimize impacts regarding water quality and erosion. Such measures could include, for example, a stilling basin with cattail plantings.

4.4 Developments ≥ 5 ha

Proposed developments with drainage areas greater than or equal to 5 ha shall require the design of water quality/erosion and quantity control facilities (i.e. wet pond, constructed wetland or hybrid wet pond / constructed wetland) as described in **Section 4.7** of this document.

4.5 Source and Conveyance Controls

The following source and conveyance controls are acceptable for use within the City of Barrie:

- Roof leaders directed to pervious areas
- Rooftop storage
- Green Roofs
- Parking lot storage
- Permeable pavements
- Rainfall harvesting
- Oil / grit separators (for lots ≤ 2 ha)
- Underground storage
- Infiltration trenches
- Soakaway pits
- Grassed swales
- Vegetated filter strips
- Natural channels

- Sand filters
- Roadside ditches (industrial areas only)
- Pervious pipe systems (for treated runoff only) subject to review by the City

The following source and conveyance controls are not permitted for use within the City of Barrie:

- Rear lot ponding
- Pervious pipe systems (for untreated runoff)
- Pervious catchbasin (for untreated runoff or with exfiltration pit located underneath the CB)

With the exception of the municipal-specific guidelines identified in the sections below, the guidelines for the design of source and conveyance controls shall be in accordance with the governing guidelines which are currently documented in the *Stormwater Management Planning and Design Manual* (MOE, 2003) as a minimum requirement. In some cases, additional policies and guidelines per the NVCA's *Development Review Guidelines* and the LSRCA's *Watershed Development Policies* may also apply.

4.5.1 Roof Leaders

Roof leaders should be directed to front or rear yard pervious (grassed) areas wherever possible to promote infiltration and shall not discharge to impervious areas directly connected to the storm sewer (e.g. driveways, parking areas) unless there is no other feasible option. Roof leaders shall discharge to the ground surface via splash pads or extension pipes and flows shall be directed a minimum of 0.6 m away from buildings such as to prevent ponding or seepage into the weeping tile. Roof leader outlet locations shall be identified on the lot development plan.

4.5.2 Rooftop Storage

Flat roofs may be used to store runoff to reduce peak flow rates to storm sewer systems to mitigate the need for downstream storm sewer size increases. Per the *SWMPD Manual* (MOE, 2003), rooftop storage can typically store 50 mm to 80 mm of runoff subject to the roof loading design. Detention time is typically between 12 to 24 hours. Supporting calculations and design drawings must be provided to indicate the following:

- The total number and location of proposed roof drains and emergency overflow weirs
- The type of control device proposed (i.e. product name and manufacturer). Tamper proof devices are preferred where feasible (provision of shop drawings required).
- The City's current policy indicates a maximum flow rate of 42 L/s/ha of roof area.
- Product specifications (i.e. design release rates for identified control devices)

- Emergency overflow weirs shall be provided at the maximum design water level elevation.
- The maximum ponding depth, storage volume, and drawdown time for roof top storage during the 2-yr through 100-yr design storms

Within the jurisdiction of the Conservation Authorities, additional guidelines may also apply (e.g. roof top control devices may require registration on title as part of the Site Plan Agreement and/or Subdivision Agreement).

4.5.3 Parking Lot Storage

Parking lots may be used to store runoff to reduce peak flow rates to storm sewer systems. The maximum ponding depth shall be 300 mm and grading shall be between 0.5% and 5%. The outlet flow may be regulated through the use of permanently attached orifice plates (ICD's). The 5-yr and 100-yr ponding elevations and storage volume at each ponding location must be included on the design drawings. In addition, Regulatory storm overland flow routes are also to be indicated on the drawings. Within the jurisdiction of the Conservation Authorities, additional guidelines may also apply (e.g. parking lot control devices may require registration on title as part of the Site Plan Agreement and/or Subdivision Agreement).

4.5.4 Rear Lot Ponding Areas

Rear lot ponding or other areas of extended ponding on residential lots is not permitted.

4.5.5 Permeable Pavements

Permeable pavements are encouraged for use to reduce runoff and promote infiltration. The reduction in runoff achieved will vary based on the product used and the identified manufacturer's specifications. The City does not permit a reduction in runoff coefficient for permeable pavements (i.e. standard c-value for asphalt shall be used) for peak flow, conveyance and storage calculations.

4.5.6 Rainfall Harvesting

Rainfall harvesting facilities may be used to temporally store runoff for future use (e.g. rain barrel for watering the lawn). An overflow by-pass shall be provided at a minimum distance of 0.6 m from the foundation wall.

4.5.7 Oil / Grit Separators

Subject to approval by the City and governing Conservation Authority, designated approved oil/grit separators may be installed on small sites ≤ 2 ha where a water quality control pond/wetland is not feasible. For developments on sites > 2 ha, oil/grit separators are only permitted as a pre-treatment in the treatment train approach in conjunction with other stormwater management options approved by the City.

When completing sizing calculations for oil/grit separators, the following guidelines shall apply:

- TSS removal efficiency equivalent to the Enhanced level of treatment is required (i.e. minimum 80% TSS removal) and shall be based on the particle size distribution presented in **Table 4.1** or as otherwise indicated below.
- Calculations shall be completed using the approved rainfall data for the City of Barrie (Barrie WPCC, 1978 – 2009) with a time interval of 15 minutes. A copy of the City approved rainfall data file is provided on the CD in **Appendix I**.
- For sites exhibiting typical suspended solids characteristics, the following particle size distribution should be used:

Table 4.1: Particle Size Distribution

Particle Size Fraction [µm]	Percent by Mass [%]
≤ 20 µm	20
20 µm ≤ x ≤ 40 µm	10
40 µm ≤x ≤ 60 µm	10
60 µm ≤ x ≤ 130 µm	20
130 µm ≤ x ≤ 400 µm	20
400 µm ≤ x ≤ 4000 µm	20

Adapted from SWMP Planning & Design Manual (MOE, 1994)

- The particle size distribution identified above does not apply for special sites such as cement, aggregate, or other such manufacturing facilities that may contribute a much higher proportion of very fine or coarse particles. In such cases, a site specific particle size distribution must be determined and used in sizing calculations to ensure that the Enhanced Level of treatment is achieved.
- For sites that exhibit unstable wash-off characteristics, such as construction sites or sites with material storage, special design considerations must be addressed and supporting calculations provided to demonstrate that the Enhanced Level of treatment is achieved.

The owner is responsible for maintaining and repairing oil/grit separators installed on private property. Operation and maintenance requirements for oil/grit separators shall be identified in the SWM report for the site and shall be implemented by the owner to ensure that the continued performance of the device as designed is achieved as per the Certificate of Approval, if applicable.

4.5.8 Underground Storage and/or Infiltration

Underground storage may be used where surface SWM storage is not feasible or the volume is not adequate (subject to acceptable geotechnical and hydrogeological investigations in support of the approach). If the underground storage facility is designed for infiltration of road or parking lot runoff, a pretreatment structure shall be provided. The outlet structure shall be designed to meet the SWM control requirements. Any such facilities shall be readily accessible for any required maintenance activities. Operation and maintenance requirements for underground storage facilities shall be identified in the SWM report for the site and shall be implemented by the owner to ensure that the continued performance of the facility as designed is achieved.

4.5.9 Infiltration Trenches

Infiltration trenches are permitted and encouraged for use in the City to promote infiltration of runoff (subject to acceptable geotechnical and hydrogeological investigations in support of the approach). The maximum draw down time should be less than 48 hours, soils permitting. Longer drawdown times may be permitted where soils exhibit lower percolation rates. Infiltration trenches shall be located a minimum of 5.0 m from buildings with basements to avoid infiltration to drainage tiles and sump pumps. Operation and maintenance requirements for infiltration trenches shall be identified in the SWM report for the site and shall be implemented by the owner to ensure that the continued performance of the facility as designed is achieved.

4.5.10 Soakaway Pits

A soakaway pit is typically connected to the roof leader of a single house and may be used to store runoff and promote infiltration (subject to acceptable geotechnical and hydrogeological investigations in support of the approach). The maximum draw down time should be less than 48 hours, soils permitting. Longer drawdown times may be permitted where soils exhibit lower percolation rates. Soakaway pits shall be located a minimum of 5.0 m from buildings with basements to avoid infiltration to drainage tiles and sump pumps. Operation and maintenance requirements for soakaway pits shall be identified in the SWM report for the site and shall be implemented by the owner to ensure that the continued performance of the unit as designed is achieved.

4.5.11 Pervious Pipe Systems

Subject to the City's review, pervious pipe systems may be used to store stormwater and promote infiltration for *treated* runoff only (subject to acceptable geotechnical and hydrogeological investigations in support of the approach). Operation and maintenance requirements for pervious pipe systems shall be identified in the SWM report for the site and shall be implemented by the owner to ensure that the continued performance of the system as designed is achieved.

4.5.12 Grassed Swales

The use of grassed swales for extended detention by impoundment of water on residential lots is not permitted by the City. Grassed swales are permitted as a means to promote infiltration, but must be free flowing and designed primarily to convey runoff from the lot without any ponding with a minimum slope of 2%.

4.5.13 Natural Channels

Natural channels are designed to convey the overland flow and may also be used as a flow filter and to temporally detain storm runoff, in particular where the overland flow route uses an extended linear open space area.

4.5.14 Sand Filters

Sand filters may be used to treat stormwater from roads or parking lots prior to discharge to infiltration facilities in order to prevent clogging of the voids within the storage media and to polish the runoff prior to infiltration. Operation and maintenance requirements for sand filters shall be identified in the SWM report for the site and shall be implemented by the owner to ensure that the continued performance of the system as designed is achieved.

4.5.15 Roadside Ditches

Similar to natural channels, roadside ditches may be used as a flow filter and storm runoff detention area subject to flow conveyance design requirements and a minimum slope of 2%.

4.6 End-of-Pipe Controls

End-of-pipe control facilities shall provide the required quantity and quality control in accordance with the governing guidelines which are currently documented in the *Stormwater Management Planning and Design Manual* (MOE, 2003), unless otherwise specified below by the City.

4.6.1 Wet Pond with Extended Detention

Wet ponds are typically the preferred end-of-pipe control facility for large drainage areas. Wet ponds shall be designed in accordance with the governing guidelines which are currently documented in the *Stormwater Management Planning and Design Manual* (MOE, 2003) (Section 4.6.2), unless otherwise specified in the City’s guidelines provided in **Section 4.7**.

4.6.2 Wetland with Extended Detention

A constructed wetland is an acceptable stand-alone end-of-pipe control facility. Constructed wetlands shall be designed in accordance with the governing guidelines which are currently documented in the *Stormwater Management Planning and Design Manual* (MOE, 2003) (Section 4.6.3), unless otherwise specified in the City’s guidelines provided in **Section 4.7**.

4.6.3 Hybrid Wet Pond / Wetland with Extended Detention

A wet pond / constructed wetland hybrid is an acceptable stand-alone end-of-pipe control facility. Hybrid wet ponds / constructed wetlands shall be designed in accordance with the governing guidelines which are currently documented in the Stormwater Management Planning and Design Manual (MOE, 2003) (Section 4.6.4), unless otherwise specified in the City’s guidelines provided in **Section 4.7**.

4.6.4 Dry Pond with Extended Detention

Per Ontario Regulation 219/09, dry ponds shall not be permitted as a stand-alone treatment system. Dry ponds may be used as a part of a treatment train approach provided that the Enhanced level of water quality treatment is achieved.

4.6.5 Infiltration Basin

In general, infiltration basins shall not be accepted as a stand-alone end-of-pipe facility, unless as part of a treatment train approach or as an additional feature. Infiltration basins shall not be permitted for drainage areas > 5 ha.

4.7 Stormwater Management Facilities (Wet Ponds and Wetlands)

Effective 02 June 2009 as per the *Lake Simcoe Protection Plan* and Ontario Regulation 219/09 made under the *Lake Simcoe Protection Act*, 2008, it is required by law that all new SWM facilities shall be designed to meet the Enhanced level of protection per the *SWMPD Manual* (MOE, 2003). Regarding infill developments and the redevelopment of one or more properties only, Ontario Regulation 219/09 may not apply if the applicant can demonstrate to the satisfaction of the Director (MOE) that it is impractical to achieve the Enhanced level of protection. Stormwater management facilities shall be designed per the *SWMPD Manual* (MOE, 2003) as a minimum requirement unless otherwise specified in this document. An Operation and Maintenance Manual for the SWM facility shall be submitted to the City for the site and shall be implemented by the owner to ensure that the continued performance of the facility as designed is achieved.

4.7.1 Length to Width Ratio

The SWM facility length to width ratio shall be designed in accordance with the governing guidelines which are currently documented in the *Stormwater Management Planning and Design Manual* (MOE, 2003) (Table 4.6 and 4.7).

4.7.2 Grading (Side slope)

Grading within SWM facilities shall be designed in accordance with City of Barrie Infrastructure Standard D780 (see **Appendix A**). The maximum slope from the bottom of the permanent pool to 0.5m below the normal water level (NWL) shall be 3:1 (h:v). Within 3 m on either side of the NWL, the maximum slope shall be 6:1. Elsewhere, the maximum slopes shall be 4:1 (where the slope backs on to the rear yard lot line or an adjacent valley system), 5:1 (where the slope backs on to an adjacent road system), and 3:1 in a fenced facility. Retaining walls are not permitted in the pond block.

4.7.3 Water Levels

Water levels within SWM facilities shall be designed in accordance with City of Barrie Infrastructure Standard D780 (see **Appendix A**). The minimum depth in the forebay shall be

1.0 m. For a wetland design, the mean depth in the main cell for 75% of the surface area shall be 0.15 m to 0.30 m, the maximum depth in the deep pools shall be 1.0 m, and the maximum depth at the inlet and outlet shall be 2.0 m. The maximum depth of a wetland shall be 4.0 m from the pond bottom to the high water level. The maximum depth for water quality and erosion control and all events less than or equal to the 10-year storm is 1.0 m above the NWL and the maximum active water level is 2.0 m.

For a wet pond design, maximum depth of the permanent pool is 2.5 m with an average depth of 1.0 to 2.0 m. The maximum depth of a wet pond shall be 4.5 m from the pond bottom. The maximum depth for water quality and erosion control is 1.5 m and the maximum active water level is 2.0 m.

Regarding hybrid wet pond / wetland facilities, the active storage depths for wetlands shall apply for the entire facility, unless a terraced, overflow configuration is employed.

4.7.4 Permanent Pool, Quality and Quantity Storage Requirements

The SWM pond sizing, including the permanent pool volume, quality and quantity volume shall be designed in accordance with the governing guidelines which are currently documented in the *Stormwater Management Planning and Design Manual* (MOE, 2003). The erosion control volume shall consist of the 25 mm 4-hr Chicago storm runoff volume released over 24 hours. Where feasible, a drawdown pipe with a control valve shall be included to drain the facility by gravity for maintenance.

4.7.5 Forebay

The forebay, including dispersion length, minimum required bottom width and forebay berm, shall be designed in accordance with the governing guidelines which are currently documented in the *Stormwater Management Planning and Design Manual* (MOE, 2003). A berm shall be constructed with a forebay spillway invert at the NWL with appropriate erosion protection to enable, as a minimum, the flow of the water quality event (25 mm event) without overtopping any other part of the forebay into the main cell of the facility. The minimum top width of the berm shall be 1.0 m. A dewatering sump per City of Barrie Infrastructure Standard D781 (see **Appendix A**) shall be installed in the forebay to enable the drawdown of the permanent pool for maintenance and sediment removal. Where feasible, the forebay sump shall be connected to the pond outlet structure with a control valve to drain by gravity. Where draining by gravity is not feasible, a dewatering sump shall be included and drained by pump.

Unless it can be demonstrated by a geotechnical engineer that the bearing capacity of the native soils on the bottom of the forebay is sufficient to support maintenance machinery for the removal of sediment, the bottom of the forebay shall be lined with 300 mm of 50 mm diameter crusher run rock, or as recommended by a geotechnical engineer. Unstable native soils may warrant the use of geotextile lining under the rock. The forebay lining shall be certified by a geotechnical engineer to provide sufficient bearing capacity to support maintenance equipment during sediment removal assuming that the forebay is dewatered prior to maintenance activities.

4.7.6 Freeboard

A 0.3 m freeboard is required above the *maximum routed water level* under the Regional Storm. For Regional control ponds (i.e., ponds intended to provide post-to-pre control for the Regional event), the maximum routed water level will equal the maximum water level to control the storm. For 100 year control ponds (i.e., ponds intended to provide post-to-pre control for the 100 year event), the maximum routed water level will equal the maximum water level required for the pond to convey the Regional Storm through the pond. This assumes that the Regional outflow rate is not limited to pre-development levels.

4.7.7 Berming

Berms around wetlands and wet ponds shall be designed with a minimum top width of 2.0 m (where trails and access roads are not located) with a 3:1 maximum side slope on the outside. The core of the berms shall be constructed with engineered fill on the basis of the recommendations of a licensed geotechnical engineer. Topsoil is not permitted for berm construction except as a dressing to support vegetation on the top of the core. For pond berms exceeding 2.0 m in height, the berm must be designed by a qualified professional engineer in accordance with the *Ontario Dam Safety Guidelines*.

4.7.8 Sediment Drying Area

A sediment drying area shall be provided, where feasible, as follows:

- Sized for a minimum of 10 years of sediment accumulation.
- Sized assuming a maximum sediment height of 1.5 m and sediment slope of 10:1.
- Located at or above the predicted 2 year water level and near the maintenance access road.
- Setback a minimum of 6.0 m away from all property lines.

Temporary sediment drying areas may be provided on adjacent parks and within road allowances with drainage directed back to the facility subject to approval by the City.

4.7.9 Maintenance Access Roadway

Maintenance access roads are required to all inlets, outlet structures, sediment forebays, and sediment drying areas (if applicable) within the SWM facilities. Where feasible, two access points shall be provided from the municipal road allowance such that the access road is looped to key hydraulic features. In situations where this is not practical, dead end access roads shall be designed with a hammerhead turning area consisting of a minimum hammerhead width of 17.0 m and a 12.0 m centerline turning radius.

The maintenance access road shall consist of a minimum 300 mm of compacted granular “A” (or as recommended by a geotechnical engineer) with a surface treatment consisting of 50 mm topsoil and Simcoe County Native Seed Mixture. The access roads shall provide for all-weather ingress and egress with a minimum width of 5.0 m and a maximum grade of 10%. Curves on all access roads shall have a maximum centerline radius of 12.0 m.

Where the access road enters the forebay below the NWL, the forebay ramp shall be constructed consistent with the lining of the bottom of the forebay or as recommended by a geotechnical engineer. Ramp access should favour “green” solutions.

4.7.10 Fencing

Fencing shall be installed where the SWM facilities abut private lots unless maximum slopes of 6:1 are provided. Where required, fencing shall be installed as per City of Barrie standards.

4.7.11 Aesthetics

The SWM facilities shall be constructed with acceptable building materials (e.g., no gabions) that are not unsightly. A landscape plan shall be prepared as per **Section 4.8**. SWM facilities shall be integrated with parks and trails where feasible.

4.7.12 Warning Signage

Warning signs shall be clearly visible and erected at all access points to the SWM facility. Warning signs shall be supplied and installed by the developer and designed in accordance with City of Barrie Infrastructure Standard D783 (see **Appendix A**).

4.7.13 Inlet Structures

Inlet structures shall be installed with the invert set to the NWL or higher. Submerged inlets shall only be permitted if the obvert of the pipe lies below the maximum anticipated thickness of ice. Suitable erosion control and energy dissipation treatment shall be provided at all inlets to the pond. Headwalls and safety grating shall be installed at all inlets per OPSD. SWM pond inlet elevations are to be designed such that the 1:5 year storm design sewer capacity as per the storm sewer design sheet is maintained and not reduced due to tailwater conditions.

4.7.14 Outlet Control Structures

Outlet control structures shall be designed with flow regulating devices (e.g. orifice) to control the flow and pond drawdown time. Where feasible, wet pond and wetland outlet structures shall be designed per City of Barrie Infrastructure Standards D777 **and** D778, respectively (see **Appendix A**). Outlet structures are to be designed in a safe and aesthetic manner with the majority of the structure contained within the berm. A perforated riser should be installed at the intake associated with the bottom draw pipe connected to the outlet control structure. A maintenance draw down pipe with valve shall be installed where feasible to enable the dewatering of the pond for maintenance activities such as sediment removal. Suitable erosion control and energy dissipation treatment shall be provided at the pond outfall per City of Barrie Infrastructure Standard D782 (see **Appendix A**) where it discharges to the receiving body. The sizing of rip rap or river stone at the outfall shall be based on appropriate erosive velocity calculations. The outlet structure should be designed to operate under free-flowing conditions where feasible. The return period water surface elevations of the receiving body must be determined and verified to ensure the proper operation of the outlet structure. Where it is not feasible to operate the outlet structure under free-flowing conditions, appropriate submergence calculations must be completed to ensure that the outlet structure is sized correctly.

When a temporary SWM facility is required and approved by the City (e.g. when the ultimate downstream SWM facility has not yet been constructed), a temporary outlet structure shall be designed in accordance with City of Barrie Infrastructure Standard D779 (see **Appendix A**). Temporary SWM facilities shall remain in place until the ultimate downstream controls have been constructed to the satisfaction of the City. The maintenance, operation and full decommissioning of temporary SWM facilities shall be the sole responsibility of the land owner and such responsibility shall be reflected in the site plan or subdivision agreements.

4.7.15 Emergency Spillway

All SWM facilities shall be designed with an emergency spillway. The emergency spillway shall be designed to convey the larger of the unrouted 1:100 year or the Regional peak flow with the invert of the spillway set, as a minimum, at the 100-yr controlled water level (or Regional controlled water level for ponds where Regional control may be required). A freeboard of 0.3 m shall be provided above the maximum routed water level under the Regional storm. The spillway shall be treated for erosion protection that is adequately designed to withstand the erosive velocity associated with the uncontrolled governing flow. The erosion protection shall be integrated with a natural vegetated surface treatment that is aesthetically pleasing. Spillway side slopes shall not be steeper than 3:1 and shall be no steeper than 10% when incorporated into the access road. The spillway shall not be located directly above the outlet control structure and a minimum clearance of 3.0 m shall be provided.

4.7.16 Major System Overland Flow Routes

The major system overland flow route to the SWM facilities shall be designed to safely convey the Regulatory (*i.e.* the larger of the 100-yr storm and Hurricane Hazel) overland flow. Should the overland flow route to the SWM facility consist of the access road and path, then the flow depth shall not exceed 0.30 m or a velocity of 0.65 m/s. Where feasible, the overland flow should not be directed into the forebay to avoid the re-suspension of settled sediments.

4.7.17 Anti-seepage Collars

Anti-seepage collars shall be installed on all outlet pipes or as directed by a geotechnical engineer.

4.7.18 Existing Groundwater Elevation

The bottom of the SWM pond shall be a minimum of 1.0 m above the seasonal high GWL unless it can be demonstrated by a hydrogeologist to the satisfaction of the City that there will be no impact to groundwater elevation and groundwater quality. Otherwise, if it is not feasible to maintain the required separation distance, a suitable liner shall be installed based on consultation with a hydrogeologist.

4.7.19 Fire Use

In certain locations of the City, and subject to review by the City, it may be desirable to utilize the SWM pond as a source of water for fire use by incorporating a dry hydrant design. The design must meet the requirements of the Ontario Building Code for dry hydrants which is currently in accordance with FPA 1142, *Water Supplies for Suburban and Rural Fire Fighting*.

4.7.20 West Nile Virus

Reasonable measures should be incorporated in the design of wet ponds and wetlands to minimize the proliferation of mosquitoes and the potential spread of the West Nile virus and to reduce the need to apply larvicide. Such measures, which focus on creating habitat less suitable for mosquito breeding and survival, include the following (adapted from *TRCA Innovative Stormwater Management Workshop*, Culex Environmental, May 2008):

- *Encourage a plant-dominated state as opposed to an algae-dominated state* – A plant-dominated state (i.e. lots of submerged and floating-leaved aquatic plants) provides habitat for predators whereas an algae-dominated state is less favourable for predators and more favourable for mosquitoes with increased availability of nutrients and turbidity as a food source and warmer water. In addition, mosquito larvae tend to avoid submerged and floating-leaved plants.
- *Introduce predators* – Along with a plant-dominated state introduce predators that feed on mosquito eggs and larvae, such as: grazing invertebrates (e.g. snails, Mayfly larvae, Chironomids), neustonic insects (e.g. water striders, water boatmen, whirligig beetles), benthic invertebrates (e.g. flatworms, leeches, Asellus, shrimps), three-spined sticklebacks, fathead minnows, dragonfly nymphs, water beetles, Alderfly larvae, and frogs and toads. In addition, bird and bat houses should be erected to encourage the nesting of bats and birds such as swallows and purple martins which rely on flying insects including mosquitoes as their primary food source.
- *Maximize water depths* – Where possible, the minimum depth of water within the permanent pool should be 1 m or greater.

4.7.21 Thermal Impacts

When discharging to a watercourse identified as a cold water fishery, mitigation measures such as shoreline planting, shading by trees, bottom draw outlet pipes from deeper pools, or cooling trenches shall be implemented to minimize thermal loading to the receiving watercourse.

4.7.22 Trails

Pedestrian circulation trails shall be incorporated into SWM facilities where public safety has been fully addressed in terms of access, side slopes and fencing requirements. The feasibility of connections to adjacent neighbourhood parks, recreation areas and existing trail networks is to be explored as part of the initial pond submission plans to the satisfaction of the City.

4.7.23 Maintenance and Inspections Protocol

An operation and maintenance manual shall be prepared that identifies on-going operation protocol and maintenance issues (as required by the *Lake Simcoe Protection Plan*), including, but not limited to, the following:

- The procedure for draining the forebay during required maintenance
- The method for sediment removal from the forebay
- The annual sediment loading rate and the estimated sediment accumulation in the facility
- The sediment clean-out frequency
- The inspection procedures and frequency of inspections
- A description of the pond features and pond operating characteristics
- A monitoring program plan for periodic water quality sampling for priority SWM works as per the *Lake Simcoe Protection Plan*.

4.7.24 In-fill Development and Re-development

Per Ontario Regulation 60/08, all new SWM facilities shall provide Enhanced level of water quality protection. For in-fill and re-development sites where it can be demonstrated that the Enhanced level of protection is not feasible, a reduced level of protection may be acceptable subject to approval by the Director (MOE) and the City.

4.8 Stormwater Management Facility Planting Guidelines

The following section outlines the specific design criteria and planting requirements which are to be followed within stormwater management (SWM) facilities and/or wetlands within the City of Barrie. These criteria are in addition to the minimum standards outlined within the MOE's *Stormwater Management, Planning and Design Manual* and planting standards for both the LSRCA. and the NVCA. Landscaped areas shall consist of native species only as per the

Native Plant Species in Ontario (Riley, 1989) provided in the *NVCA Pond Planting Guidelines* (NVCA, April 2006) with the exception of those unacceptable/invasive species identified by the LSRCA and included in **Appendix J**. If a development is located within an area where an overall SWM planning study (*i.e. Environmental Impact Study, Ministry of the Environment Special Provisions*) is available, the design criteria and recommendations as specified in the appropriate study must also be followed where specific direction is given.

4.8.1 Planting Zones

1. SUBMERGENT (*Deep Water*) – Water depth 0.5m to 2.0m
    - Planting is to consist of a combination of both floating and submergent species.
    - Planting must include at least (3) three species each of robust, broadleaf and narrow leaf plant varieties.
2. AQUATIC FRINGE (Shallow Water) – Water depth 0.0m to 0.5m
    - Planting is to consist of a combination of both floating and submergent species.
    - Planting must include at least (4) four species each of robust, broadleaf and narrow leaf plant varieties.
3. SHORELINE FRINGE (Extended Detention) – 1.0m (horizontal) from the permanent pool elevation
    - Plantings zone appropriate wetland species must include perennial sedges, rushes and wild flowers in combination with shrubs and wetland seed mix.
    - The shoreline fringe is subject to fluctuations in water levels which will result in regular flooding and therefore plant selections must be flood tolerant.
4. FLOOD FRINGE – 2.0m (horizontal) from the limit of the shoreline fringe limit or to the 100 year flood level (whichever is greater)
    - Plantings must include a diverse variety of no less than (4) four flood tolerant species each of shrubs, deciduous trees and coniferous trees.
    - Trees and shrubs within the flood fringe will provide canopy structure to mitigate thermal effects on water temperature.
    - Herbaceous plant material may be provided by the use of an approved wet meadow seed mix which will be applied in combination with an annual rye nurse crop.
5. UPLAND – includes all areas outside the 3.0m flood fringe
    - Plantings will include a minimum of (5) five species each of drought tolerant deciduous and coniferous trees and shrubs.

- Upland planting is intended to provide visual screening, aesthetic appeal, wind blockage and shading to mitigate thermal effects on water temperature.
- Provide a minimum 1.5m buffer between plantings and any structures such as maintenance roads and drying areas and fencing which abuts residentially zoned property.

4.8.2 Planting Guidelines

AQUATICS (Submergent and Aquatic Fringe)

- Spacing requirements for aquatics in plug form is 5 units per m^2.
- Spacing requirements for aquatics in 100cm potted form is 4 units per m^2.
- Spacing requirements for aquatics in 150cm potted form is 3 units per m^2.
- Cattails (*Typha spp.*) will be planted as interim perimeter vegetation in sediment forebays to increase sediment trapping. The use of this material will not limit maintenance access and it is acceptable that this material will be removed during dredging operations.
- Other aquatic species will not to be placed within the forebays as they would be less likely to re-colonize after dredging operations.
- Plant material must be comprised of 100% native stock.
- Protection from geese and other water foul may be required during initial aquatic plant installations.
- Aquatic fringe plant installations should be installed (1) full growing season after that of both the shoreline and flood fringe or at such time as a complete vegetative buffer is established around the pond perimeter as deterrence to geese.

TERRESTRIAL (Shoreline Fringe, Flood Fringe and Upland)

- Do not utilize plant material which has been removed or harvested from natural wetlands or roadsides as they may contain invasive or non-native species.
- Plant material must be comprised of 100% native stock.
- Plant shrubs in groupings of no less than 15 units to promote both colonization and spreading.
- Shrubs are to be no less than 60cm height (*container grown stock only*).
- Deciduous trees within the flood fringe are to be no less than 60mm caliper stock.

- Deciduous trees within the upland may utilize a combination of caliper material and whip stock where caliper trees are planted based on a rate of 1 unit per 25m^2. Whip stock is to be installed at a rate of 6.25 units per 25m^2.
- Coniferous material well be no less than 2000mm in height where height is measured from the top of the root ball to the first whorl (*does not include the leader*).
- Where applicable, shrubs, deciduous trees and coniferous trees are to be installed in accordance to current City of Barrie Standards.
- Rodent protection will be installed around the base of all deciduous trees.
- Bio-engineering (*e.g. live staking*) should be implemented on steep slopes in conjunction with other stabilization methods. Live staking will not be considered for use against density calculations for plant material.

4.8.3 Calculation Table for Planting Density

Table 4.2: Calculation Table for Planting Density

	A	**B**	**C**	**D**	**E**	**F**
ZONE	ZONE AREA	WATER'S EDGE	[1]QUANTITY OF AQUATIC SPECIES 35% Coverage	QUANTITY OF PLANT COVERAGE 50% Coverage	[2]NUMBER OF TREES REQUIRED	NUMBER OF SHRUBS REQUIRED
SUBMERGENT	n/a	B (lin. m)	C = B* 0.35	n/a	n/a	n/a
AQUATIC FRINGE	n/a	B (lin. m)	C = B* 0.35	n/a	n/a	n/a
SHORELINE FRINGE	A (m^2)	n/a	n/a	D = A*0.5	n/a	F = D
FLOOD FRINGE	A (m^2)	n/a	n/a	D = A*0.5	E = (A/1000)*25	F = D-(E*15)
UPLAND	A (m^2)	n/a	n/a	D = A*0.5	E = (A/1000)*25	F = D-(E*15)

1. *Quantities are based on plugs (5 units per sq/m)*
2. *Quantities are based on caliper stock (1 unit per 25m^2)*

4.8.4 Topsoil

- Topsoil must meet the current Ontario Provincial Standard Specification No.570 (OPSS-570).
- Topsoil will be laboratory tested and the subsequent findings forwarded to Parks Planning and Development for approval prior to placement of topsoil.
- Testing must demonstrate that topsoil has sufficient organic and nutrient content and is suitable for sustaining plant material which is to be placed into the pond and/or wetland.
- Soil amendments required as a result of laboratory testing must be completed prior to or during the placement of topsoil in accordance with laboratory findings and amendment requirements.
- Provide topsoil at a minimum depth of 0.45m to a maximum depth of 1.0m beginning at the permanent pool elevation and including all terrestrial planting areas.
- Provide topsoil at a minimum depth of 0.35m from the permanent pool elevation to 1.0m (horizontal) into the pond. The remaining pond area is to receive a minimum topsoil depth of 0.2m.
- Stabilize topsoil after placement prior to the installation of woody plant material. In the event that erosion control blankets are utilized in combination to approved seed mixes for stabilization purposes, the netting and blanket material will be 100% bio-degradable. Photo-degradable plastic or plastic netting is not permitted for stabilization products.
- If topsoil stabilizations can not be completed within (1) one construction year's growing season, the topsoil should not be placed until the following spring. In this event, sediment controls must be in place to prevent erosion of stockpiled materials.

4.8.5 Seeding

- All seed mixes are to be placed in combination with an annual rye nurse crop and will be applied at a rate of 12kg per hectare.
- All upland areas are to be seeded using a 'Simcoe County Native Seed Mix' applied at a rate of 20kg per hectare.
- Shoreline Fringe and Flood Fringe areas are to be seeded using an approved 'Wet Meadow' or seasonally flooded annual/perennial seed mix which are to be applied at a rate of 20kg per hectare.
- Seed application is to follow directly after topsoil placement in order to establish vegetative cover quickly for stabilization of topsoil.
- Erosion control blankets are to be placed over top of seeded areas immediately after application where required.

- Contractor will insure 100% coverage and establishment within the stormwater facility throughout the warranty period.

4.8.6 Guarantee Period

- All aquatics, perennials, trees and shrubs are to be guaranteed for a period of not less than one year from the beginning of the general maintenance period.
- If aquatics, perennials, trees and/or shrubs are found dead, diseased, missing or are deemed to be unhealthy within the guarantee period the defective plants are to be replaced and re-guaranteed for an additional two years.

4.8.7 Monitoring and Maintenance

- Vegetation monitoring plans and schedules are required with all landscape plan submissions which will include monitoring of the performance and effectiveness of interim measures (e.g. nurse crops) and monitoring of plant health during droughts.
- Monitoring reports for will be provided to the City of Barrie from the time of the initial plant installations until the end of the guarantee period. Inspections are to take place during September of each year and are to be provided to the City of Barrie no later than October 7th of each year.
- Mulch saucers should be placed and maintained around the base of trees to retain water.
- Watering activities should continue for the first two years after planting.

4.9 Emerging Technologies

The City of Barrie will consider the use of emerging technologies for stormwater management. Some existing emerging technologies that have demonstrated an ability to provide water quality and quantity benefits include the following:

- Greenroofs (vegetated roofs)
- Subsurface infiltration tanks
- Infiltration drainfields
- Subsurface infiltration beds
- Phosphorus removal technologies
- Phoslock
- Low Impact Development (LID)

Additional details and descriptions of various emerging technologies for stormwater management are provided in **Appendix F**. Due to the nature of emerging technologies, there is typically a lack of available monitoring data or design guidelines. As such, it is incumbent upon the proponent or Consulting Engineer to provide complete supporting calculations when submitting stormwater management designs utilizing emerging technologies. A pre-consultation meeting with the City and governing Conservation Authority to discuss the use of emerging technologies is recommended to review the proposed design and to establish any specific requirements. All submissions employing stormwater management designs with emerging technologies will be reviewed by the City and other review agencies on a site-by-site basis.

4.10 General Maintenance Requirements

In order to ensure the optimal and long term continued operation of the source and conveyance controls and end-of- pipe controls for stormwater management prior to and following assumption (where applicable), it is important that the stormwater management controls be regularly maintained. Some of the key components of an effective maintenance program include:

- Regular cleaning of source and conveyance controls, and inspections to identify clogging (e.g. permeable pavements, infiltration trenches), sediment/oil accumulation (e.g. oil/grit separators), and structural failure in need of maintenance.
- Regular inspections and maintenance of end-of-pipe controls (e.g. wet ponds, constructed wetlands, hybrid ponds) as outlined in the operation and maintenance manual prepared for each facility.
- Provide and maintain a log book noting all maintenance activities.

5.0 REQUIREMENTS FOR EROSION AND SEDIMENT CONTROL DURING CONSTRUCTION

The SWM report shall include the list of items below in terms of controlling erosion and the transport of sediment into natural watercourses during construction. However, since the list is intended to cover a broad range of development proposals, portions of the submission list may not be applicable for all development proposals.

- Erosion and Sediment Control Plans
- Erosion and Sediment Control Phasing
- Worksite Isolation Plan for In-stream Construction
- Spill Control and Response Plan
- De-watering plan
- Storm Drain Outfall Protection
- Storm Drain Inlet Protection
- Seeding/Sodding
- Sediment/Silt Control Fence
- Interception/Diversion Swales and Dykes
- Vehicle Tracking Control/Mud Mats
- Sediment Traps
- Rock Check Dams
- Temporary Sediment Control Ponds/Basins
- Topsoil Stockpiles
- Construction Access Mud Mats
- Restoration

The design of erosion and sediment control measures shall be in accordance with the City of Barrie *Site Alteration By-Law (2006-101)* and permit requirements as well as the *Erosion and Sediment Control Guideline for Urban Construction* (December, 2006) and with applicable City of Barrie standards.

6.0 ASSUMPTION PROTOCOL FOR STORM SEWERS AND SWM PONDS

6.1 Performance Evaluation of Storm Sewer Prior to Assumption

Prior to assumption of the storm sewer by the City, the following protocol shall be followed to ensure that the storm sewer system is operating per the design:

- A survey shall be completed for the storm sewer including maintenance holes and as-constructed drawings shall be prepared.
- The storm sewer design sheets shall be revised as required to verify adequate design capacity.
- A video inspection of the storm sewer including maintenance holes shall be undertaken by the developer/owner with City staff in attendance to identify any deficiencies (including damages). A digital and hardcopy record of the video inspection along with written certification from the developer's consulting engineer confirming that the storm system has been constructed as per the approved design drawings and approved plans must also be provided.
- A deformation test (PEGG Test) shall be completed on all PVC storm pipe to identify pipe sections that may require replacement. Pipe sections that do not allow the "pig" to pass freely shall be replaced.
- The storm sewer and catchbasins shall be thoroughly flushed and cleaned to remove all sediments as required.

All inspections shall be conducted in compliance with the Occupational Health and Safety Act (OHSA) (e.g. confined space entry protocol).

6.2 Performance Monitoring of SWM Ponds Prior to Assumption

All new SWM facilities shall undergo a 1 year performance monitoring evaluation and shall meet the design requirement to the satisfaction of the City. Prior to assumption, the performance evaluation shall include, as a minimum requirement, the following items:

- Complete inspection and verification of hydraulic structure design, dimensions and elevations.
- Bathymetry to determine the volume of sediment accumulation within the facility.
- Water quality (phosphorus) monitoring.
- Plant monitoring as per **Section 4.8.7**.
- Provide and maintain a log book noting all inspection and monitoring activities

6.3 SWM Pond Assumption Protocol

Prior to assumption of any SWM facilities by the City, the following steps shall be taken:

- Complete a pond performance evaluation.
- Complete inspection of facilities.
- Bathymetry, including removal, testing, and safely disposing of any accumulated sediments at a suitable offsite location, if required.
- As-constructed survey of SWM pond block and all key pond elements and hydraulic structures.
- Written clearance from a Landscape Architect that all pond plantings are as approved on the design drawings and are established. Pond plantings must be shown to be healthy and complete. Any dead, diseased or missing material must be replaced prior to assumption inspection.

6.4 Lot Grading

Lot grading shall conform to current City guidelines.

7.0 GUIDELINES FOR HYDROLOGIC AND HYDRAULIC ANALYSES

The guidelines in this section provide some direction for completing hydrologic and hydraulic studies for submission to and review by the City of Barrie. Prior to undertaking hydrology and hydraulic modeling work, the City of Barrie Infrastructure Department shall be contacted to confirm the use of an approved and appropriate software package. A number of relevant sample problems and calculations are provided in **Appendix C**.

7.1 Rainfall Data

7.1.1 City of Barrie IDF Curves

Until the Regional Intensity-Duration-Frequency (IDF) curves are available, stormwater management facilities should be designed based on the most current IDF tables developed by Environment Canada for Barrie including a 15% increase in rainfall intensity data to account for impacts due to climate change. The Chicago distribution parameters for different return periods provided in **Table 7.1** should be used for modeling purposes.

Table 7.1: Barrie WPCC IDF Curve Parameters - Adjusted to Account for Climate Change

Parameter	Return Period					
	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr
A	675.586	843.019	976.898	1133.123	1251.473	1383.628
B	4.681	4.582	4.745	4.734	4.847	4.905
C	0.780	0.763	0.760	0.756	0.753	0.754

Rainfall Intensity, $I\ (mm/hr) = A/(t+B)^C$, where t is time duration in minutes

Parameters based on rain gauge data for the period 1979 – 2003 for the Barrie WPCC Station #6110557

Based on a review of the literature, the IDF intensity values for Barrie WPCC Station were increased by 15% before calculating a, b, c values to account for climate change.

7.1.2 Return Period Design Storms and Regional Storm

1: 2 year, 1:5 year, 1:10 year, 1:25 year, 1:50 year, 1:100 year and the Regional Storms shall be applied for quantity control and the 25 mm 4-hour Chicago storm shall be applied for erosion control as required. In order to determine the critical design storms, the SCS Type II (6-hr, 12-hr and 24-hr durations) and the 4-hour Chicago storm distributions for the 1:2 year through 1:100 year return period shall be applied.

Unless otherwise directed by the City, Hurricane Hazel shall be applied throughout the City as the Regional storm for the sizing of municipal infrastructure associated with storm drainage and stormwater management. It should be noted, however, that either the Timmins storm or Hurricane Hazel shall be used as the Regional storm within the respective jurisdictions of the

NVCA and the LSRCA for the preparation of floodplain mapping where applicable. In addition, watershed and subwatershed hydrology models within the City that lie within the NVCA jurisdiction must include the Timmins storm such that appropriate peak flow information is available as required (*e.g.* for either floodplain mapping or culvert/bridge designs on a watercourse where applicable.

City approved design storm hyetographs for computer modeling (adjusted to account for climate change) are provided in **Appendix B** and on CD in **Appendix I**. An analysis of design storm durations for use within the City of Barrie is provided in **Appendix H**. A map delineating the flood hazard criteria zone boundaries (*i.e.* where to apply Hurricane Hazel and the Timmins storm) within the City of Barrie is provided in **Appendix B**.

7.1.3 Probable Maximum Rainfall (PMR)

The probable maximum rainfall (PMR) is defined as the largest precipitation event that can be reasonably expected to occur over a selected basin. Hydrological/hydraulic calculations using the PMR may be required and/or requested by the City or Conservation Authority under special circumstances where the risk of catastrophic loss of life is deemed to outweigh the cost of implementing a more stringent design criterion using the PMR.

7.1.4 Snowmelt and Winter Precipitation

During the winter months the occurrence of rainfall is typically less intense than during the summer. However, due to frozen ground conditions that result in lower infiltration rates and in conjunction with snowmelt, significant runoff volume and flow rates are possible that may exceed that resulting from summer storms. Based on previous studies, the rain plus snowmelt design event can exceed the summer design rainfall event for long duration storms (i.e. the 24 hour or 48 hour event). Given the limited size of the watersheds within the City, it is unlikely that an analysis of snowmelt and winter precipitation would be required, however, the City may request such an analysis under certain circumstances (*e.g.* areas with severe spring flooding) where there is deemed to be a high risk to public safety.

7.2 Runoff and Flow Calculations

7.2.1 Rational Method

The rational method shall be used for the design of storm sewers and conveyance infrastructure within the proposed development for drainage areas ≤ 50 ha. Storm sewers and conveyance infrastructure with a drainage area > 50 ha shall be designed using a computer model approved by the City and verified with the rational method. An analysis of drainage area size limitations for the application of the rational method is provided in **Appendix G**.

Regarding flow control calculations (*e.g.* SWM facility), the rational method can be used for small (≤5 ha) sites. Otherwise, an approved hydrologic model shall be used.

When the rational method is used, the minor storm sewer system design shall be based on a 5 year return frequency unless otherwise directed by the City. The design of the storm sewers shall be computed using the City of Barrie's Storm Sewer Design Sheet as provided on the City of Barrie Website under the Stormwater category**.**

All storm sewers shall be designed according to the rational formula where:

$$Q = \frac{(C)(i)(A)}{360}$$

where,

Q = the design flow (m^3/s)

C = the site specific runoff coefficient

A = the drainage area (ha)

i = rainfall intensity (mm/hr)

The average rainfall intensity shall be calculated in accordance with **Table 7.1** using the following equation:

$$I = \frac{A}{(T_c + B)^C}$$

where,

I = average rainfall intensity (mm/hr)

A,B,C = the IDF equation coefficients (dimensionless)

T_c = the time of concentration (min)

where *T* (in minutes) is the sewer pipe inlet time plus the time of travel in a closed conduit or open channel to the design point. The first leg of a storm sewer system shall be designed using an initial time of concentration or inlet time of 10 minutes.

7.2.2 Hydrologic Computer Programs

Some of the hydrologic programs supported by the City include Visual OTTHYMO (VO2), SWMHYMO, and PCSWMM.NET. Prior consultation with the City should be completed to ensure that the selected software is acceptable to the municipality if proposing to use a program other than those noted above.

Single Event Models

Event based hydrologic programs, including Visual OTTHYMO (VO2), SWMHYMO, and PCSWMM.NET can be used to simulate peak flows associated with different return period design storms.

Continuous Models

Continuous hydrology programs, including PCSWMM.NET and SWMHYMO can be used to simulate flows associated with actual continuous rainfall data.

Model Calibration and Verification

Hydrology models shall be calibrated and verified for runoff volume, peak flow, and timing when reasonably feasible or if requested by the City and suitable flow data and precipitation data is available. Calibration parameters such as CN should be adjusted to AMCII conditions (average soil moisture) for calibrated event based models.

When it is not feasible to calibrate the hydrology model, the critical physical parameters (e.g., CN numbers, Imperviousness, Average Slope and Time to Peak) shall be derived from the guidelines and the best available information such as watershed plans or master drainage plans. A sensitivity analysis should be completed for uncalibrated models since small changes in parameter values can often result in significant changes in model results.

Channel and Reservoir Routing

The rating curves and travel times used in channel routing and reservoir routing shall be determined by preliminary hydraulic calculations of the backwater profile or by procedures available in the approved hydrologic model. Sufficient channel routing should be incorporated into the hydrologic model.

The routing computation time step must be relative to the smallest channel section, and at a maximum equal to the hydrograph time step.

Antecedent Moisture Conditions

The antecedent moisture conditions used for hydrologic modeling, including the selection of CN values shall be AMC II (average moisture condition). When the last 12 hours of the Hurricane Hazel storm is used for modeling (as is common practice), the AMCIII condition shall be used to account for saturated soil conditions due to the previous 36 hours of rainfall associated with the event. A conversion table for CN values under different antecedent moisture conditions is provided in **Appendix B**.

7.2.3 Flow Through Hydraulic Structures

The following table provides a list of acceptable coefficients for free flowing hydraulic structures such as weirs, orifices and spillways. The associated flow equations for common structures are as follows:

Sharp Crested Weir with End Contractions

$$Q = C(L - 0.2H)(H)^{\frac{3}{2}}$$

where,

Q = flow rate (m^3/s)

H = head on the weir (m)

L = crest length of the weir (m)

C = weir coefficient.

Sharp Crested Weir Without End Contractions and Broad-crested Weir

$$Q = (C)(L)(H)^{\frac{3}{2}}$$

where,

Q = flow rate (m^3/s)

H = head on the weir (m)

L = crest length of the weir (m)

C = weir coefficient.

Orifice and Orifice Tube

$$Q = (C)(A)\sqrt{2g\Delta h}$$

where,

Q = flow rate (m^3/s)

Δh = differential head measured from the centroid of the orifice (m)

g = acceleration due to gravity (m/s^2)

C = coefficient of discharge. The coefficient for an orifice tube (C=0.80) is valid for a short tube where the tube length is approx. equal to 2.5 times the orifice diameter.

Table 7.2: Weir and Orifice Coefficients

Application	C
Orifice	0.63
Orifice Tube	0.80
Sharp Crested Weir	1.837
Broad Crested Weir (SWMP and dam spillway)	1.7
Broad Crested Weir (road crossing)	1.5

Adapted from NVCA Development Review Guidelines (April 2006)

Time of Concentration and Time to Peak

Airport Formula

The Airport formula should be used when the composite runoff coefficient for the catchment is < 0.40. The Airport formula is defined as follows:

$$t_c = \frac{3.26(1.1 - C)(L)^{0.5}}{S_w^{\ 0.33}}$$

where,

t_c = time of concentration (minutes)

C = runoff coefficient

S_w = watershed slope (%) calculated as per MTO methodology (*MTO Drainage Management Manual*, 1997)

L = watershed length (m) calculated as per MTO methodology (*MTO Drainage Management Manual*, 1997)

Bransby Williams Formula

The Bransby-Williams formula should be used when the composite runoff coefficient for the catchment is > 0.40.

$$t_c = \frac{(0.057)(L)}{(S_w)^{0.2}\,(A)^{0.1}}$$

where,

t_c = time of concentration (minutes)

A = watershed area (ha)

S_w = watershed slope (%) calculated as per MTO methodology (MTO Drainage Management Manual, 1997)

L = watershed length (m) calculated as per MTO methodology (MTO Drainage Management Manual, 1997)

Uplands Method

The Uplands Method is appropriate when the flow path consists of a number of different land covers. The average overland flow velocity is determined for a catchment based on the catchment slope and land cover type. The individual travel time for each land cover is summed to obtain the total travel time. The velocity used in the Uplands Method is calculated as follows:

$$V = (C_u)(S)^{0.5}$$

where,

V = average overland flow velocity (m/s)

C_u = $V/S^{0.5}$ (Uplands coefficient)

S = average slope (m/m)

And the Uplands coefficient for different land covers is defined in the following table:

Table 7.3: Uplands Coefficients for Different Land Covers

Land Cover	Cu (V/S^0.5)
Forest with heavy ground litter, meadow (overland flow)	0.6
Fallow or minimum tillage cultivation (overland flow)	1.5
Short grass pasture and lawns (overland flow)	2.3
Cultivated, straight row (overland flow)	2.7
Nearly bare ground (overland flow)	3.0
Grassed waterway (ditch)	4.6
Paved areas (sheet flow) and shallow gutter flow	6.1

Source: modified from Figure 3.11, American Iron and Steel Institute, "Modern Sewer Design: Canadian Edition," Corrugated Steel Pipe Institute, 1996 and Stormwater Conveyance Modeling and Design, Haestad Methods, First Edition, 2003.

The time to peak should be calculated based on the following formula:

$$T_p = 0.67(t_c)$$

where,

T_p = time to peak (hours)

T_c = time of concentration (minutes)

7.2.4 Dual Drainage Analysis

Dual drainage analysis programs (*e.g.* PCSWMM.NET) shall be used to generate the inflow captured by the minor system during the design storm for the major system and HGL analysis, if the major system and HGL analysis design event is larger than the minor system design storm.

7.2.5 Calculation of Model Parameters

Model parameters shall be site specific, area weighted if required, and provided with the design documents. Soils information shall be obtained from on-site soil testing (*e.g.* borehole data) or soil survey mapping (*e.g. Soil Survey of Simcoe County*).

Table 7.4: Curve Numbers for Selected Land Uses

Land Use Description	Hydrologic Soil Group (AMC II)						
	A	**AB**	**B**	**BC**	**C**	**CD**	**D**
Cultivated Land (Fallow)	77	82	86	89	91	93	94
[2]**Cultivated Land** (Row Crops)							
---- without agricultural BMPs	72	77	81	85	88	90	91
---- [3]with agricultural BMPs	62	67	71	75	78	80	81
[4]**Cultivated Land (Small Grain)**							
---- without agricultural BMPs	65	71	76	80	84	86	88
---- with agricultural BMPs	59	65	70	74	78	80	81
[5]**Cultivated Land** (Close-seeded Legumes or Rotation Meadow)							
---- without agricultural BMPs	66	72	77	81	85	87	89
---- with agricultural BMPs	51	59	67	72	76	78	80
Pasture or Range Land							
---- [6]poor condition	68	74	79	83	86	88	89
---- [7]good condition	39	50	61	68	74	77	80
Meadow							
---- good condition	30	44	58	65	71	75	78
Wooded or Forest Land							
---- [8]poor cover	45	56	66	72	77	80	83
---- [9]good cover	25	40	55	63	70	74	77
Open Spaces, Lawns, Parks, Golf Courses, Cemeteries							
---- good condition (≥75% grass coverage)	39	50	61	68	74	77	80

---- fair condition (50% - 75% grass coverage)	49	59	69	74	79	82	84
Commercial and Business Areas (~85% impervious)	89	91	92	93	94	95	95
Industrial Areas (~72% impervious)	81	85	88	90	91	92	93
[10]**Residential Areas**							
---- ≤ 1/8 acre lot size (~65% impervious)	77	81	85	88	90	91	92
---- 1/4 acre lot size (~38% impervious)	61	68	75	79	83	85	87
---- 1/3 acre lot size (~30% impervious)	57	65	72	77	81	84	86
---- ½ acre lot size (~25% impervious)	54	62	70	75	80	83	85
---- 1 acre lot size (~20% impervious)	51	60	68	74	79	82	84
Paved Parking Lots, Roofs, Driveways	98	98	98	98	98	98	98
Streets and Roads							
---- paved with curb and storm sewer connection	98	98	98	98	98	98	98
---- gravel	76	81	85	87	89	90	91
---- dirt	72	77	82	85	87	88	89
[11]**Open Water Bodies** (Lakes, Wetlands, Ponds)	100	100	100	100	100	100	100

1 -- Adapted from U.S. Soil Conservation Service National Engineering Handbook (1972), MTC Drainage Manual Chapter B (1984),

MTO Drainage Management Manual (1997).
2 -- Includes row crops such as soybeans, corn, sorghum hay, peanut, potato, etc.
3 -- Includes agricultural best management practices (BMPs) such as contouring and terracing.
4 -- Includes small grain crops such as winter wheat, spring wheat, durham wheat, barley, oats, rye, etc.
5 -- Includes close-seeded legumes such as alfalfa, timothy grass, grass hay, etc.
6 -- Poor condition is defined as heavily grazed, no mulch, or has plant cover on less than 50% of the area.
7 -- Good condition is defined as lightly grazed, more than 75% of the area has plant cover.
8 -- Poor cover is defined as heavily grazed or regularly burned so that litter, small trees and brush are regularly destroyed.
9 -- Good cover is defined as protected from grazing so that litter and shrubs cover the soil.
10 -- Curve numbers are calculated assuming that roof leaders are connected to the driveway and/or road with a minimum of additional infiltration.
11 – When a number of water bodies within a large multi-land use catchment is modeled, a CN value of 50 may be applied to the water bodies in calculating the area-weighted CN value. When isolating a water body and modeling as a separate catchment, then a CN value of 100 should be used and the catchment is typically routed through a reservoir.

Table 7.5: Initial Abstraction / Depression Storage

Cover	Depth (mm)
Woods	10
Meadows	8
Cultivated	7
Lawns	5
Impervious areas	2

Adapted from UNESCO, Manual on Drainage in Urbanized Areas, 1987

Total Imperviousness (TIMP) and Directly Connected Imperviousness (XIMP)

Table 7.6 outlines typical parameter values that should be applied at the preliminary/conceptual design stage. The TIMP and XIMP values at the high end of the range given in **Table 7.6** shall be used at the preliminary/conceptual design stage. Adjustment of parameter values will be considered and accepted by the City at the functional and detailed design stage subject to the submission of relevant engineering calculations from the consulting engineer to justify the revision of these parameters.

Table 7.6: Typical Impervious Values by Land Use

Land Use	Total Impervious Percentage (TIMP)	Directly Connected Impervious Percentage (XIMP)
Estate Residential (> ¾ acre lot);	11% - 30%	8% - 20%
Low Density Residential (1/3 to ¾ acre lot)	18% - 50%	15% - 35%
Medium Density Residential (1/10 to ¼ acre lot)	35% - 60%	20% - 45%
High Density Residential (<1/10 acre lot)	60% - 75%	35% - 60%
Institutional (e.g. school, religious centre)	45% - 75%	40% - 60%
Industrial	70% - 85%	65% - 80%
Commercial / Business	80% - 95%	80% - 95%
Park	0% - 5%	0% - 3%

Adapted from *Stormwater Management Pond Requirements*, City of London, 2005;

Visual OTTHYMO Reference Manual, 2001; and review of typical site plans.

An approximation of the total impervious fraction (TIMP) can be calculated using the following formula:

$$TIMP = \frac{C - 0.2}{0.7}$$

where,

TIMP = total impervious fraction (dimensionless)

C = runoff coefficient

<u>Infiltration</u>

Infiltration is the movement of water from the ground surface into the soil. The most widely used methods for calculating infiltration include the SCS Curve Number Method, Horton's Method, and the Green-Ampt Method (*MTO Drainage Management Manual*, 1997)

SCS Curve Number Method

The SCS Curve Number Method is most appropriate for rural and natural basins.

$$Q=\frac{(P-I_a)^2}{(P+S-I_a)}$$

where,

Q = runoff depth (mm)

P = precipitation (mm)

S = soil storage capacity (mm) = (25400/CN) – 254 (mm)

CN = curve number based on vegetative cover and hydrologic soil group (A, B,C, and D)

I_a = initial abstraction (mm)

CN ≤ 70	IA = 0.075(S)
70 < CN ≤ 80	IA = 0.10(S)
80 < CN ≤ 90	IA = 0.15(S)
CN > 90	IA = 0.2(S)

(Visual OTTHYMO Reference Manual, Version 2.0, July 2002)

Horton Infiltration Method

The Horton Infiltration Method is widely accepted for use within small urban catchments in areas without much soil variability. The Horton Infiltration Method is not ideally suited for use in rural and natural basins due to the large variation in soil and land cover types typically encountered. The Horton Infiltration Method is not recommended for storm durations ≥ 12 hours as predicted flows are sometimes erroneous (VO2 Reference Manual, July 2002).

$$f_t = f_\infty + (f_o - f_\infty)(e)^{-kt}$$

If $i < f_t$ then $f = i$

where,

f_t = infiltration rate (mm/hr)

f_∞ = minimum infiltration rate (mm/hr)

f_o = maximum infiltration rate (mm/hr)

e = natural logarithm

k = decay coefficient (1/hr)

t = time from beginning of precipitation (hr)

i = rainfall intensity (mm/hr)

The following table provides typical parameter values used in the Horton Infiltration Method.

Table 7.7: Typical Parameter Values for Horton Infiltration Method

Parameter	HSG A	HSG B	HSG C	HSG D
f_o (mm/hr) (dry soil conditions)	250	200	125	75
f_∞ (mm/hr)	25	13	5	3
k (1/hr)	2	2	2	2

Source: M.L. Terstriep and J.B. Stall, Illinois Urban Drainage Area Simulator (ILLUDAS) Illinois State Water Survey Urbana, 1979.

Green-Ampt Infiltration Method

The Green-Ampt Infiltration Method has been used in Canada for both agricultural and urban watersheds.

When $F < F_s$, $f = i$

When $F > F_s$

$$f_p = K_s \left[1 + \frac{(S_u)(IMD)}{F} \right]$$

where,

F = cumulative infiltration volume (mm)

F_s = cumulative infiltration volume required to cause surface saturation (mm)

$$F_s = \frac{(S_u)(IMD)}{{i}/{K_s} - 1} \quad \text{when } i > K_s$$

Where,

F_s = no calculation when $i < K_s$

f = infiltration rate (mm/hr)

f_p = infiltration capacity (mm/hr)

i = rainfall intensity (mm/hr)

K_s = saturated hydraulic conductivity (mm/hr)

S_u = average capillary suction at the wetting front (mm)

IMD = initial moisture deficit for the event (mm/mm)

The following table provides typical parameter values used in the Green-Ampt Method.

Table 7.8: Typical Parameter Values for Green-Ampt Infiltration Method

Various Hydrologic Soil Groups (HSG)

Parameter	HSG A	HSG B	HSG C	HSG D
IMD (mm/mm)	0.34	0.32	0.26	0.21
S_u (mm)	100	300	250	180
K_s (mm/hr)	25	13	5	3

Source: Design Chart 1.13, MTO Drainage Management Manual, 1997

7.3 Hydraulic Calculations

7.3.1 Minor System Hydraulic Calculations and HGL Analysis

Head losses in storm sewers occur as a result of friction losses and form losses (minor losses). Friction losses are the result of shear stress between the moving fluid and the boundary material. Form losses are the result of abrupt transitions due to the geometry of maintenance holes, bends, expansions and contractions. Where an HGL analysis is required, a spreadsheet or equivalent method using computer modeling (*e.g.* PCSWMM.NET) shall be used that includes design information including storm sewer sizes, lengths and inverts, tailwater elevations, flow, and velocities to calculate the losses that will occur through the storm sewer system. The use of any modeling software other than those noted in this document (see **Section 7.2.2**) requires prior consultation with and approval by the City. Sample problems and calculations regarding HGL analyses are provided in **Appendix C**.

When completing spreadsheet calculations, head losses through the storm sewer system shall be calculated using Bernoulli's equation of head loss in the form of:

$$h = \frac{kV^2}{2g}$$

where,

h = head loss (m)

k = loss coefficient (dimensionless)

V = average pipe flow velocity (m/s)

g = gravitational constant, (9.81 m/s^2)

For the frictional component of the losses through the pipe, the k coefficient becomes:

$$k = \frac{fL}{D}$$

where,

k = loss coefficient (dimensionless)

f = friction factor (dimensionless)

L = length of storm sewer (m)

D = actual diameter of the pipe (m)

The friction factor is defined by:

$$f = 124 \frac{n^2}{d^{1/3}}$$

where,

f = friction factor (dimensionless)

n = Mannings n (dimensionless)

d = actual diameter of the pipe (m)

Head losses through maintenance holes shall be calculated using Bernoulli's equation of head loss, as outlined above, with an appropriate value of k consistent with the type of junction (*Design and Construction of Urban Stormwater Management Systems*, ASCE, 1992, p.146 – 159).

For a straight through maintenance hole, with one incoming and one outgoing pipe, the loss shall be calculated as follows:

$$h_{MH} = 0.05 \frac{V_d^{\,2}}{2g}$$

where,

h_{MH} = head loss through the maintenance hole (m)

0.05 = loss coefficient, k (dimensionless)

V_d = average pipe flow velocity in the downstream sewer (m/s)

g = gravitational constant, (9.81 m/s^2)

For a junction maintenance hole, with an incoming pipe, outgoing pipe and one or more laterals, the loss shall be calculated based on the velocities in the main branch sewers and the angle of the lateral sewer to the main branch as follows:

15° lateral: $$h_{MH} = \frac{V_d^{\ 2}}{2g} - 0.85\frac{V_u^{\ 2}}{2g}$$

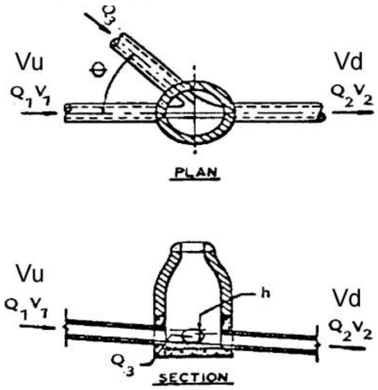
22.5° lateral: $$h_{MH} = \frac{V_d^{\ 2}}{2g} - 0.75\frac{V_u^{\ 2}}{2g}$$

30° lateral: $$h_{MH} = \frac{V_d^{\ 2}}{2g} - 0.65\frac{V_u^{\ 2}}{2g}$$

45° lateral: $$h_{MH} = \frac{V_d^{\ 2}}{2g} - 0.50\frac{V_u^{\ 2}}{2g}$$

60° lateral: $$h_{MH} = \frac{V_d^{\ 2}}{2g} - 0.35\frac{V_u^{\ 2}}{2g}$$

90° lateral: $$h_{MH} = \frac{V_d^{\ 2}}{2g} - 0.25\frac{V_u^{\ 2}}{2g}$$



where,

h_{MH} = head loss through the maintenance hole (m)

V_d = average pipe flow velocity in the downstream main branch sewer (m/s)

V_u = average pipe flow velocity in the upstream main branch sewer (m/s)

g = gravitational constant, (9.81 m/s^2)

For a maintenance hole, with an incoming and outgoing pipe benched through 90°, the loss shall be calculated based on the radius of curvature of the benching as follows:

Radius = the diameter of the pipe: $$h_{MH} = 0.50\frac{V_d^{\ 2}}{2g}$$

Radius = 2 to 8 times the diameter of the pipe: $$h_{MH} = 0.25\frac{V_d^{\ 2}}{2g}$$

Radius = 8 to 20 times the diameter of the pipe: $$h_{MH} = 0.40\frac{V_d^{\ 2}}{2g}$$

where,

h_{MH} = head loss through the maintenance hole (m)

V_d = average pipe flow velocity in the downstream sewer (m/s)

G = gravitational constant, (9.81 m/s^2)

7.3.2 Culvert / Bridge Hydraulic Analysis

Bridge and culvert calculations should be completed by computer programs such as CulvertMaster and HEC-RAS or SWMM. CulvertMaster is suitable for completing capacity and headwater elevation calculations for culverts while HEC-RAS is more appropriate for completing similar hydraulic calculations associated with bridges. When completing hydraulic analyses with HEC-RAS, the location of cross sections and modeling conventions should be in accordance with the HEC-RAS User Manual and Reference Manual.

7.3.3 Erosion and Erosion Mitigation Analyses

Erosion studies shall be based on an appropriate level of analysis to demonstrate the extent of unmitigated and mitigated erosion control criteria.

The MTO maximum permissible velocity method is acceptable for simple design needs, such as inlet/outlet, culvert erosion protection (see Section 5, *MTO Drainage Management Manual*, 1997).

For downstream erosion assessments within watercourses, a more detailed erosion analysis, including fluvial geomorphology and continuous modeling may be required at the discretion of the City and/or Conservation Authority.

7.3.4 Floodline Analysis

Floodline studies must be completed using a current version of HEC-RAS and the approved peak flows. Acceptable Manning's roughness values for routing calculations are provided in **Section 3, Table 3.7 and Table 3.8**. The use of any modeling software other than those noted in this document requires prior consultation with and approval by the City.

7.4 Water Balance

Water balance calculations shall be completed and provided per the methodology in the governing guidelines which are currently documented in the *Stormwater Management Planning and Design Manual* (MOE, 2003).

Infiltration facilities shall be provided to mitigate the water balance deficit. The infiltration facilities shall be designed based on soil percolation rates, local rainfall data, and maximum allowable detention time. The infiltration facilities shall conform to the governing guidelines which are currently documented in the *Stormwater Management Planning and Design Manual* (MOE, 2003) unless otherwise specified in the City's guidelines.

Where poor soils exist (i.e., soil percolation rate < 15 mm/hour), the detention time within the proposed infiltration facilities may be extended beyond 48 hours subject to approval by the City and Conservation Authority.

A suitable overflow bypass shall be provided for all infiltration facilities.

7.4.1 New Subdivisions

Infiltration facilities for large new development sites shall be designed to ensure that the annual infiltration volume for the post-development condition matches the volume for the pre-development condition. An overflow bypass shall be provided for the infiltration facilities.

7.4.2 Infill or Re-developments

Infiltration facilities for small infill or re-developments (< 5ha) shall be designed to minimize any anticipated changes in the water balance between pre-development and post-development conditions and to infiltrate as a minimum the first 5 mm rainfall volume from the subject development.

8.0 ENGINEERING SUBMISSION REPORTING REQUIREMENTS (DRAINAGE DESIGNS / SWM REPORTS)

A complete submission package must be delivered to the City for detailed engineering review of Stormwater Management Plans for both the conceptual/preliminary design stage and the detailed design stage. Submissions at the conceptual/preliminary design stage will consist of a Preliminary SWM Report, Functional SWM Report, or Functional Servicing Report. Submissions at the detailed design stage will consist of a Stormwater Management Report. The specific content requirements for the two types of Stormwater Management Plan submissions is provided below. However, as the list is intended to cover a broad range of development proposals, some of the items may not be applicable for infill development or small site plans. Exemptions may be made on a site-by-site basis, through pre-consultation with the City.

In general, printed and digital copies of the Stormwater Management Plan must be submitted with each development proposal. Digital copies are to be submitted in original format, and include report text, drawings and appendices, as well as the full set of engineering drawings (for detailed design). The report must be signed and sealed by a Licensed Professional Engineer of Ontario and include, as a minimum, the items outlined below. The City of Barrie has a Memorandum of Understanding (MOU) with the LSRCA regarding the protocol for the circulation and review of site plan applications (see **Appendix J**).

8.1 Submissions to External Agencies

Submissions shall be made to the following external agencies as required.

- Nottawasaga Valley Conservation Authority (NVCA). The NVCA is typically circulated on all applications that potentially impact the ecological resources and the quality and quantity of stormwater runoff and baseflow to watercourses within the jurisdiction of the NVCA. The NVCA jurisdiction corresponds to Zone 3 as delineated on the Flood Hazard Criteria Zones figure provided in **Appendix B**.
- Lake Simcoe Region Conservation Authority (LSRCA). The LSRCA jurisdiction corresponds to Zone 1 as delineated on the Flood Hazard Criteria Zones figure provided in **Appendix B**. In order to streamline the circulation and review procedures for site plan applications, a Memorandum of Understanding (MOU) exists between the City and the LSRCA. A copy of the MOU is provided in **Appendix J**. As per the MOU, the LSRCA will be circulated by the City on all site plan applications if the proposed development is partially or wholly located within a regulated area under Ontario Regulation 179/06 which governs such areas as floodplain, erosion hazards and wetlands. In non-regulated areas, the City will circulate site plans to the LSRCA for properties which host natural heritage lands. The City will collect the base site plan review fee on behalf of the LSRCA (separate cheque payable to the LSRCA) and will attach payment to the application prior to circulation to the LSRCA. The City will undertake stormwater reviews

(including the review of associated landscape plans) for all site plans. The LSRCA will review the site plan application and provide conditions of site plan approval or comments pertaining to the application within ten (10) business days of the receipt of the application (recognizing that stormwater review will be carried out by the City). The LSRCA review and approval of site plans will focus on conformity with the *Provincial Policy Statement* under the *Planning Act* and in accordance with the regulations under the *Conservation Authorities Act.* These will include natural heritage resources and natural hazard land management related to areas of valley and streams, wetlands and woodlands, flood plains, watercourse alteration, erosion, steep slope, and hazardous sites (e.g. unstable soils). The LSRCA will issue permits under their regulations in a timely manner upon the submission of a complete application which satisfies the Conservation Authority's development policies. Permits will specify as a condition of approval, that storm water management will be subject to approval by the City.

- Ministry of Environment (MOE) District and Approvals offices. The MOE is typically circulated on applications for which a Certificate of Approval (C of A) is required for municipal and private water and sewage works such as SWM facilities.
- Ministry of Natural Resources (MNR). The MNR is typically circulated on applications in which a permit is required under the *Lakes and Rivers Improvement Act* for construction within a watercourse.
- Ministry of Transportation (MTO). The MTO is typically circulated on applications in which provincial roads / highways under the authority of the MTO may be directly or indirectly impacted by the proposed works (400 m each side). For example, proposed development adjacent provincial roads / highways that may impact future expansion of travel corridors or may impact flows under MTO culverts or level of flood protection, typically require MTO review and approval.
- As directed by the City of Barrie Infrastructure Department

8.2 Reporting Requirements for a Stormwater Management Plan (Conceptual / Preliminary Design)

8.2.1 Background Information

- Introductory material describing the property location, including both municipal and legal descriptions, planning status, proposed development scheme, construction phasing plan, intent of the report, and existing / historical land use.
- Reference for the topographic information used to determine internal and external catchment areas under existing and proposed conditions as well as references for soils, and water surface elevations (WSEL's) adjacent the site and downstream of any proposed outfalls or SWM facility outlet structures.

- Relevant recommendations and requirements from the Master Drainage Plan must be summarized for the site.
- Information related to the Class Environmental Assessment process must be included, if applicable.
- A copy of the Draft Plan must be provided.

8.2.2 Storm Drainage Areas

- Pre-development conditions must be indicated including: internal and external catchment areas and catchment I.D.'s, and drainage patterns for the site and applicable external lands.
- Post development conditions must be provided including: internal and external catchment areas and catchment I.D.'s, and major and minor flow routes for the site and relevant external lands. All external flows must be identified.

8.2.3 Stormwater Management Targets / Objectives and Design Criteria

- Conceptual/Preliminary SWM reports should identify how applicable recommendations from Master Drainage Plans, geotechnical and hydrogeological reports have been incorporated into the design.
- Outline the SWM design criteria being applied in the report. This should include criteria for water quality, erosion and quantity control as well as infiltration (water balance).

8.2.4 Storm Drainage System Design

- A conceptual storm sewer design must be provided to ensure sufficient sewer slope and pipe cover. Major overland flow paths should be indicated and any capacity restriction should be identified.
- Any interim servicing conditions should be identified.
- The routing of any external flows through the site must be identified.

8.2.5 Stormwater Management Facility Design

- Pre-development conditions must be indicated including: hydrologic parameters used for modeling, and pre-development peak flow rates for the 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, and 100-yr year design storms for the critical storm distribution and duration (i.e. must look at both 4 hour Chicago and 6, 12 and 24 hour SCS Type II distributions) and the Regional Storm Event for each sub catchment.
- Post development conditions must be provided including: hydrologic parameters used for modeling, and post development peak flow rates for the 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, and 100-yr year design storms for the critical storm distribution and duration (i.e. must

look at both 4 hour Chicago and 6, 12 and 24 hour SCS Type II distributions) and the Regional Storm Event for each sub catchment.

- Any requirements for thermal mitigation measures must be identified and conceptually described for any proposed SWM facilities.
- The water balance methodology must be provided along with input parameters, summary of results, and the requirements and concepts for any proposed infiltration measures.
- It must be demonstrated conceptually that sufficient measures can be provided to meet the required level of water quality control per the established criteria.
- It must be demonstrated conceptually that sufficient measures can be provided to achieve the required level of erosion control per the established criteria including an evaluation of anticipated changes in phosphorus loadings from pre-development to post-development conditions and how loadings will be minimized.

8.2.6 Erosion and Sediment Control During Construction

- Requirements and concepts for erosion and sediment control measures during construction are to comply with the City of Barrie *Site Alteration By-law 2006-101* and should be identified in the design drawing package.

8.2.7 SWM Facility Inspection and Maintenance Requirements

- A detailed manual of required inspection requirements and maintenance requirements to ensure that the SWM facilities will continue to operate as designed must be provided.

8.2.8 Primary Tables

- Stage vs. Discharge and Storage Table (if required) – The table should include, as a minimum, all points used in the reservoir routing command.
- SWM facility operation characteristics table must be provided for the conceptual level of detail, including pond bottom, normal water level (NWL), extended detention WL, high water level (HWL) and incremental and cumulative storage volumes. A conceptual storage-discharge rating curve table must be included.
- A comparison of Predevelopment, Uncontrolled Post Development and Controlled Post Development Flows Table – showing peak flows for the Regional and 2-yr through 100-yr design storm events at significant points of interest throughout the catchment area.
- Comparison of pre-development, unmitigated post-development and mitigated post-development water balance volumes and infiltration volumes.

8.2.9 Primary Figures and Drawings

- Site Location Plan.
- Draft Plan.
- Hazard Area Mapping (if applicable).
- Pre-development internal and external catchment areas and catchment I.D.'s on a topographic base showing existing land use and drainage patterns.
- Post-development internal and external catchment areas and catchment I.D.'s on a topographic base showing future land use, and major and minor flow routes.
- Conceptual drawings and siting of any proposed SWM facilities, including location of inlet, outlet and spillway. NWL and HWL must be indicated on the conceptual drawings.
- Conceptual siting and details for any proposed infiltration measures.
- Conceptual siting and details for any proposed thermal mitigation measures.
- Full set of folded Engineering Conceptual / Preliminary Design Drawings, signed and sealed by a licensed Professional Engineer of Ontario.

8.2.10 Supporting Hydrology and Hydraulics Calculations and Modeling Details and Output

- Printed copies of the model schematics and hydrologic modeling, including input and detailed output files for the 2-yr through 100-yr return period events (*i.e.* must look at both 4 hour Chicago and 6, 12 and 24 hour SCS Type II distributions), 25 mm 4 hour Chicago quality storm, and Hurricane Hazel / Timmins storm for existing and future land uses as required.
- Digital copies of all modeling are to be included with the report. Digital files must include all files necessary to run the model, (i.e., both input and storm files) as well as the detailed output files generated for the Regional and 2-yr through 100-yr design storm events. Digital files are to include both pre and post-development scenarios.
- Relevant Storm Design Parameters Table - Identifying the design storm duration and distribution; referencing the source of the rainfall intensity duration and frequency values; and listing the intensity-duration-frequency values for the 2-yr through 100-yr return periods. Any other relevant design storm values not specified above should also be included. Tables and calculations should be provided in digital format.
- Table should be provided comparing the pre and post development peak flows for different storm distributions and durations for the site and required storage volumes to determine the critical storm to be used.

- Soil Characteristics Table – Listing the areal distribution of each soil type (expressed as a %) within every subcatchment.
- Model Input Parameters Table - Summarizing key input parameters for existing and future land use for each catchment including subcatchment I.D., drainage area, CN, IA, Tp, Slope, % impervious, modeling time step, pervious and impervious Manning's roughness, etc.
- Model input parameters, i.e., CN, IA, Tc, % imperviousness, etc. calculations.
- Incremental and cumulative volume calculations for the stormwater management facility.
- Drawdown time calculations for SWM facility (if applicable).
- Water balance calculations showing post-to-pre infiltration volume analysis and an evaluation demonstrating how phosphorus loadings from the site will be minimized.
- Pre and post-development watershed modeling schematics reflecting the model subcatchment I.D.'s and catchment areas.

8.2.11 Stand Alone Reports

- Geotechnical Report providing borehole information, including existing groundwater conditions, for the site and proposed pond block (if applicable)
- Environmental reports (e.g. fisheries impacts, hydrogeology, fluvial geomorphology), if applicable.

8.3 Reporting Requirements for a Stormwater Management Plan (Detailed Design)

8.3.1 Background Information

- Introductory material describing the property location, including both municipal and legal descriptions, planning status, proposed development scheme, construction phasing plan, intent of the report, and existing / historical land use.
- Reference for the topographic information using the City of Barrie horizontal and vertical control monuments used to determine internal and external catchment areas under existing and proposed conditions as well as references for soils, and water surface elevations (WSEL's) adjacent the site and downstream of any proposed outfalls or SWM facility outlet structures.
- Information related to the Class Environmental Assessment process must be included, if applicable.

8.3.2 Storm Drainage Areas

- Pre-development conditions must be indicated including: internal and external catchment areas and catchment I.D.s, and drainage patterns for the site and applicable external lands.
- Post development conditions must be provided including: internal and external catchment areas and catchment I.D.s, and major and minor flow routes for the site and relevant external lands.

8.3.3 Stormwater Management Targets / Objectives and Design Criteria

- SWM reports should identify how applicable recommendations from Master Drainage Plans, geotechnical and hydrogeological reports have been incorporated into the design.
- Outline the SWM design criteria being applied in the report. This should include criteria for water quality, erosion and quantity control as well as infiltration (water balance).

8.3.4 Storm Drainage System Design

- It must be shown that the site provides safe conveyance of both the minor storm and regulatory flows from both the subject site and any external lands, through the development to a sufficient outlet, with no adverse impact to either the upstream or downstream landowners. A sufficient outlet constitutes: a permanently flowing watercourse or lake; a public right of way (provided the proponent has obtained written permission to discharge storm flows from the land owner); or in the case of privately owned lands, a legal right of discharge registered on title.
- Any interim servicing conditions should be identified.

8.3.5 Stormwater Management Facility Design

- Pre-development conditions must be indicated including: hydrologic parameters used for modeling, and pre-development peak flow rates for the 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, and 100-yr year design storms for the critical storm distribution and duration (i.e. must look at both 4 hour Chicago and 6, 12 and 24 hour SCS Type II distributions) and the Regional Storm Event for each sub catchment.
- Post development conditions must be provided including: hydrologic parameters used for modeling, and post development peak flow rates for the 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, and 100-yr year design storms for the critical storm distribution and duration (i.e. must look at both 4 hour Chicago and 6, 12 and 24 hour SCS Type II distributions) and the Regional Storm Event for each sub catchment.
- The WSEL's adjacent the site and downstream of the SWM facility outlet structure must be indicated to ensure the appropriate hydraulic calculations should backwater conditions exist.

- If required, thermal mitigation measures must be clearly identified and described for any proposed SWM facilities.
- The water balance methodology must be provided along with input parameters, summary of results, proposed siting, and functioning of any proposed infiltration measures.
- It must be demonstrated that sufficient measures are provided to meet the required level of water quality control per the established guidelines including an evaluation of anticipated changes in phosphorus loadings from pre-development to post-development conditions and how loadings will be minimized.
- It must be demonstrated that sufficient measures are provided to achieve the required level of erosion control per the established guidelines.

8.3.6 Erosion and Sediment Control During Construction

- Description of proposed erosion and sediment control measures to be in place before, during and after municipal servicing construction up to the end of the servicing maintenance period, including schedule for implementing/decommissioning and maintenance requirements.

8.3.7 SWM Facility Inspection and Maintenance Requirements

- Description of proposed inspection requirements and maintenance activities to ensure that the SWM facilities will continue to operate as designed. A schedule and frequency of maintenance activities is required.

8.3.8 Primary Tables

- Stage vs. Discharge and Storage Table (if required) – The table should include, as a minimum, all points used in the reservoir routing command.
- Existing and proposed runoff coefficients for each catchment.
- SWM Facility Operation Characteristics and Summary of Significant SWMF Features Table(s) - These include type of facility, contributing drainage area, lumped catchment imperviousness ratio, permanent pool, extended detention and quantity control volumes, as well as elevations for base of pond, base of forebay, normal water level, active storage and quantity control design high water level, Regional and 100-yr design storm high water levels, and top of berm, inlet and outlet structure design details, such as: pipe size, orifice size, weir length, and invert elevation, and total draw down time required for the extended detention volume.
- Comparison of Predevelopment, Uncontrolled Post Development and Controlled Post Development Flows Table – showing peak flows for the Regional and 2-yr through 100-yr design storm events at significant points of interest throughout the catchment area.

- Comparison of pre-development, unmitigated post-development and mitigated post-development water balance volumes and infiltration volumes.

8.3.9 Primary Figures and Drawings

- Site Location Plan.
- Pre-development internal and external catchment areas and catchment I.D.'s on a topographic base showing existing land use and drainage patterns.
- Post-development internal and external catchment areas and catchment I.D.'s on a topographic base showing future land use, and major and minor flow routes.
- Siting and details for any proposed infiltration measures.
- Siting and details for any proposed thermal mitigation measures.
- Full set of folded Engineering Detailed Design Drawings, signed and sealed by a licensed Professional Engineer of Ontario

8.3.10 Supporting Hydrology and Hydraulics Calculations and Modeling Details and Output

- Calculations demonstrating that all storm outlets have sufficient energy dissipation and/or erosion protection based on calculated erosive velocities at each outlet.
- Storm sewer design sheets must be provided.
- Printed and digital copies of the model schematics and hydrologic modeling, including input and detailed output files for the 2-yr through 100-yr return period events (*i.e.* must look at both 4 hour Chicago and 6, 12 and 24 hour SCS Type II distributions), 25 mm 4 hour Chicago quality storm, and Hurricane Hazel / Timmins storm for existing and future land uses as required.
- Digital copies (on DVD or CD) of all modeling are to be included with the report. Digital files must include all files necessary to run the model, (i.e., both input and storm files) as well as the detailed output files generated for the Regional and 2-yr through 100-yr design storm events. Digital files are to include both pre and post-development scenarios.
- Relevant Storm Design Parameters Table - Identifying the design storm duration and distribution, referencing the source of the rainfall intensity duration and frequency values, and listing the intensity-duration-frequency values for the 2-yr through 100-yr return periods. Any other relevant design storm values not specified above should also be included. Tables and calculations should be provided in digital format.

- Table should be provided comparing the pre and post-development peak flows for different storm distributions and durations for the site and required storage volumes to determine the critical storm to be used.
- Soil Characteristics Table – Listing the areal distribution of each soil type (expressed as a %) within every subcatchment.
- Model Input Parameters Table - Summarizing key input parameters for existing and future land use for each catchment including subcatchment I.D., drainage area, CN, IA, Tp, Slope, % impervious, modeling time step, pervious and impervious Manning's roughness, etc.
- Model input parameters, i.e., CN, IA, Tc, % imperviousness, etc. calculations.
- Conveyance capacity calculations for the major system flow path.
- Stage-Storage-Discharge spreadsheet with hydraulic calculations for any proposed outlet control structures (Note: Calculation equations, coefficients, and design values for all hydraulic structures should be clearly identified).
- Incremental and cumulative volume calculations for the stormwater management facility.
- Sizing of emergency spillway (if applicable) for Regulatory flows.
- Drawdown time calculations for SWM facility (if applicable).
- Sizing of erosion control structures.
- Water balance calculations showing post-to-pre infiltration volume analysis.
- Calculations demonstrating that any proposed infiltration measures will provide the required infiltration volumes for the site and an evaluation demonstrating how phosphorus loadings from the site will be minimized.
- Dual drainage and hydraulic grade line calculations (if applicable).
- Tailwater elevations must be indicated for the outlet of any storm sewer and/or proposed SWM facility to demonstrate that any backwater conditions have been properly accounted for in the hydraulic design of the conveyance structures.
- Pre and post-development watershed modeling schematics reflecting the model subcatchment I.D.'s and catchment areas.
- Pre and post-development hydrograph plots for all significant points of interest.

8.3.11 Stand Alone Reports

- Operation and Maintenance Manual including a monitoring program plan for priority stormwater management facilities indicating how the facility will be monitored including water quality on a periodic basis (as per the *Lake Simcoe Protection Plan*).

- Geotechnical Engineering Report providing borehole information for the site and proposed pond block (if applicable) and certifying geotechnical feasibility of any stormwater management facilities and identifying any liner requirements for proposed SWM facilities.
- Environmental reports (e.g. fisheries impacts, hydrogeology, fluvial geomorphology), if applicable.
- Reports shall be submitted in PDF format.

9.0 REFERENCES

Adams, B.J., University of Toronto, *Impacts of Climate Change on Toronto Precipitation Characteristics and Stormwater Infrastructure*, Prepared for: Ontario Ministry of the Environment Stormwater Management Working Group, 10 December 2008.

American Concrete Pipe Association, *Concrete Pipe Design Manual*, 1970.

ASCE, *Design and Construction of Urban Stormwater Management Systems*, p. 146 - 159, 1992.

Canadian Standards Association.

City of Barrie, *City of Barrie Standards*, February 2006.

City of Barrie, *Lot Grading Policy Manual*, 1997.

City of Brampton, *Stormwater Management Facilities: Landscaping*.

City of Hamilton, *Public Works Park and Open Space Development Manual*.

City of London, *Stormwater Management Pond Requirements*, 2005.

Comer, Neil, Environment Canada, *Climate Change Model Scenarios: A Primer for Stormwater Management*, Prepared for: Ontario Ministry of the Environment Stormwater Management Working Group, 10 December 2008.

Conservation Halton, *Landscape Planting Guidelines*, May 2005.

Corrugated Steel Pipe Institute, *Modern Sewer Design*, Canadian Edition, 1996.

Coulibaly, P. and Shi, X., McMaster University and MTO Innovation Funding Program, *Identification of the Effect of Climate Change on Future Design Standards of Drainage Infrastructure in Ontario*, June 2005.

Denault, C., Millar, R.G., and Lence, B.J., University of British Columbia, *Climate Change and Drainage Infrastructure Capacity in an Urban Catchment*, Annual Conference of the Canadian Society of Civil Engineering, Montreal, 05-08 June 2002.

Dillon Consulting, *Technical Guidelines for Flood Plain Management in Ontario, Working Paper C, Rainfall Analysis, Report to MNR*, August 1985.

Environment Canada, Atmospheric Environment Service, *Rainfall Intensity-Duration-Frequency Values - Barrie WPCC (1979 – 2003)*, June 2008.

Greater Golden Horseshoe Area Conservation Authorities, *Erosion and Sediment Control Guidelines for Urban Construction*, December 2006.

Haestad Methods, *Stormwater Conveyance Modeling and Design*, 2003.

Haley, D. and Ness, R., Toronto and Region Conservation Authority, *Climate Change and Water Management Initiatives at the TRCA*, MOE Stormwater Management Working Group, 10 December 2008.

Lake Simcoe Region Conservation Authority, *Watershed Development Policies*, 26 October 2007.

Larrivee, C. and Bourque, A., Consortium on Regional Climatology and Adaptation to Climate Change, *Stormwater Management Practices in a Context of Climate Change: Recent Findings from Work Using Climate Models*, Ontario Stormwater Management Working Group, Toronto, February 10, 2009.

Municipal Engineers Association, *Municipal Class Environmental Assessment*, September, 2007.

National Fire Protection Association, *FPA 1231 – Standard on Water Supplies for Suburban and Rural Fire Fighting*, 1993.

Natural Resources Canada, *From Impacts to Adaptation: Canada in a Changing Climate*, Chapter 6, Ontario, 2007.

Nottawasaga Valley Conservation Authority, *Development Review Guidelines*, April 2006.

Ontario Ministry of Municipal Affairs and Housing, *Ontario Building Code 1997*, 1997.

Ontario Ministry of Municipal Affairs and Housing, *Provincial Policy Statement 2005*, 01 March 2005.

Ontario Ministry of Natural Resources (Riley, J.L.), *Distribution and Status of the Vascular Plants of Central Region*, Parks and Recreation Areas Section, OMNR, Central Region, December 1989.

Ontario Ministry of Natural Resources, *Ontario Dam Safety Guidelines*, September 1999.

Ontario Ministry of Natural Resources, *Shoreline Flood Elevation Study, Lake Simcoe, Lake Couchiching*, April 1981.

Ontario Ministry of Natural Resources, *Natural Hazard Technical Guidelines – Adaptive Management*, April 1981.

Ontario Ministry of Natural Resources, *Technical Guidelines for Flood Plain Management in Ontario, 1*985.

Ontario Ministry of Natural Resources, *Natural Hazards Technical Guides – Adaptive Management of Stream Corridors in Ontario*, 2002.

Ontario Ministry of the Environment, *Lake Simcoe Protection Plan*, June 2009.

Ontario Ministry of the Environment, *Stormwater Management Planning and Design Manual*, March 2003.

Ontario Ministry of the Environment, *Stormwater Management Practices Planning and Design Manual*, June 1994.

Ontario Ministry of Transportation and Communications, *Ministry Directive B-100*, 16 October 1980.

Ontario Ministry of Transportation, *Highway Drainage Design Standards*, January 2008.

Ontario Ministry of Transportation, *M.T.C. Drainage Manual, Chapter B, Design Flood Estimation for Small Watersheds*, 1984.

Ontario Ministry of Transportation, *MTO Drainage Management Manual*, 1997.

Ontario Ministry of Transportation, *Ontario Provincial Standards for Roads and Public Works*.

Ontario Water Resources Act, *Ontario Regulation 219/09*, 02 June 2009.

Schaeffer and Associates, *Visual OTTHYMO Reference Manual*, 2001.

Simonovic, Slobodan P., The Institute for Catastrophic Loss Reduction, University of Western Ontario, *Assessment of Water Resources Risk and Vulnerability to Changing Climatic Conditions*, Prepared for: Ontario Ministry of the Environment Stormwater Management Working Group, 10 December 2008.

Terstriep, M.L. and Stall, J.B., *Illinois Urban Drainage Area Simulator (ILLUDAS)*, Illinois State Water Survey, 1979.

Toronto and Region Conservation Authority, *TRCA Innovative Stormwater Management Workshop, West Nile Virus,*

Culex Environmental, May 2008.

Toronto and Region Conservation Authority, *Preparing for the Impacts of Climate Change on Stormwater and Floodplain Management: A Review of Adaptation Plans and Practices*, Prepared by the TRCA for the Region of Peel, February 2009.

Town of New Tecumseth, *Engineering Design Criteria and Standards*, 2004.

Town of Richmond Hill, *Stormwater Management Design Criteria*, December 2005.

U.S. Department of Agriculture, Soil Conservation Service, Engineering Division, *Urban Hydrology for Small Watersheds*, Technical Release 55, June 1986.

U.S. Soil Conservation Service, *National Engineering Handbook*, 1972.

UNESCO, *Manual on Drainage in Urbanized Areas*, 1987.

Visual OTTHYMO Reference Manual, Version 2.0, July 2002.

Watt, W.E., Waters, D., and McLean, R., Hydrology Research Group, Queen's University, Report 2003-1: *Climate Change and Urban Stormwater Infrastructure in Canada: Context and Case Studies*, 2003.

APPENDIX A

INFRASTRUCTURE STANDARDS

CORPORATE ASSET MANAGEMENT

- Storm Sewer Design Sheet

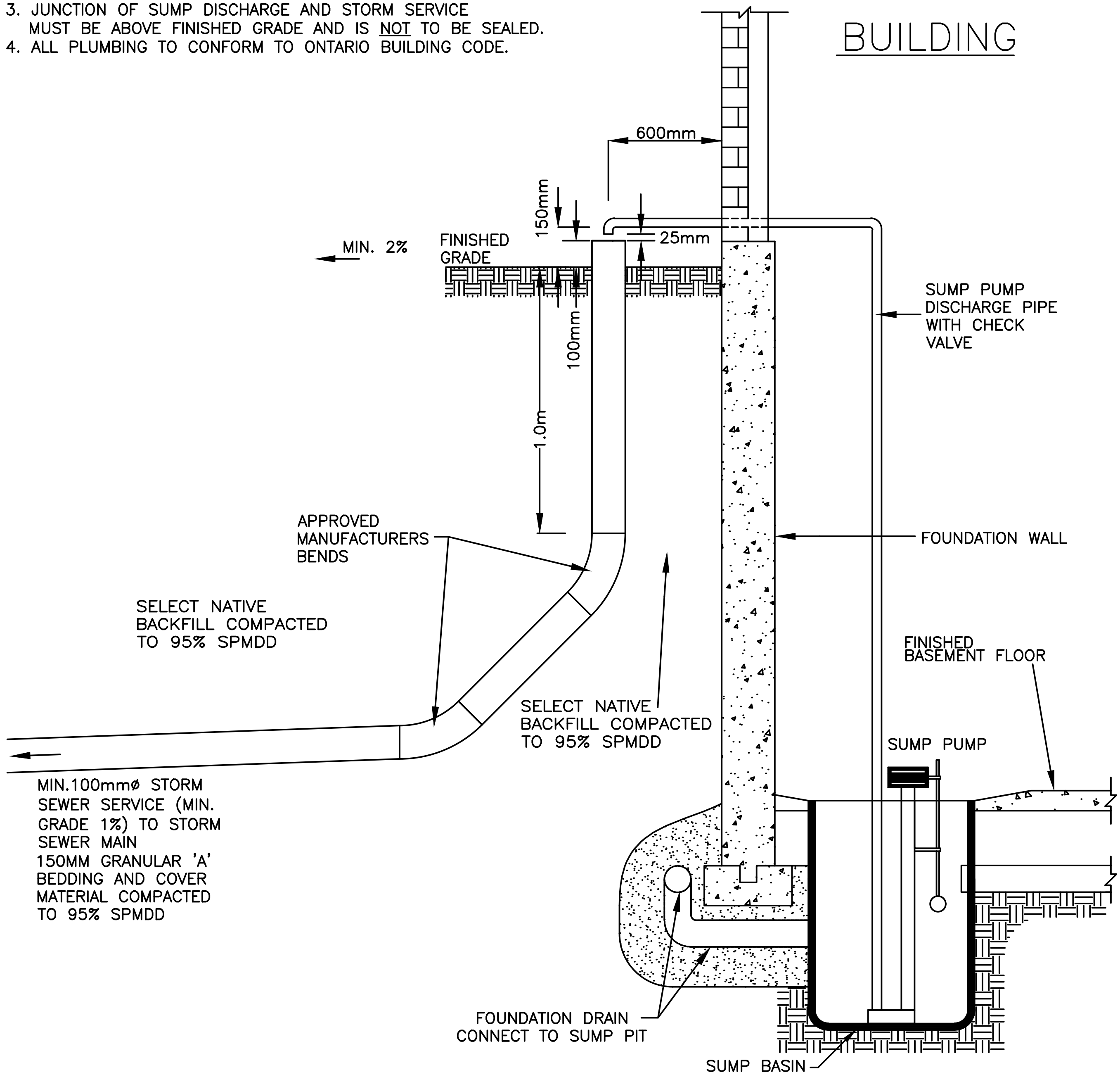
- Stormwater Management Standard Drawings

    - D774 – Foundation Drain Layout - Alternate 1
    - D775 – Foundation Drain Layout - Alternate 2
    - D776 – Foundation Drain Layout - Preferred
    - D777 – SWM Facility with Maintenance Pipe
    - D778 – SWM Facility without Maintenance Pipe
    - D779 – Outlet Structure (Temporary)
    - D780 – SWM Facility Grading
    - D781 – Forebay Dewatering Sump
    - D782 – Outlet Erosion Protection
    - D783 – SWM Facility Warning Sign

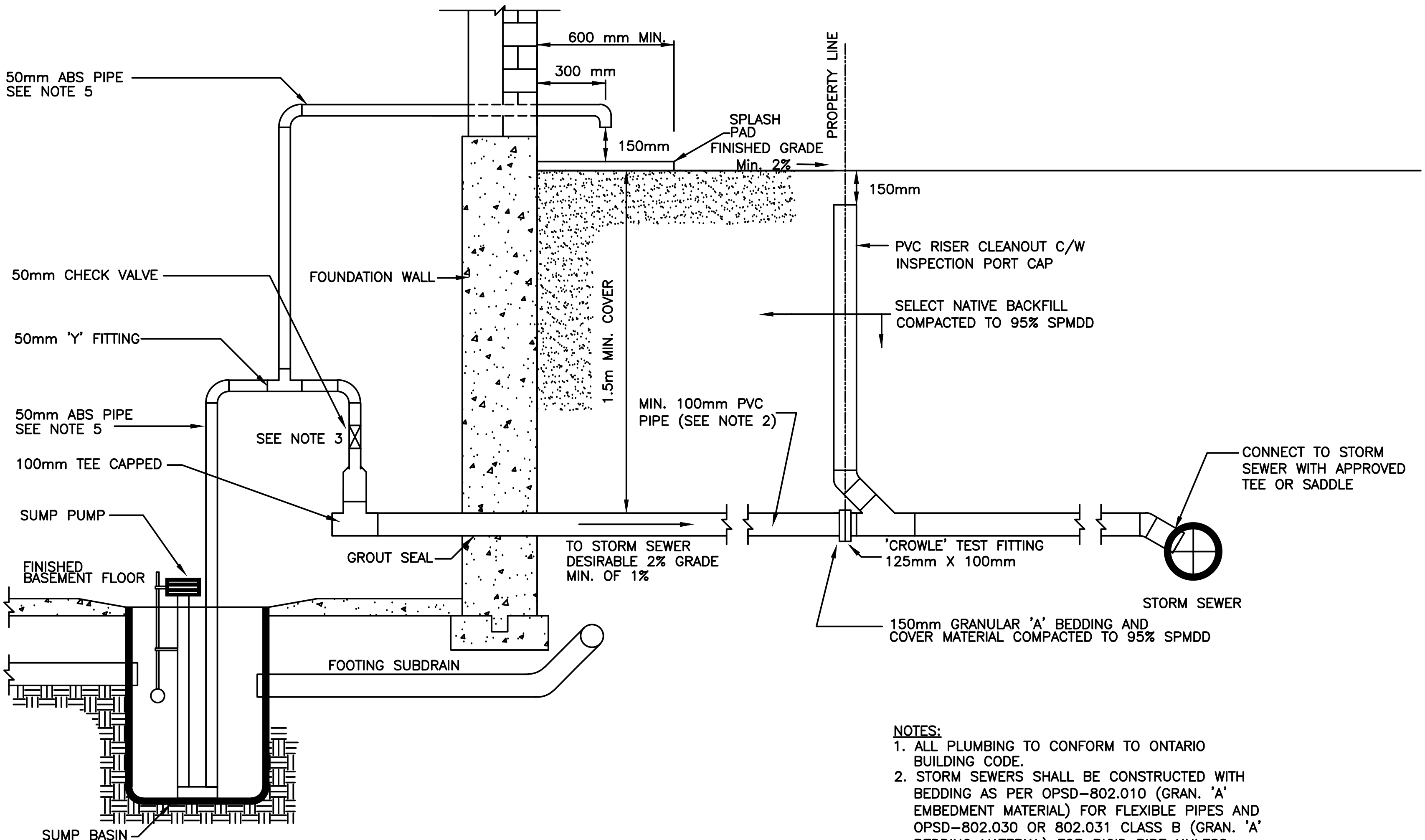
Reference:

D777, D778, D779 and D782 adapted from *Town of Richmond Hill Stormwater Management Design Criteria (Dec. 2005)*

NOTES:
1. PIPE SHALL BE 100mm DIA. PVC. MEETING CSA–B182.4–M90, RUBBER GASKET TYPE JOINTS OR EQUIVALENT
2. MIN. SLOPE OF PIPE TO BE 1%.
3. JUNCTION OF SUMP DISCHARGE AND STORM SERVICE MUST BE ABOVE FINISHED GRADE AND IS NOT TO BE SEALED.
4. ALL PLUMBING TO CONFORM TO ONTARIO BUILDING CODE.



Barrie	Foundation Drain Layout - Alternate 1	REV No. 1	DATE: APR 2023
			SCALE: N.T.S
		D774	

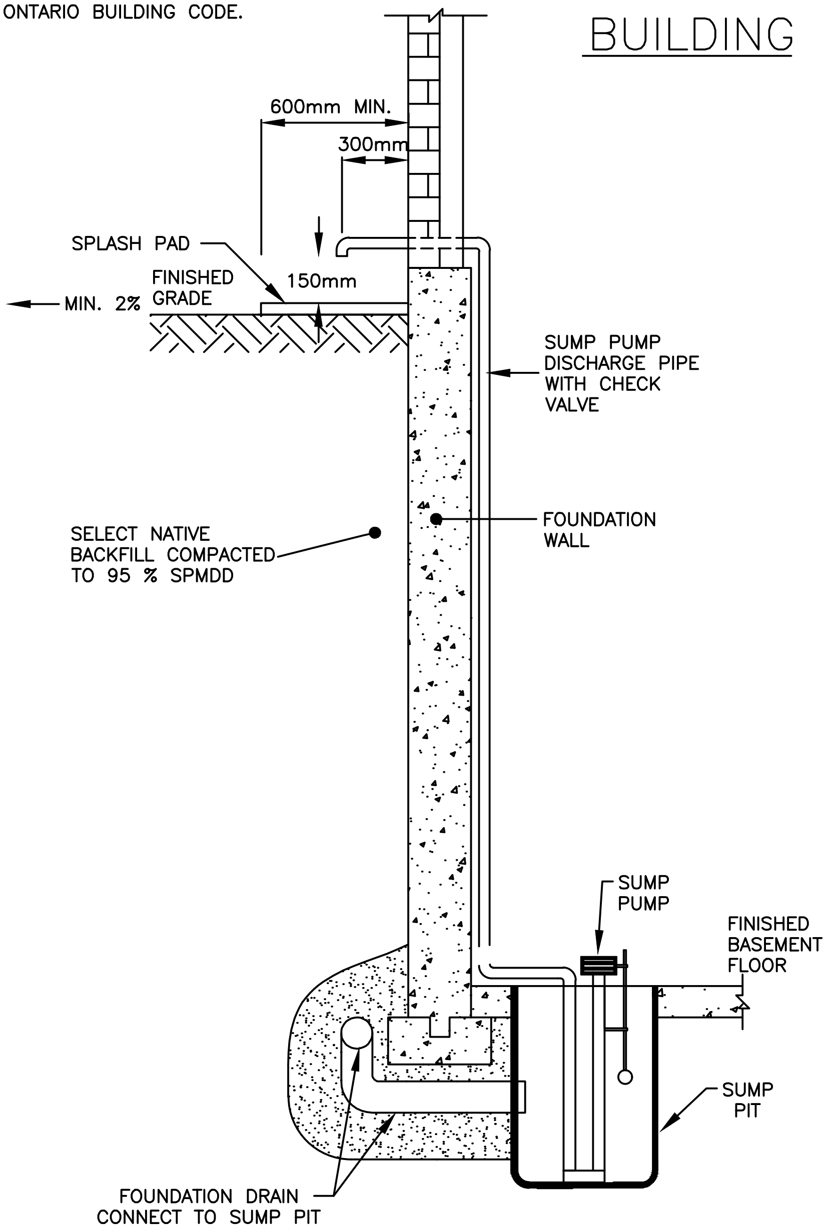


NOTES:

1. ALL PLUMBING TO CONFORM TO ONTARIO BUILDING CODE.
2. STORM SEWERS SHALL BE CONSTRUCTED WITH BEDDING AS PER OPSD-802.010 (GRAN. 'A' EMBEDMENT MATERIAL) FOR FLEXIBLE PIPES AND OPSD-802.030 OR 802.031 CLASS B (GRAN. 'A' BEDDING MATERIAL) FOR RIGID PIPE UNLESS OTHERWISE APPROVED BY THE DIRECTOR OF ENGINEERING.
3. REQUIRES ABS TO PVC ADAPTER CONNECTION.
4. POLYVINYL CHLORIDE SEWER PIPE (PVC) STORM PIPE B182.1 B181.2, B182.4
5. ACRYLONITRILE-BUTADIENE-STYRENE (ABS) PIPE B181.1

Barrie	Foundation Drain Layout - Alternate 2	REV No. 1	DATE: APR 2023
			SCALE: N.T.S.
		D775	

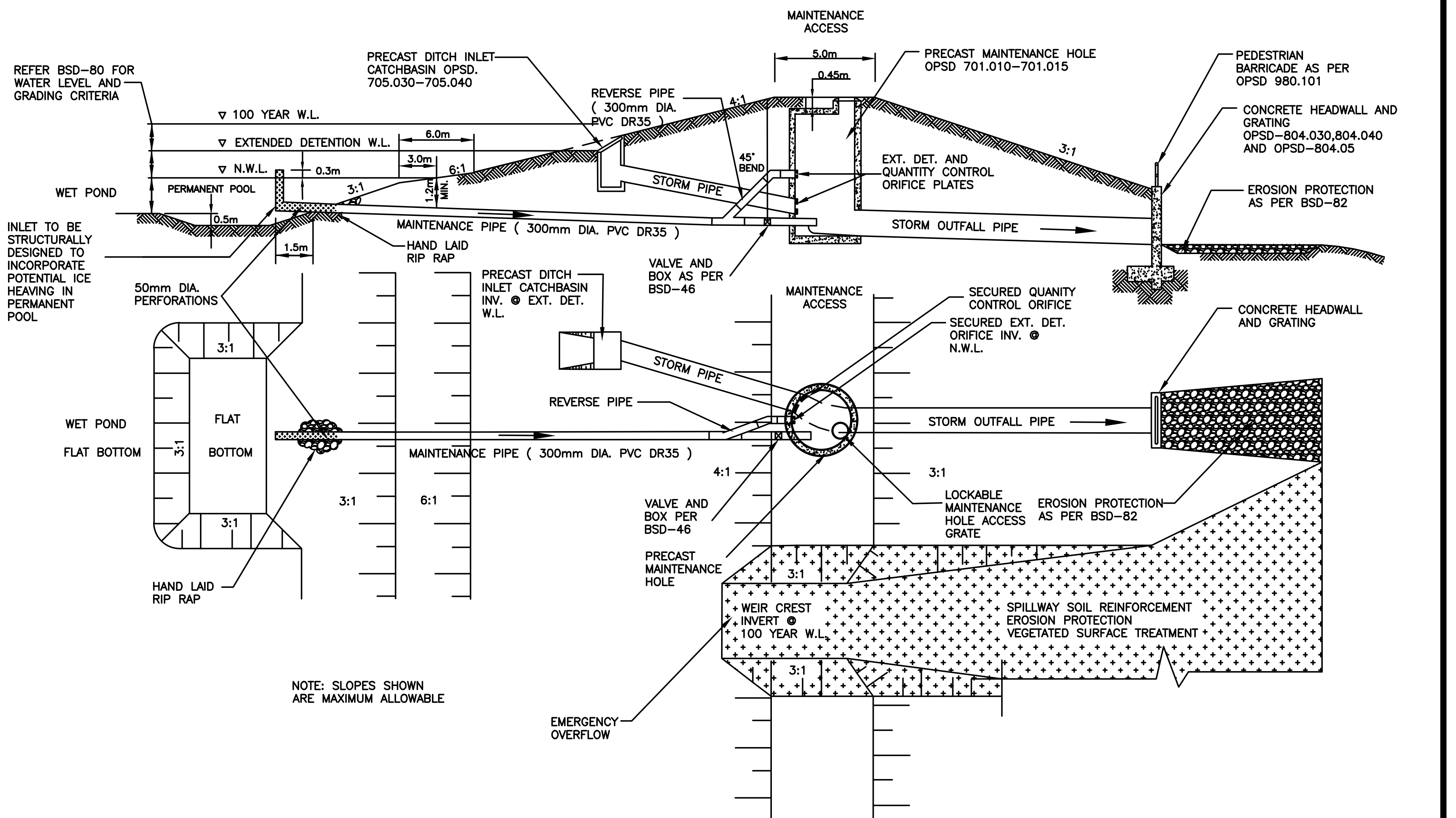
NOTES:
1. ALL PLUMBING TO CONFORM TO ONTARIO BUILDING CODE.



Barrie

Foundation Drain Layout - Preferred

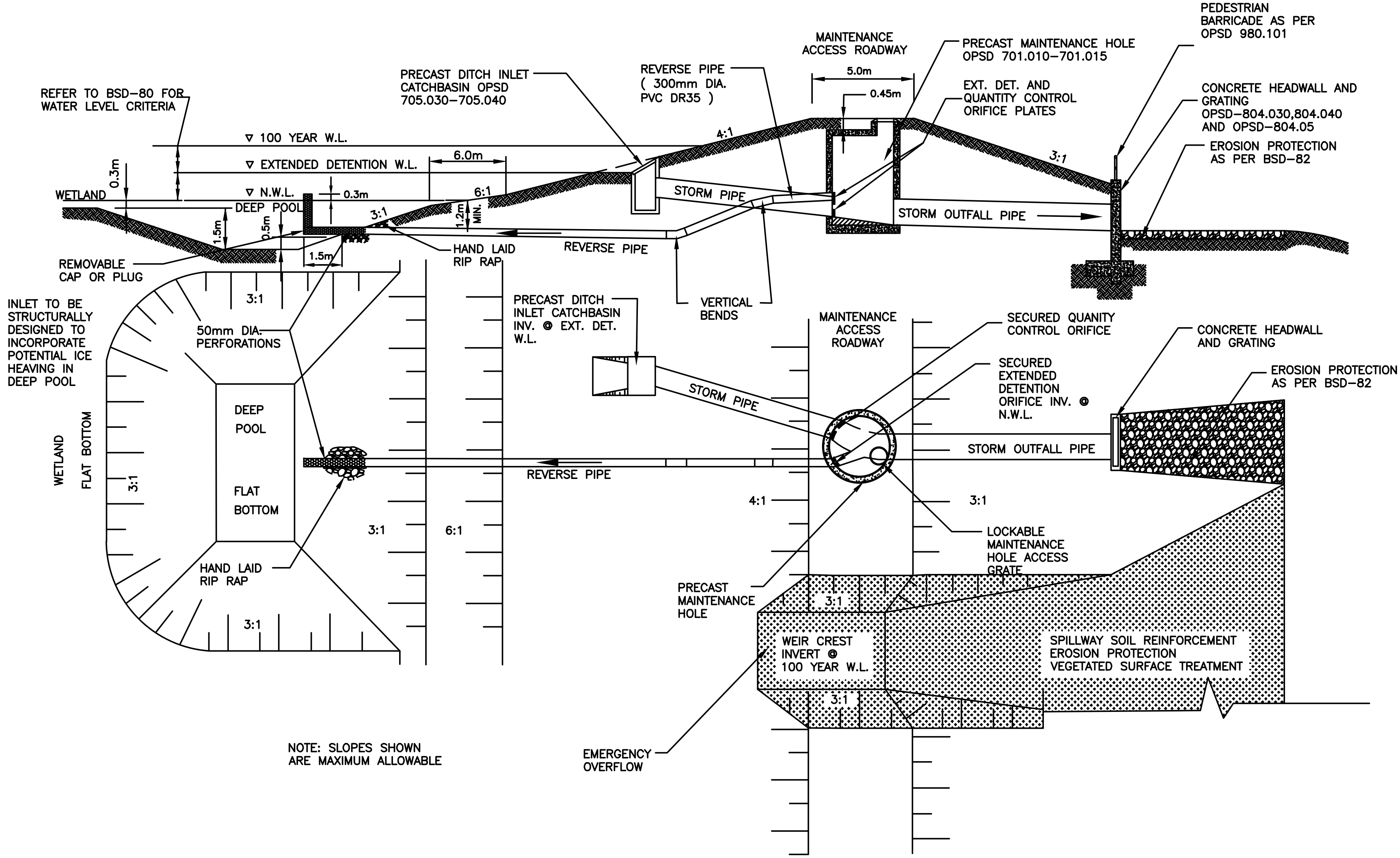
REV No.	DATE: APR 2023
1	SCALE: N.T.S
D776	



Barrie

SWM Facility with Maintenance Pipe

REV No.	DATE: APR 2023
1	SCALE: N.T.S.
D777	

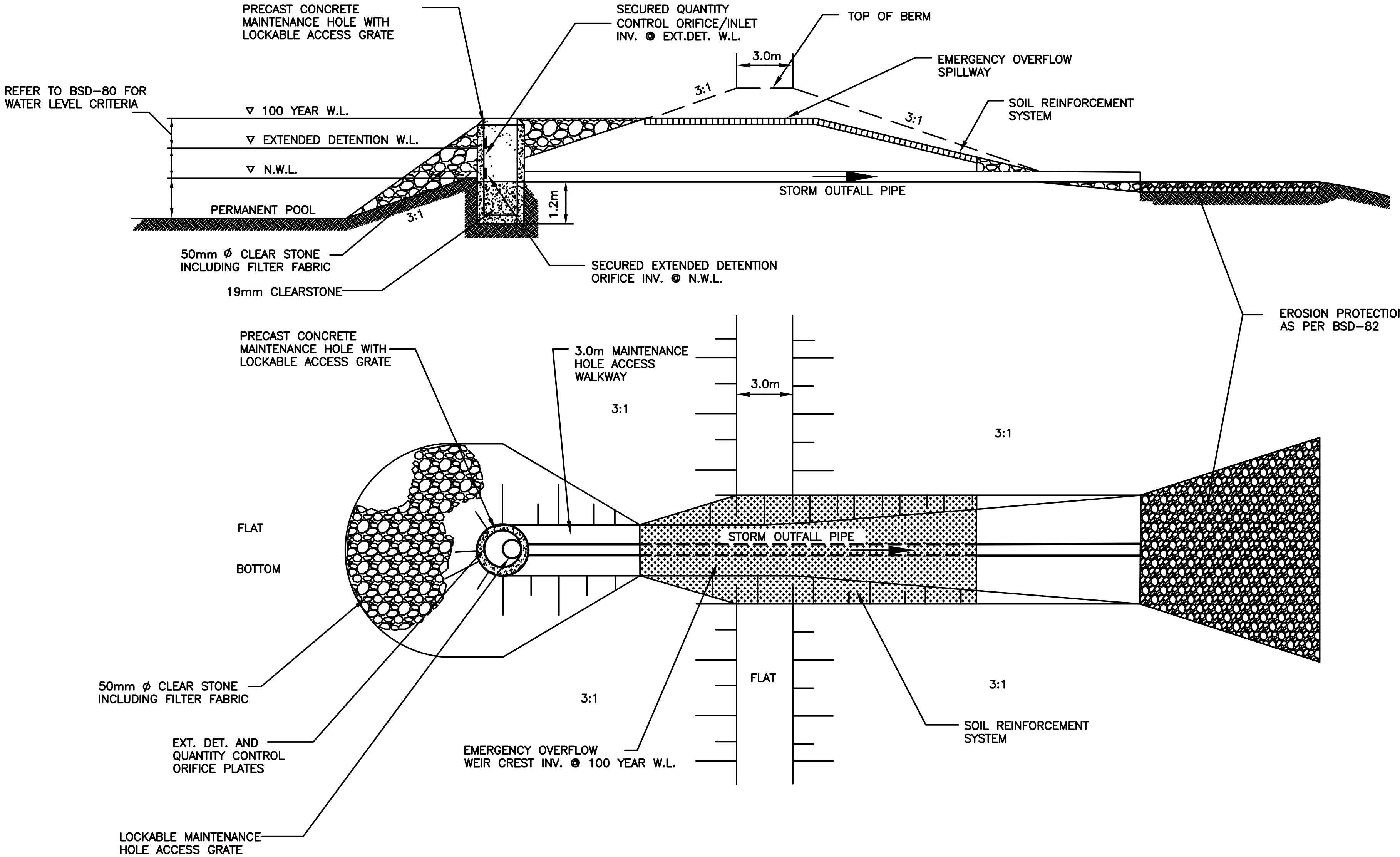


Barrie

SWM Facility without Maintenance Pipe

REV No.	DATE: APR 2023
1	SCALE: N.T.S.

D778

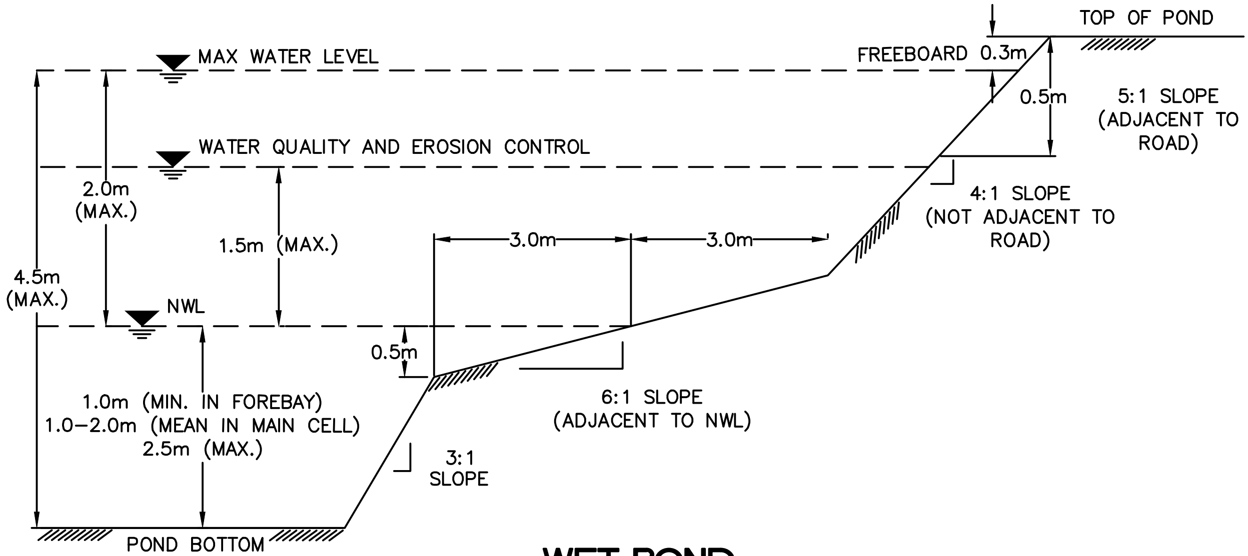


Barrie

Outlet Structure (Temporary)

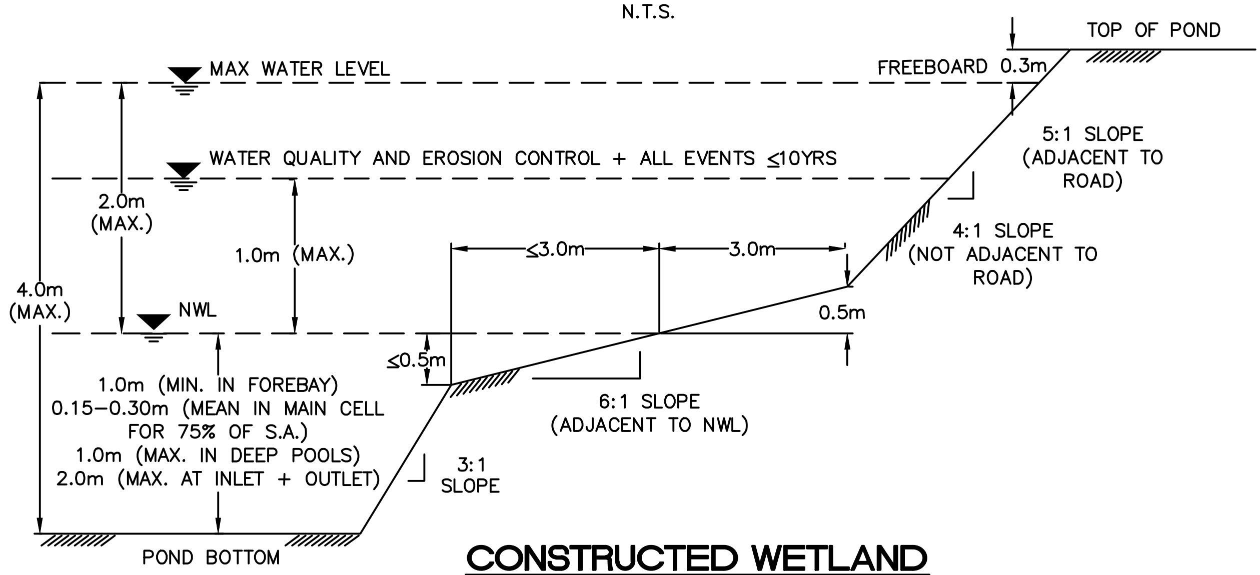
REV No.	DATE: APR 2023
1	SCALE: N.T.S.

D779



WET POND

N.T.S.

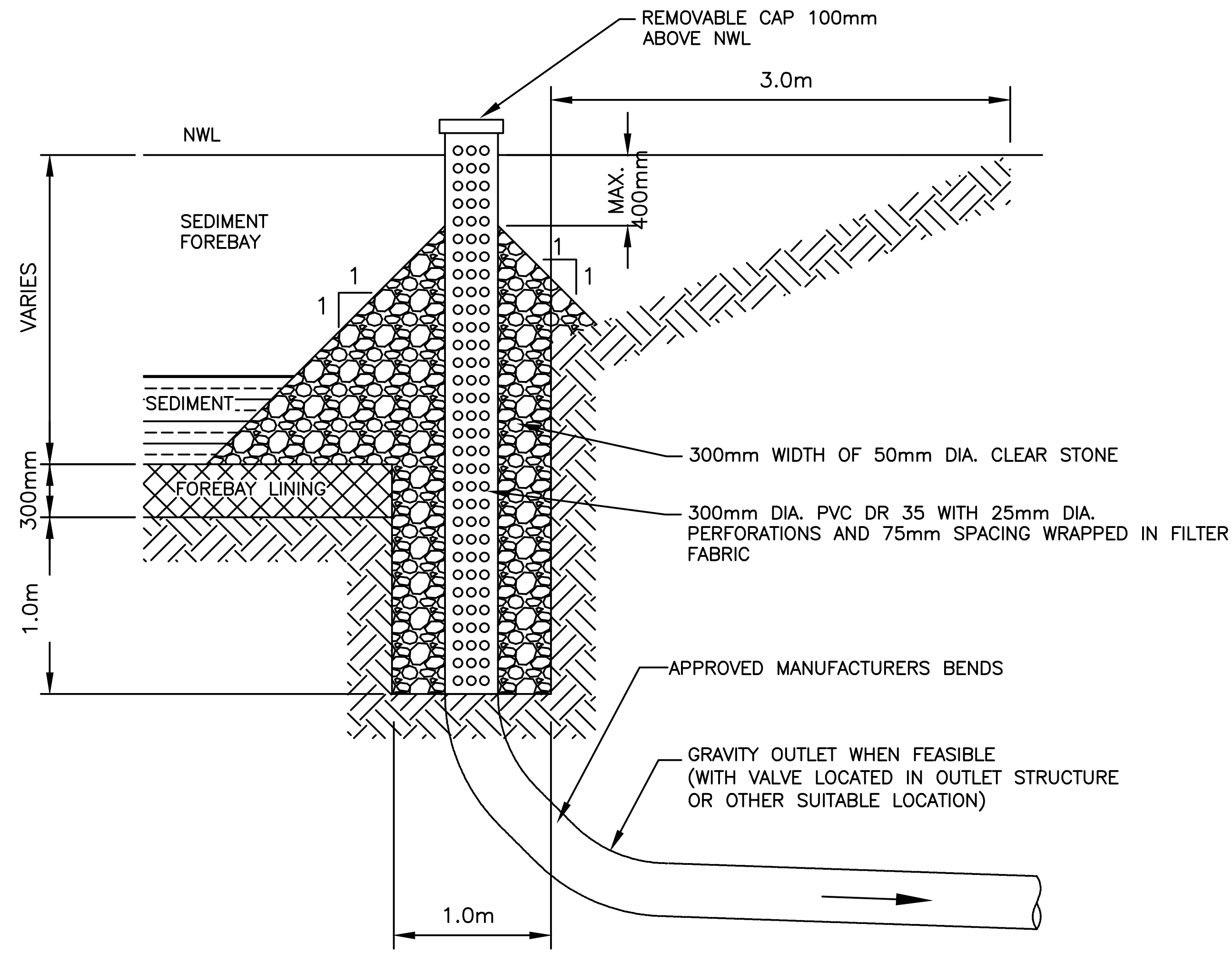


CONSTRUCTED WETLAND

NOTE: FOR HYBRID WET POND / WETLAND FACILITIES, THE ABOVE NOTED CRITERIA FOR DEPTH AND SLOPE SHALL APPLY TO THE RESPECTIVE WET POND AND WETLAND COMPONENTS OF THE HYBRID FACILITY WITH THE FOLLOWING CLARIFICATION:

1. DEPTH FOR ACTIVE STORAGE SHALL NOT EXCEED THE CRITERIA FOR A WETLAND UNLESS A TERRACED OVERFLOW CONFIGURATION IS EMPLOYED.
2. THE MINIMUM LENGTH TO WIDTH RATIO FOR THE WET POND COMPONENT SHALL BE 2:1

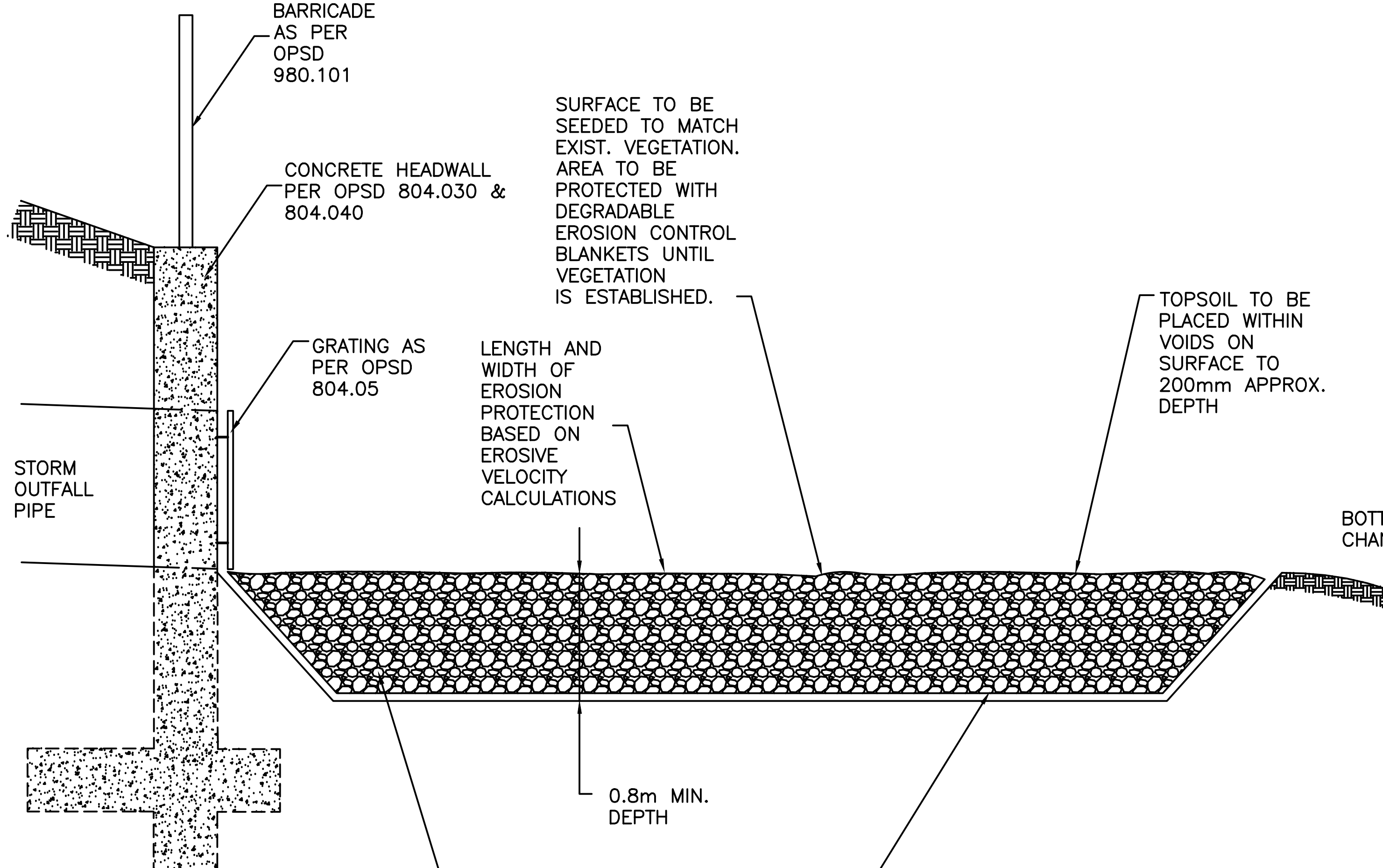
Barrie	SWM Facility Grading	REV No. 1	DATE: APR 2023
			SCALE: N.T.S
		D780	



Barrie

Forebay Dewatering Sump

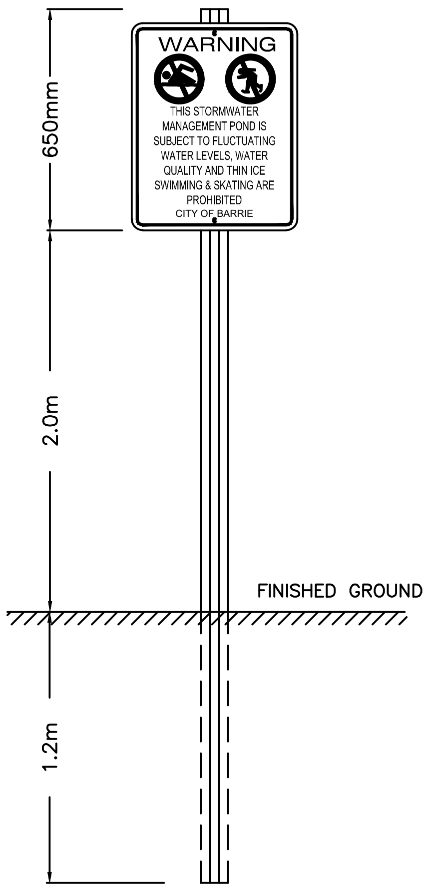
REV No. 1	DATE: APR 2023
	SCALE: N.T.S.
D781	

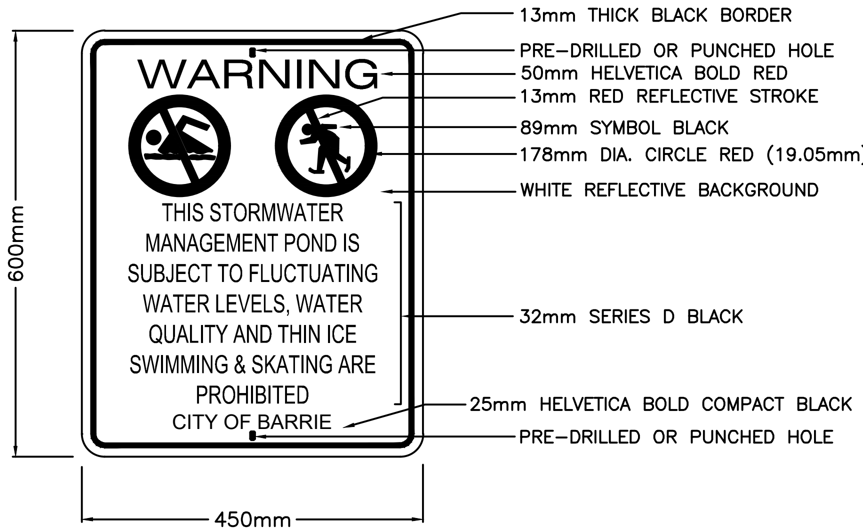


Barrie

Outlet Erosion Protection

REV No. 1	DATE: APR 2023
	SCALE: N.T.S.
D782	





SIGN REQUIREMENTS
SIGN(S) MUST BE PLACED AT ALL POND ENTRANCES.

SIGNAGE FACE
SIGN(S) TO BE MANUFACTURED USING REFLECTIVE FINISH (ENGINEER GRADE)
3.2mm THICK ALUMINUM PANEL (50mm RADIUS CORNERS), WITH TOP AND BOTTOM MOUNT HOLES.

MOUNTING
SIGN(S) TO BE MOUNTED TO 3.85m U-CHANNEL GALVANIZED STEEL POST.

Barrie	SWM Facility Warning Sign	REV No. 1	DATE: APR 2023 SCALE: N.T.S
		D783	

APPENDIX B

IDF DATA, DESIGN STORMS, CN VALUE CONVERSION TABLE, NVCA AND LSRCA REGIONAL STORM BOUNDARY

CORPORATE ASSET MANAGEMENT

- Intensity-Duration-Frequency Data (Barrie WPCC – 1979-2003) Modified to Account for Climate Change (includes a 15% increase in rainfall depth and intensity)

- Environment Canada Intensity-Duration-Frequency Data (Barrie WPCC – 1979-2003) – Un-Modified

- Design Storms

    - Chicago Storm Hyetographs (2-yr through 100-yr) (includes a 15% increase in rainfall depth and intensity to account for climate change)
    - SCS Type II Distributions (6-hr, 12-hr and 24-hr)
    - SCS Type II Storm Hyetographs (2-yr through 100yr) (includes a 15% increase in rainfall depth and intensity to account for climate change)
    - Hurricane Hazel Rainfall Depths
    - Hurricane Hazel – Areal Reduction
    - Timmins Storm Rainfall Depths
    - Timmins Storm – Areal Reduction

- CN Value Conversion Table (AMC I, II and III)

- NVCA & LSRCA Regional Storm Boundary

Barrie IDF Data – Adjusted to Account for Climate Change

Barrie WPCC Rainfall Intensity (mm/hr) + 15% to Account for Climate Change									
Return Period	**Duration (min)**								
	5	***10***	***15***	***30***	***60***	***120***	***360***	***720***	***1440***
2 years	115.5	81.5	67.4	43.1	25.3	15.5	7.0	3.9	2.3
5 years	150.0	107.9	89.9	56.2	32.8	21.9	9.9	5.4	3.2
10 years	173.0	125.5	104.9	65.1	37.6	26.1	11.8	6.3	3.8
25 years	201.8	147.4	123.7	76.0	43.8	31.4	14.3	7.6	4.5
50 years	223.3	163.9	137.7	84.3	48.4	35.4	16.0	8.5	5.1
100 years	244.7	180.1	151.6	92.3	53.0	39.3	17.7	9.4	5.5

Barrie WPCC Rainfall Depth (mm) + 15% to Account for Climate Change									
Return Period	**Duration (min)**								
	5	***10***	***15***	***30***	***60***	***120***	***360***	***720***	***1440***
2 years	9.7	13.6	16.8	21.5	25.3	31.1	42.3	46.7	55.0
5 years	12.5	17.9	22.4	28.2	32.8	43.8	59.5	64.3	76.0
10 years	14.4	20.9	26.2	32.5	37.6	52.2	70.8	76.0	89.9
25 years	16.8	24.6	30.9	38.1	43.8	62.9	85.2	90.7	107.5
50 years	18.6	27.3	34.4	42.1	48.4	70.7	95.9	101.7	120.6
100 years	20.4	30.0	37.8	46.2	53.0	78.5	106.5	112.5	133.6

ATMOSPHERIC ENVIRONMENT SERVICE
SERVICE DE L"ENVIRONNEMENT ATMOSPHERIQUE

RAINFALL INTENSITY-DURATION FREQUENCY VALUES
INTENSITE, DUREE ET FREQUENCE DES PLUIES

DATA INTEGRATION DIVISION
LA DIVISION DU TRAITEMENT DES DONNEES

GUMBEL - METHOD OF MOMENTS/METHODE DES MOMENTS - 1990

****

TABLE 1 BARRIE WPCC ONT 6110557

LATITUDE 4423 LONGITUDE 7941 ELEVATION/ALTITUDE 221 M

****

YEAR ANNEE	5 MIN	10 MIN	15 MIN	30 MIN	1 H	2 H	6 H	12 H	24 H
1979	12.1	14.9	18.6	24.6	25.9	26.4	45.9	45.9	46.5
1980	7.6	11.7	16.9	20.4	21.2	-99.9	-99.9	-99.9	74.2
1981	-99.9	-99.9	-99.9	-99.9	25.0	25.7	25.7	28.4	43.2
1982	5.5	9.4	13.5	16.5	18.8	20.2	29.5	39.0	39.2
1983	13.3	15.5	17.4	20.2	26.0	28.5	29.7	30.0	30.0
1984	12.2	13.3	14.6	18.0	18.3	23.2	27.8	28.0	28.0
1985	9.0	13.0	16.0	22.7	28.3	38.4	43.2	50.3	50.9
1986	9.5	12.9	15.2	20.2	32.3	50.6	74.9	75.8	113.3
1987	9.3	14.8	18.4	20.2	20.2	23.8	43.2	47.0	47.0
1988	8.8	10.8	12.7	14.4	20.0	22.0	30.4	37.6	60.0
1989	7.4	13.1	17.4	24.0	24.2	24.3	27.6	29.0	34.0
1990	6.6	9.7	10.9	14.5	15.9	17.3	-99.9	-99.9	43.0
1991	8.7	12.5	17.9	21.8	23.6	27.6	29.5	32.4	41.7
1992	4.5	4.8	5.4	9.2	11.6	16.8	26.3	27.8	31.6
1993	7.8	13.2	14.6	19.6	22.1	23.2	26.7	35.5	35.5
1994	5.8	9.2	13.4	16.4	20.1	22.0	28.4	33.4	37.5
1995	11.4	16.4	20.1	31.7	39.1	70.0	85.9	95.2	96.0
1996	8.5	9.5	10.9	14.8	16.8	23.8	37.6	42.4	53.6
1997	7.3	9.1	10.4	11.4	13.2	20.5	32.9	36.6	36.6
1998	6.4	11.1	15.0	17.5	25.8	29.7	43.8	50.1	54.5
1999	17.1	28.6	36.1	40.2	41.7	46.8	67.6	67.8	67.8
2000	8.0	12.9	18.0	24.8	32.2	45.1	53.0	57.1	73.8
2001	5.9	8.3	10.2	16.8	18.5	25.9	32.8	35.2	42.3
2002	9.7	14.1	16.4	20.8	22.5	25.2	28.0	32.2	38.7
2003	9.5	11.9	13.3	14.7	17.2	20.7	-99.9	-99.9	60.0

NOTE:-99.9 INDICATES MSG DATA
DONNEES MANQUANTES

	5 MIN	10 MIN	15 MIN	30 MIN	1 H	2 H	6 H	12 H	24 H
# YRS. ANNEES	24	24	24	24	25	24	22	22	25
MEAN MOYENNE	8.8	12.5	15.6	19.8	23.2	29.1	39.6	43.5	51.2
STD. DEV. ECART-TYPE	2.8	4.3	5.5	6.5	7.3	12.5	16.9	17.3	20.7
SKEW DISSYMETRIE	1.12	2.08	2.02	1.39	.95	1.98	1.64	1.69	1.58
KURTOSIS KURTOSIS	5.08	11.05	11.01	6.58	4.19	7.21	5.23	6.03	5.73

WARNING / AVERTISSEMENT
YEAR 1995 HAD VALUE GREATER THAN 100 YEAR STORM.
EN 1995 L"INTENSITE DE LA PLUIE A DE PASSE
CELLE POUR UNE PERIODE DE RETOUR DE 100 ANS
DATA/LA VALEUR = 70.0 100 YEAR/ANNEE = 68.3

WARNING / AVERTISSEMENT
YEAR 1999 HAD VALUE GREATER THAN 100 YEAR STORM.
EN 1999 L"INTENSITE DE LA PLUIE A DE PASSE
CELLE POUR UNE PERIODE DE RETOUR DE 100 ANS
DATA/LA VALEUR = 28.6 100 YEAR/ANNEE = 26.1

WARNING / AVERTISSEMENT
YEAR 1999 HAD VALUE GREATER THAN 100 YEAR STORM.
EN 1999 L"INTENSITE DE LA PLUIE A DE PASSE
CELLE POUR UNE PERIODE DE RETOUR DE 100 ANS
DATA/LA VALEUR = 36.1 100 YEAR/ANNEE = 32.9

WARNING / AVERTISSEMENT

YEAR 1999 HAD VALUE GREATER THAN 100 YEAR STORM.
EN 1999 L"INTENSITE DE LA PLUIE A DE PASSE
CELLE POUR UNE PERIODE DE RETOUR DE 100 ANS
DATA/LA VALEUR = 40.2 100 YEAR/ANNEE = 40.2

NOTE: -99.9 INDICATES LESS THAN 10 YEARS OF DATA AVAILABLE
INDIQUE MOINS DE 10 ANNEES DE DONNEES DISPONIBLES

ATMOSPHERIC ENVIRONMENT SERVICE
SERVICE DE L"ENVIRONNEMENT ATMOSPHERIQUE

RAINFALL INTENSITY-DURATION FREQUENCY VALUES
INTENSITE, DUREE ET FREQUENCE DES PLUIES

GUMBEL - METHOD OF MOMENTS/METHODE DES MOMENTS - 1990

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TABLE 2 BARRIE WPCC ONT 6110557

LATITUDE 4423 LONGITUDE 7941 ELEVATION/ALTITUDE 221 M

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RETURN PERIOD RAINFALL AMOUNTS (MM)
PERIODE DE RETOUR QUANTITIES DE PLUIE (MM)

DURATION DUREE	2 YR/ANS	5 YR/ANS	10 YR/ANS	25 YR/ANS	50 YR/ANS	100 YR/ANS	# YEARS ANNEES
5 MIN	8.4	10.9	12.5	14.6	16.2	17.7	24
10 MIN	11.8	15.6	18.2	21.4	23.7	26.1	24
15 MIN	14.6	19.5	22.8	26.9	29.9	32.9	24
30 MIN	18.7	24.5	28.3	33.1	36.6	40.2	24
1 H	22.0	28.5	32.7	38.1	42.1	46.1	25
2 H	27.0	38.1	45.4	54.7	61.5	68.3	24
6 H	36.8	51.7	61.6	74.1	83.4	92.6	22
12 H	40.6	55.9	66.1	78.9	88.4	97.8	22
24 H	47.8	66.1	78.2	93.5	104.9	116.2	25

RETURN PERIOD RAINFALL RATES (MM/HR)-95% CONFIDENCE' LIMITS
INTENSITE DE LA PLUIE PAR PERIODE DE RETOUR (MM/H)-LIMITES DE CONFIANCE DE 95%

DURATION DUREE	2 YR/ANS	5 YR/ANS	10 YR/ANS	25 YR/ANS	50 YR/ANS	100 YR/ANS
5 MIN	100.4	130.4	150.4	175.5	194.2	212.8
	+/- 12.5	+/- 21.1	+/- 28.4	+/- 38.4	+/- 45.9	+/- 53.5
10 MIN	70.9	93.8	109.1	128.2	142.5	156.6
	+/- 9.5	+/- 16.1	+/- 21.7	+/- 29.2	+/- 35.0	+/- 40.8
15 MIN	58.6	78.2	91.2	107.6	119.7	131.8
	+/- 8.1	+/- 13.7	+/- 18.5	+/- 25.0	+/- 29.9	+/- 34.8
30 MIN	37.5	48.9	56.6	66.1	73.3	80.3
	+/- 4.8	+/- 8.0	+/- 10.8	+/- 14.6	+/- 17.5	+/- 20.4
1 H	22.0	28.5	32.7	38.1	42.1	46.1
	+/- 2.6	+/- 4.4	+/- 6.0	+/- 8.0	+/- 9.6	+/- 11.2
2 H	13.5	19.0	22.7	27.3	30.8	34.2
	+/- 2.3	+/- 3.9	+/- 5.2	+/- 7.0	+/- 8.4	+/- 9.8
6 H	6.1	8.6	10.3	12.4	13.9	15.4
	+/- 1.1	+/- 1.8	+/- 2.5	+/- 3.3	+/- 4.0	+/- 4.6
12 H	3.4	4.7	5.5	6.6	7.4	8.2
	+/- .6	+/- .9	+/- 1.3	+/- 1.7	+/- 2.0	+/- 2.4
24 H	2.0	2.8	3.3	3.9	4.4	4.8
	+/- .3	+/- .5	+/- .7	+/- 1.0	+/- 1.1	+/- 1.3

ATMOSPHERIC ENVIRONMENT SERVICE
SERVICE DE L"ENVIRONNEMENT ATMOSPHERIQUE

RAINFALL INTENSITY-DURATION FREQUENCY VALUES
INTENSITE, DUREE ET FREQUENCE DES PLUIES

GUMBEL - METHOD OF MOMENTS/METHODE DES MOMENTS - 1990

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TABLE 3 BARRIE WPCC ONT 6110557

LATITUDE 4423 LONGITUDE 7941 ELEVATION/ALTITUDE 221 M

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INTERPOLATION EQUATION / EQUATION D"INTERPOLATION: R = A * T ** B
R = RAINFALL RATE / INTENSITE DE LA PLUIE (MM /HR)

T = TIME IN HOURS / TEMPS EN HEURES

STATISTICS STATISTIQUES	2 YR ANS	5 YR ANS	10 YR ANS	25 YR ANS	50 YR ANS	100 YR ANS
MEAN OF R MOYENNE DE R	34.9	46.1	53.5	62.8	69.7	76.6
STD. DEV. R ECART-TYPE	34.7	45.3	52.4	61.2	67.8	74.4
STD. ERROR ERREUR STANDARD	7.4	9.7	11.2	13.2	14.7	16.2
COEFF. (A) COEFFICIENT (A)	20.6	27.7	32.4	38.3	42.7	47.0
EXPONENT (B) EXPOSANT (B)	-.705	-.693	-.687	-.682	-.680	-.677
MEAN % ERROR % D'ERREUR	7.9	8.2	8.3	8.5	8.7	8.9

City of Barrie 4-hr Chicago Storm Hyetographs (Adjusted to Account for Climate Change)

Time (min)	Intensity (mm/hr)					
	2-YR	**5-YR**	**10-YR**	**25-YR**	**50-YR**	**100-YR**
0	0.00	0.00	0.00	0.00	0.00	0.00
10	2.47	3.57	4.32	5.22	5.93	6.41
20	2.82	4.07	4.91	5.94	6.74	7.29
30	3.31	4.76	5.73	6.93	7.85	8.52
40	4.05	5.79	6.96	8.42	9.50	10.36
50	5.30	7.53	9.03	10.91	12.27	13.45
60	7.98	11.20	13.36	16.13	18.04	19.96
70	18.78	25.64	30.27	36.37	40.22	45.22
80	83.11	108.92	126.55	148.15	164.22	180.15
90	24.57	33.31	39.22	47.06	51.92	58.54
100	13.01	17.99	21.35	25.72	28.58	31.96
110	9.01	12.60	15.01	18.11	20.23	22.45
120	6.97	9.82	11.74	14.17	15.88	17.52
130	5.73	8.12	9.72	11.74	13.20	14.50
140	4.89	6.96	8.35	10.09	11.37	12.44
150	4.28	6.12	7.35	8.89	10.03	10.94
160	3.82	5.48	6.59	7.96	9.00	9.80
170	3.46	4.97	5.99	7.24	8.19	8.90
180	3.17	4.56	5.50	6.65	7.53	8.16
190	2.93	4.22	5.09	6.15	6.98	7.56
200	2.72	3.93	4.74	5.74	6.51	7.04
210	2.55	3.68	4.45	5.38	6.11	6.60
220	2.39	3.47	4.19	5.08	5.77	6.22
230	2.26	3.28	3.97	4.80	5.46	5.89
240	2.15	3.12	3.77	4.57	5.19	5.59
Depth (mm)	**36.96**	**50.52**	**59.69**	**71.24**	**79.45**	**87.58**

A	678.085	853.608	975.865	1146.275	1236.152	1426.408
B	4.699	4.699	4.699	4.922	4.699	5.273
C	0.781	0.766	0.760	0.757	0.751	0.759

S.C.S. TYPE II - 6 AND 12 HOUR DISTRIBUTION

12 HOUR			6 HOUR		
Time (Hours)	Ratio of Accumulated To Total (%)	Incremental (%)	Time (Hours)	Ratio of Accumulated To Total (%)	Incremental (%)
0	0	0	0	0	0
2	5	5	0.5	2	2
3	8	3	1	5	3
3.5	10	2	1.5	8	3
4	12	2	2	13	5
4.5	15	3	2.5	19	6
5	19	4	2.75	34	15
5.5	25	6	3	73	39
5.75	37	12	3.5	84	11
6	70	33	4	89	5
6.5	79	9	4.5	93	4
7	83	4	5	96	3
7.5	86	3	6	100	4
8	89	3			100
10	96	7			
12	100	4			
		100			

S.C.S. TYPE II - 24 HOUR DISTRIBUTION

Time (Hours)	Ratio of Accumulated To Total (%)	Incremental
0.0	0.0	0.0
2	2.2	2.2
4	4.8	2.6
6	8.0	3.2
7	-	-
8	12.0	4.0
8.5	-	-
9	14.7	2.7
9.5	16.3	1.6
9.75	-	-
10	18.1	1.8
10.5	20.4	2.3
11	23.5	3.1
11.5	28.3	4.8
11.75	38.7	10.4
12	66.3	27.6
12.5	73.5	7.2
13	77.2	3.7
13.5	77.9	0.7
14	82.0	4.1
16	88.0	6.0
20	95.2	7.2
24	100.0	4.8
		100.0

Note: A copy of the 6-hr, 12-hr and 24-hr SCS storm files is available from the City of Barrie and are provided on the CD included with the *Storm Drainage and Stormwater Management Policies and Design Criteria* document.

Source: Technical Guidelines for Flood Plain Management in Ontario, Working Paper C, Rainfall Analysis, Report to MNR, Dillon Consulting, August 1985

City of Barrie SCS Storm Hyetographs
(Adjusted to Account for Climate Change)
2-yr Return Period

Total Rainfall Depth (mm): 42.3
6 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	1	1	0.423	1.692
0.5	2	1	0.423	1.692
0.75	3.5	1.5	0.635	2.538
1	5	1.5	0.635	2.538
1.25	6.5	1.5	0.635	2.538
1.5	8	1.5	0.635	2.538
1.75	10.5	2.5	1.058	4.23
2	13	2.5	1.058	4.23
2.25	16	3	1.269	5.076
2.5	19	3	1.269	5.076
2.75	34	15	6.345	25.38
3	73	39	16.497	65.988
3.25	78.5	5.5	2.327	9.306
3.5	84	5.5	2.327	9.306
3.75	86.5	2.5	1.058	4.23
4	89	2.5	1.058	4.23
4.25	91	2	0.846	3.384
4.5	93	2	0.846	3.384
4.75	94.5	1.5	0.635	2.538
5	96	1.5	0.635	2.538
5.25	97	1	0.423	1.692
5.5	98	1	0.423	1.692
5.75	99	1	0.423	1.692
6	100	1	0.423	1.692
		Sum:	**42.3**	

Total Rainfall Depth (mm): 46.7
12 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	0.625	0.625	0.292	1.1675
0.5	1.25	0.625	0.292	1.1675
0.75	1.875	0.625	0.292	1.1675
1	2.5	0.625	0.292	1.1675
1.25	3.125	0.625	0.292	1.1675
1.5	3.75	0.625	0.292	1.1675
1.75	4.375	0.625	0.292	1.1675
2	5	0.625	0.292	1.1675
2.25	5.75	0.75	0.350	1.401
2.5	6.5	0.75	0.350	1.401
2.75	7.25	0.75	0.350	1.401
3	8	0.75	0.350	1.401
3.25	9	1	0.467	1.868
3.5	10	1	0.467	1.868
3.75	11	1	0.467	1.868
4	12	1	0.467	1.868
4.25	13.5	1.5	0.701	2.802
4.5	15	1.5	0.701	2.802
4.75	17	2	0.934	3.736
5	19	2	0.934	3.736
5.25	22	3	1.401	5.604
5.5	25	3	1.401	5.604
5.75	37	12	5.604	22.416
6	70	33	15.411	61.644
6.25	74.5	4.5	2.102	8.406
6.5	79	4.5	2.102	8.406
6.75	81	2	0.934	3.736
7	83	2	0.934	3.736
7.25	84.5	1.5	0.701	2.802
7.5	86	1.5	0.701	2.802
7.75	87.5	1.5	0.701	2.802
8	89	1.5	0.701	2.802
8.25	89.875	0.875	0.409	1.6345
8.5	90.75	0.875	0.409	1.6345
8.75	91.625	0.875	0.409	1.6345
9	92.5	0.875	0.409	1.6345
9.25	93.375	0.875	0.409	1.6345
9.5	94.25	0.875	0.409	1.6345
9.75	95.125	0.875	0.409	1.6345
10	96	0.875	0.409	1.6345
10.25	96.5	0.5	0.234	0.934
10.5	97	0.5	0.234	0.934
10.75	97.5	0.5	0.234	0.934
11	98	0.5	0.234	0.934
11.25	98.5	0.5	0.234	0.934
11.5	99	0.5	0.234	0.934
11.75	99.5	0.5	0.234	0.934
12	100	0.5	0.234	0.934
		Sum:	**46.7**	

Total Rainfall Depth (mm): 55
24 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	0.25	0.25	0.138	0.55
0.5	0.5	0.25	0.138	0.55
0.75	0.75	0.25	0.138	0.55
1	1	0.25	0.138	0.55
1.25	1.25	0.25	0.138	0.55
1.5	1.5	0.25	0.138	0.55
1.75	1.75	0.25	0.138	0.55
2	2.2	0.45	0.248	0.99
2.25	2.525	0.325	0.179	0.715
2.5	2.85	0.325	0.179	0.715
2.75	3.175	0.325	0.179	0.715
3	3.5	0.325	0.179	0.715
3.25	3.825	0.325	0.179	0.715
3.5	4.15	0.325	0.179	0.715
3.75	4.475	0.325	0.179	0.715
4	4.8	0.325	0.179	0.715
4.25	5.2	0.4	0.220	0.88
4.5	5.6	0.4	0.220	0.88
4.75	6	0.4	0.220	0.88
5	6.4	0.4	0.220	0.88
5.25	6.8	0.4	0.220	0.88
5.5	7.2	0.4	0.220	0.88
5.75	7.6	0.4	0.220	0.88
6	8	0.4	0.220	0.88
6.25	8.5	0.5	0.275	1.1
6.5	9	0.5	0.275	1.1
6.75	9.5	0.5	0.275	1.1
7	10	0.5	0.275	1.1
7.25	10.5	0.5	0.275	1.1
7.5	11	0.5	0.275	1.1
7.75	11.5	0.5	0.275	1.1
8	12	0.5	0.275	1.1
8.25	12.675	0.675	0.371	1.485
8.5	13.35	0.675	0.371	1.485
8.75	14.025	0.675	0.371	1.485
9	14.7	0.675	0.371	1.485
9.25	15.5	0.8	0.440	1.76
9.5	16.3	0.8	0.440	1.76
9.75	17.2	0.9	0.495	1.98
10	18.1	0.9	0.495	1.98
10.25	19.25	1.15	0.632	2.53
10.5	20.4	1.15	0.632	2.53
10.75	21.95	1.55	0.853	3.41
11	23.5	1.55	0.853	3.41
11.25	25.9	2.4	1.320	5.28
11.5	28.3	2.4	1.320	5.28
11.75	38.7	10.4	5.720	22.88
12	66.3	27.6	15.180	60.72
12.25	69.9	3.6	1.980	7.92
12.5	73.5	3.6	1.980	7.92
12.75	75.35	1.85	1.018	4.07
13	77.2	1.85	1.018	4.07
13.25	77.55	0.35	0.193	0.77
13.5	77.9	0.35	0.192	0.77
13.75	79.95	2.05	1.128	4.51
14	82	2.05	1.128	4.51
14.25	82.75	0.75	0.413	1.65
14.5	83.5	0.75	0.413	1.65
14.75	84.25	0.75	0.413	1.65
15	85	0.75	0.413	1.65
15.25	85.75	0.75	0.413	1.65
15.5	86.5	0.75	0.413	1.65
15.75	87.25	0.75	0.413	1.65
16	88	0.75	0.413	1.65
16.25	88.45	0.45	0.248	0.99
16.5	88.9	0.45	0.248	0.99
16.75	89.35	0.45	0.247	0.99
17	89.8	0.45	0.248	0.99
17.25	90.25	0.45	0.248	0.99
17.5	90.7	0.45	0.248	0.99
17.75	91.15	0.45	0.248	0.99
18	91.6	0.45	0.247	0.99
18.25	92.05	0.45	0.248	0.99
18.5	92.5	0.45	0.248	0.99
18.75	92.95	0.45	0.248	0.99
19	93.4	0.45	0.248	0.99
19.25	93.85	0.45	0.247	0.99
19.5	94.3	0.45	0.248	0.99
19.75	94.75	0.45	0.248	0.99
20	95.2	0.45	0.248	0.99
20.25	95.5	0.3	0.165	0.66
20.5	95.8	0.3	0.165	0.66
20.75	96.1	0.3	0.165	0.66
21	96.4	0.3	0.165	0.66
21.25	96.7	0.3	0.165	0.66
21.5	97	0.3	0.165	0.66
21.75	97.3	0.3	0.165	0.66
22	97.6	0.3	0.165	0.66
22.25	97.9	0.3	0.165	0.66
22.5	98.2	0.3	0.165	0.66
22.75	98.5	0.3	0.165	0.66
23	98.8	0.3	0.165	0.66
23.25	99.1	0.3	0.165	0.66
23.5	99.4	0.3	0.165	0.66
23.75	99.7	0.3	0.165	0.66
24	100	0.3	0.165	0.66
		Sum:	**55**	

City of Barrie SCS Storm Hyetographs
(Adjusted to Account for Climate Change)
5-yr Return Period

Total Rainfall Depth (mm): 59.5
6 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	1	1	0.595	2.38
0.5	2	1	0.595	2.38
0.75	3.5	1.5	0.893	3.57
1	5	1.5	0.893	3.57
1.25	6.5	1.5	0.893	3.57
1.5	8	1.5	0.893	3.57
1.75	10.5	2.5	1.488	5.95
2	13	2.5	1.488	5.95
2.25	16	3	1.785	7.14
2.5	19	3	1.785	7.14
2.75	34	15	8.925	35.7
3	73	39	23.205	92.82
3.25	78.5	5.5	3.273	13.09
3.5	84	5.5	3.273	13.09
3.75	86.5	2.5	1.488	5.95
4	89	2.5	1.488	5.95
4.25	91	2	1.190	4.76
4.5	93	2	1.190	4.76
4.75	94.5	1.5	0.893	3.57
5	96	1.5	0.893	3.57
5.25	97	1	0.595	2.38
5.5	98	1	0.595	2.38
5.75	99	1	0.595	2.38
6	100	1	0.595	2.38
		Sum:	**59.5**	

Total Rainfall Depth (mm): 64.3
12 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	0.625	0.625	0.402	1.6075
0.5	1.25	0.625	0.402	1.6075
0.75	1.875	0.625	0.402	1.6075
1	2.5	0.625	0.402	1.6075
1.25	3.125	0.625	0.402	1.6075
1.5	3.75	0.625	0.402	1.6075
1.75	4.375	0.625	0.402	1.6075
2	5	0.625	0.402	1.6075
2.25	5.75	0.75	0.482	1.929
2.5	6.5	0.75	0.482	1.929
2.75	7.25	0.75	0.482	1.929
3	8	0.75	0.482	1.929
3.25	9	1	0.643	2.572
3.5	10	1	0.643	2.572
3.75	11	1	0.643	2.572
4	12	1	0.643	2.572
4.25	13.5	1.5	0.965	3.858
4.5	15	1.5	0.965	3.858
4.75	17	2	1.286	5.144
5	19	2	1.286	5.144
5.25	22	3	1.929	7.716
5.5	25	3	1.929	7.716
5.75	37	12	7.716	30.864
6	70	33	21.219	84.876
6.25	74.5	4.5	2.894	11.574
6.5	79	4.5	2.894	11.574
6.75	81	2	1.286	5.144
7	83	2	1.286	5.144
7.25	84.5	1.5	0.965	3.858
7.5	86	1.5	0.965	3.858
7.75	87.5	1.5	0.965	3.858
8	89	1.5	0.965	3.858
8.25	89.875	0.875	0.563	2.2505
8.5	90.75	0.875	0.563	2.2505
8.75	91.625	0.875	0.563	2.2505
9	92.5	0.875	0.563	2.2505
9.25	93.375	0.875	0.563	2.2505
9.5	94.25	0.875	0.563	2.2505
9.75	95.125	0.875	0.563	2.2505
10	96	0.875	0.563	2.2505
10.25	96.5	0.5	0.322	1.286
10.5	97	0.5	0.322	1.286
10.75	97.5	0.5	0.322	1.286
11	98	0.5	0.322	1.286
11.25	98.5	0.5	0.322	1.286
11.5	99	0.5	0.322	1.286
11.75	99.5	0.5	0.322	1.286
12	100	0.5	0.322	1.286
		Sum:	**64.3**	

Total Rainfall Depth (mm): 76
24 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	0.25	0.25	0.190	0.76
0.5	0.5	0.25	0.190	0.76
0.75	0.75	0.25	0.190	0.76
1	1	0.25	0.190	0.76
1.25	1.25	0.25	0.190	0.76
1.5	1.5	0.25	0.190	0.76
1.75	1.75	0.25	0.190	0.76
2	2.2	0.45	0.342	1.368
2.25	2.525	0.325	0.247	0.988
2.5	2.85	0.325	0.247	0.988
2.75	3.175	0.325	0.247	0.988
3	3.5	0.325	0.247	0.988
3.25	3.825	0.325	0.247	0.988
3.5	4.15	0.325	0.247	0.988
3.75	4.475	0.325	0.247	0.988
4	4.8	0.325	0.247	0.988
4.25	5.2	0.4	0.304	1.216
4.5	5.6	0.4	0.304	1.216
4.75	6	0.4	0.304	1.216
5	6.4	0.4	0.304	1.216
5.25	6.8	0.4	0.304	1.216
5.5	7.2	0.4	0.304	1.216
5.75	7.6	0.4	0.304	1.216
6	8	0.4	0.304	1.216
6.25	8.5	0.5	0.380	1.52
6.5	9	0.5	0.380	1.52
6.75	9.5	0.5	0.380	1.52
7	10	0.5	0.380	1.52
7.25	10.5	0.5	0.380	1.52
7.5	11	0.5	0.380	1.52
7.75	11.5	0.5	0.380	1.52
8	12	0.5	0.380	1.52
8.25	12.675	0.675	0.513	2.052
8.5	13.35	0.675	0.513	2.052
8.75	14.025	0.675	0.513	2.052
9	14.7	0.675	0.513	2.052
9.25	15.5	0.8	0.608	2.432
9.5	16.3	0.8	0.608	2.432
9.75	17.2	0.9	0.684	2.736
10	18.1	0.9	0.684	2.736
10.25	19.25	1.15	0.874	3.496
10.5	20.4	1.15	0.874	3.496
10.75	21.95	1.55	1.178	4.712
11	23.5	1.55	1.178	4.712
11.25	25.9	2.4	1.824	7.296
11.5	28.3	2.4	1.824	7.296
11.75	38.7	10.4	7.904	31.616
12	66.3	27.6	20.976	83.904
12.25	69.9	3.6	2.736	10.944
12.5	73.5	3.6	2.736	10.944
12.75	75.35	1.85	1.406	5.624
13	77.2	1.85	1.406	5.624
13.25	77.55	0.35	0.266	1.064
13.5	77.9	0.35	0.266	1.064
13.75	79.95	2.05	1.558	6.232
14	82	2.05	1.558	6.232
14.25	82.75	0.75	0.570	2.28
14.5	83.5	0.75	0.570	2.28
14.75	84.25	0.75	0.570	2.28
15	85	0.75	0.570	2.28
15.25	85.75	0.75	0.570	2.28
15.5	86.5	0.75	0.570	2.28
15.75	87.25	0.75	0.570	2.28
16	88	0.75	0.570	2.28
16.25	88.45	0.45	0.342	1.368
16.5	88.9	0.45	0.342	1.368
16.75	89.35	0.45	0.342	1.368
17	89.8	0.45	0.342	1.368
17.25	90.25	0.45	0.342	1.368
17.5	90.7	0.45	0.342	1.368
17.75	91.15	0.45	0.342	1.368
18	91.6	0.45	0.342	1.368
18.25	92.05	0.45	0.342	1.368
18.5	92.5	0.45	0.342	1.368
18.75	92.95	0.45	0.342	1.368
19	93.4	0.45	0.342	1.368
19.25	93.85	0.45	0.342	1.368
19.5	94.3	0.45	0.342	1.368
19.75	94.75	0.45	0.342	1.368
20	95.2	0.45	0.342	1.368
20.25	95.5	0.3	0.228	0.912
20.5	95.8	0.3	0.228	0.912
20.75	96.1	0.3	0.228	0.912
21	96.4	0.3	0.228	0.912
21.25	96.7	0.3	0.228	0.912
21.5	97	0.3	0.228	0.912
21.75	97.3	0.3	0.228	0.912
22	97.6	0.3	0.228	0.912
22.25	97.9	0.3	0.228	0.912
22.5	98.2	0.3	0.228	0.912
22.75	98.5	0.3	0.228	0.912
23	98.8	0.3	0.228	0.912
23.25	99.1	0.3	0.228	0.912
23.5	99.4	0.3	0.228	0.912
23.75	99.7	0.3	0.228	0.912
24	100	0.3	0.228	0.912
		Sum:	**76**	

City of Barrie SCS Storm Hyetographs
(Adjusted to Account for Climate Change)
10-yr Return Period

Total Rainfall Depth (mm): 70.8
6 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	1	1	0.708	2.832
0.5	2	1	0.708	2.832
0.75	3.5	1.5	1.062	4.248
1	5	1.5	1.062	4.248
1.25	6.5	1.5	1.062	4.248
1.5	8	1.5	1.062	4.248
1.75	10.5	2.5	1.770	7.08
2	13	2.5	1.770	7.08
2.25	16	3	2.124	8.496
2.5	19	3	2.124	8.496
2.75	34	15	10.620	42.48
3	73	39	27.612	110.448
3.25	78.5	5.5	3.894	15.576
3.5	84	5.5	3.894	15.576
3.75	86.5	2.5	1.770	7.08
4	89	2.5	1.770	7.08
4.25	91	2	1.416	5.664
4.5	93	2	1.416	5.664
4.75	94.5	1.5	1.062	4.248
5	96	1.5	1.062	4.248
5.25	97	1	0.708	2.832
5.5	98	1	0.708	2.832
5.75	99	1	0.708	2.832
6	100	1	0.708	2.832
		Sum:	**70.8**	

Total Rainfall Depth (mm): 76
12 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	0.625	0.625	0.475	1.9
0.5	1.25	0.625	0.475	1.9
0.75	1.875	0.625	0.475	1.9
1	2.5	0.625	0.475	1.9
1.25	3.125	0.625	0.475	1.9
1.5	3.75	0.625	0.475	1.9
1.75	4.375	0.625	0.475	1.9
2	5	0.625	0.475	1.9
2.25	5.75	0.75	0.570	2.28
2.5	6.5	0.75	0.570	2.28
2.75	7.25	0.75	0.570	2.28
3	8	0.75	0.570	2.28
3.25	9	1	0.760	3.04
3.5	10	1	0.760	3.04
3.75	11	1	0.760	3.04
4	12	1	0.760	3.04
4.25	13.5	1.5	1.140	4.56
4.5	15	1.5	1.140	4.56
4.75	17	2	1.520	6.08
5	19	2	1.520	6.08
5.25	22	3	2.280	9.12
5.5	25	3	2.280	9.12
5.75	37	12	9.120	36.48
6	70	33	25.080	100.32
6.25	74.5	4.5	3.420	13.68
6.5	79	4.5	3.420	13.68
6.75	81	2	1.520	6.08
7	83	2	1.520	6.08
7.25	84.5	1.5	1.140	4.56
7.5	86	1.5	1.140	4.56
7.75	87.5	1.5	1.140	4.56
8	89	1.5	1.140	4.56
8.25	89.875	0.875	0.665	2.66
8.5	90.75	0.875	0.665	2.66
8.75	91.625	0.875	0.665	2.66
9	92.5	0.875	0.665	2.66
9.25	93.375	0.875	0.665	2.66
9.5	94.25	0.875	0.665	2.66
9.75	95.125	0.875	0.665	2.66
10	96	0.875	0.665	2.66
10.25	96.5	0.5	0.380	1.52
10.5	97	0.5	0.380	1.52
10.75	97.5	0.5	0.380	1.52
11	98	0.5	0.380	1.52
11.25	98.5	0.5	0.380	1.52
11.5	99	0.5	0.380	1.52
11.75	99.5	0.5	0.380	1.52
12	100	0.5	0.380	1.52
		Sum:	**76**	

Total Rainfall Depth (mm): 89.9
24 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	0.25	0.25	0.225	0.899
0.5	0.5	0.25	0.225	0.899
0.75	0.75	0.25	0.225	0.899
1	1	0.25	0.225	0.899
1.25	1.25	0.25	0.225	0.899
1.5	1.5	0.25	0.225	0.899
1.75	1.75	0.25	0.225	0.899
2	2.2	0.45	0.405	1.6182
2.25	2.525	0.325	0.292	1.1687
2.5	2.85	0.325	0.292	1.1687
2.75	3.175	0.325	0.292	1.1687
3	3.5	0.325	0.292	1.1687
3.25	3.825	0.325	0.292	1.1687
3.5	4.15	0.325	0.292	1.1687
3.75	4.475	0.325	0.292	1.1687
4	4.8	0.325	0.292	1.1687
4.25	5.2	0.4	0.360	1.4384
4.5	5.6	0.4	0.360	1.4384
4.75	6	0.4	0.360	1.4384
5	6.4	0.4	0.360	1.4384
5.25	6.8	0.4	0.360	1.4384
5.5	7.2	0.4	0.360	1.4384
5.75	7.6	0.4	0.360	1.4384
6	8	0.4	0.360	1.4384
6.25	8.5	0.5	0.450	1.798
6.5	9	0.5	0.450	1.798
6.75	9.5	0.5	0.450	1.798
7	10	0.5	0.450	1.798
7.25	10.5	0.5	0.450	1.798
7.5	11	0.5	0.450	1.798
7.75	11.5	0.5	0.450	1.798
8	12	0.5	0.450	1.798
8.25	12.675	0.675	0.607	2.4273
8.5	13.35	0.675	0.607	2.4273
8.75	14.025	0.675	0.607	2.4273
9	14.7	0.675	0.607	2.4273
9.25	15.5	0.8	0.719	2.8768
9.5	16.3	0.8	0.719	2.8768
9.75	17.2	0.9	0.809	3.2364
10	18.1	0.9	0.809	3.2364
10.25	19.25	1.15	1.034	4.1354
10.5	20.4	1.15	1.034	4.1354
10.75	21.95	1.55	1.393	5.5738
11	23.5	1.55	1.393	5.5738
11.25	25.9	2.4	2.158	8.6304
11.5	28.3	2.4	2.158	8.6304
11.75	38.7	10.4	9.350	37.3984
12	66.3	27.6	24.812	99.2496
12.25	69.9	3.6	3.236	12.9456
12.5	73.5	3.6	3.236	12.9456
12.75	75.35	1.85	1.663	6.6526
13	77.2	1.85	1.663	6.6526
13.25	77.55	0.35	0.315	1.2586
13.5	77.9	0.35	0.315	1.2586
13.75	79.95	2.05	1.843	7.3718
14	82	2.05	1.843	7.3718
14.25	82.75	0.75	0.674	2.697
14.5	83.5	0.75	0.674	2.697
14.75	84.25	0.75	0.674	2.697
15	85	0.75	0.674	2.697
15.25	85.75	0.75	0.674	2.697
15.5	86.5	0.75	0.674	2.697
15.75	87.25	0.75	0.674	2.697
16	88	0.75	0.674	2.697
16.25	88.45	0.45	0.405	1.6182
16.5	88.9	0.45	0.405	1.6182
16.75	89.35	0.45	0.405	1.6182
17	89.8	0.45	0.405	1.6182
17.25	90.25	0.45	0.405	1.6182
17.5	90.7	0.45	0.405	1.6182
17.75	91.15	0.45	0.405	1.6182
18	91.6	0.45	0.405	1.6182
18.25	92.05	0.45	0.405	1.6182
18.5	92.5	0.45	0.405	1.6182
18.75	92.95	0.45	0.405	1.6182
19	93.4	0.45	0.405	1.6182
19.25	93.85	0.45	0.405	1.6182
19.5	94.3	0.45	0.405	1.6182
19.75	94.75	0.45	0.405	1.6182
20	95.2	0.45	0.405	1.6182
20.25	95.5	0.3	0.270	1.0788
20.5	95.8	0.3	0.270	1.0788
20.75	96.1	0.3	0.270	1.0788
21	96.4	0.3	0.270	1.0788
21.25	96.7	0.3	0.270	1.0788
21.5	97	0.3	0.270	1.0788
21.75	97.3	0.3	0.270	1.0788
22	97.6	0.3	0.270	1.0788
22.25	97.9	0.3	0.270	1.0788
22.5	98.2	0.3	0.270	1.0788
22.75	98.5	0.3	0.270	1.0788
23	98.8	0.3	0.270	1.0788
23.25	99.1	0.3	0.270	1.0788
23.5	99.4	0.3	0.270	1.0788
23.75	99.7	0.3	0.270	1.0788
24	100	0.3	0.270	1.0788
		Sum:	**89.9**	

City of Barrie SCS Storm Hyetographs
(Adjusted to Account for Climate Change)
25-yr Return Period

Total Rainfall Depth (mm): 85.2

6 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	1	1	0.852	3.408
0.5	2	1	0.852	3.408
0.75	3.5	1.5	1.278	5.112
1	5	1.5	1.278	5.112
1.25	6.5	1.5	1.278	5.112
1.5	8	1.5	1.278	5.112
1.75	10.5	2.5	2.130	8.52
2	13	2.5	2.130	8.52
2.25	16	3	2.556	10.224
2.5	19	3	2.556	10.224
2.75	34	15	12.780	51.12
3	73	39	33.228	132.912
3.25	78.5	5.5	4.686	18.744
3.5	84	5.5	4.686	18.744
3.75	86.5	2.5	2.130	8.52
4	89	2.5	2.130	8.52
4.25	91	2	1.704	6.816
4.5	93	2	1.704	6.816
4.75	94.5	1.5	1.278	5.112
5	96	1.5	1.278	5.112
5.25	97	1	0.852	3.408
5.5	98	1	0.852	3.408
5.75	99	1	0.852	3.408
6	100	1	0.852	3.408
		Sum:	**85.2**	

Total Rainfall Depth (mm): 90.7

12 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	0.625	0.625	0.567	2.2675
0.5	1.25	0.625	0.567	2.2675
0.75	1.875	0.625	0.567	2.2675
1	2.5	0.625	0.567	2.2675
1.25	3.125	0.625	0.567	2.2675
1.5	3.75	0.625	0.567	2.2675
1.75	4.375	0.625	0.567	2.2675
2	5	0.625	0.567	2.2675
2.25	5.75	0.75	0.680	2.721
2.5	6.5	0.75	0.680	2.721
2.75	7.25	0.75	0.680	2.721
3	8	0.75	0.680	2.721
3.25	9	1	0.907	3.628
3.5	10	1	0.907	3.628
3.75	11	1	0.907	3.628
4	12	1	0.907	3.628
4.25	13.5	1.5	1.361	5.442
4.5	15	1.5	1.361	5.442
4.75	17	2	1.814	7.256
5	19	2	1.814	7.256
5.25	22	3	2.721	10.884
5.5	25	3	2.721	10.884
5.75	37	12	10.884	43.536
6	70	33	29.931	119.724
6.25	74.5	4.5	4.082	16.326
6.5	79	4.5	4.082	16.326
6.75	81	2	1.814	7.256
7	83	2	1.814	7.256
7.25	84.5	1.5	1.361	5.442
7.5	86	1.5	1.361	5.442
7.75	87.5	1.5	1.361	5.442
8	89	1.5	1.361	5.442
8.25	89.875	0.875	0.794	3.1745
8.5	90.75	0.875	0.794	3.1745
8.75	91.625	0.875	0.794	3.1745
9	92.5	0.875	0.794	3.1745
9.25	93.375	0.875	0.794	3.1745
9.5	94.25	0.875	0.794	3.1745
9.75	95.125	0.875	0.794	3.1745
10	96	0.875	0.794	3.1745
10.25	96.5	0.5	0.454	1.814
10.5	97	0.5	0.454	1.814
10.75	97.5	0.5	0.454	1.814
11	98	0.5	0.454	1.814
11.25	98.5	0.5	0.454	1.814
11.5	99	0.5	0.454	1.814
11.75	99.5	0.5	0.454	1.814
12	100	0.5	0.454	1.814
		Sum:	**90.7**	

Total Rainfall Depth (mm): 107.5

24 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	0.25	0.25	0.269	1.075
0.5	0.5	0.25	0.269	1.075
0.75	0.75	0.25	0.269	1.075
1	1	0.25	0.269	1.075
1.25	1.25	0.25	0.269	1.075
1.5	1.5	0.25	0.269	1.075
1.75	1.75	0.25	0.269	1.075
2	2.2	0.45	0.484	1.935
2.25	2.525	0.325	0.349	1.3975
2.5	2.85	0.325	0.349	1.3975
2.75	3.175	0.325	0.349	1.3975
3	3.5	0.325	0.349	1.3975
3.25	3.825	0.325	0.349	1.3975
3.5	4.15	0.325	0.349	1.3975
3.75	4.475	0.325	0.349	1.3975
4	4.8	0.325	0.349	1.3975
4.25	5.2	0.4	0.430	1.72
4.5	5.6	0.4	0.430	1.72
4.75	6	0.4	0.430	1.72
5	6.4	0.4	0.430	1.72
5.25	6.8	0.4	0.430	1.72
5.5	7.2	0.4	0.430	1.72
5.75	7.6	0.4	0.430	1.72
6	8	0.4	0.430	1.72
6.25	8.5	0.5	0.538	2.15
6.5	9	0.5	0.538	2.15
6.75	9.5	0.5	0.538	2.15
7	10	0.5	0.538	2.15
7.25	10.5	0.5	0.538	2.15
7.5	11	0.5	0.538	2.15
7.75	11.5	0.5	0.538	2.15
8	12	0.5	0.538	2.15
8.25	12.675	0.675	0.726	2.9025
8.5	13.35	0.675	0.726	2.9025
8.75	14.025	0.675	0.726	2.9025
9	14.7	0.675	0.726	2.9025
9.25	15.5	0.8	0.860	3.44
9.5	16.3	0.8	0.860	3.44
9.75	17.2	0.9	0.968	3.87
10	18.1	0.9	0.967	3.87
10.25	19.25	1.15	1.236	4.945
10.5	20.4	1.15	1.236	4.945
10.75	21.95	1.55	1.666	6.665
11	23.5	1.55	1.666	6.665
11.25	25.9	2.4	2.580	10.32
11.5	28.3	2.4	2.580	10.32
11.75	38.7	10.4	11.180	44.72
12	66.3	27.6	29.670	118.68
12.25	69.9	3.6	3.870	15.48
12.5	73.5	3.6	3.870	15.48
12.75	75.35	1.85	1.989	7.955
13	77.2	1.85	1.989	7.955
13.25	77.55	0.35	0.376	1.505
13.5	77.9	0.35	0.376	1.505
13.75	79.95	2.05	2.204	8.815
14	82	2.05	2.204	8.815
14.25	82.75	0.75	0.806	3.225
14.5	83.5	0.75	0.806	3.225
14.75	84.25	0.75	0.806	3.225
15	85	0.75	0.806	3.225
15.25	85.75	0.75	0.806	3.225
15.5	86.5	0.75	0.806	3.225
15.75	87.25	0.75	0.806	3.225
16	88	0.75	0.806	3.225
16.25	88.45	0.45	0.484	1.935
16.5	88.9	0.45	0.484	1.935
16.75	89.35	0.45	0.484	1.935
17	89.8	0.45	0.484	1.935
17.25	90.25	0.45	0.484	1.935
17.5	90.7	0.45	0.484	1.935
17.75	91.15	0.45	0.484	1.935
18	91.6	0.45	0.484	1.935
18.25	92.05	0.45	0.484	1.935
18.5	92.5	0.45	0.484	1.935
18.75	92.95	0.45	0.484	1.935
19	93.4	0.45	0.484	1.935
19.25	93.85	0.45	0.484	1.935
19.5	94.3	0.45	0.484	1.935
19.75	94.75	0.45	0.484	1.935
20	95.2	0.45	0.484	1.935
20.25	95.5	0.3	0.322	1.29
20.5	95.8	0.3	0.322	1.29
20.75	96.1	0.3	0.322	1.29
21	96.4	0.3	0.323	1.29
21.25	96.7	0.3	0.322	1.29
21.5	97	0.3	0.322	1.29
21.75	97.3	0.3	0.322	1.29
22	97.6	0.3	0.322	1.29
22.25	97.9	0.3	0.323	1.29
22.5	98.2	0.3	0.322	1.29
22.75	98.5	0.3	0.322	1.29
23	98.8	0.3	0.322	1.29
23.25	99.1	0.3	0.322	1.29
23.5	99.4	0.3	0.323	1.29
23.75	99.7	0.3	0.322	1.29
24	100	0.3	0.322	1.29
		Sum:	**107.5**	

City of Barrie SCS Storm Hyetographs
(Adjusted to Account for Climate Change)
50-yr Return Period

Total Rainfall Depth (mm): 95.9

6 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	1	1	0.959	3.836
0.5	2	1	0.959	3.836
0.75	3.5	1.5	1.439	5.754
1	5	1.5	1.439	5.754
1.25	6.5	1.5	1.439	5.754
1.5	8	1.5	1.439	5.754
1.75	10.5	2.5	2.398	9.59
2	13	2.5	2.398	9.59
2.25	16	3	2.877	11.508
2.5	19	3	2.877	11.508
2.75	34	15	14.385	57.54
3	73	39	37.401	149.604
3.25	78.5	5.5	5.275	21.098
3.5	84	5.5	5.275	21.098
3.75	86.5	2.5	2.398	9.59
4	89	2.5	2.398	9.59
4.25	91	2	1.918	7.672
4.5	93	2	1.918	7.672
4.75	94.5	1.5	1.439	5.754
5	96	1.5	1.439	5.754
5.25	97	1	0.959	3.836
5.5	98	1	0.959	3.836
5.75	99	1	0.959	3.836
6	100	1	0.959	3.836
		Sum:	**95.9**	

Total Rainfall Depth (mm): 101.7

12 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	0.625	0.625	0.636	2.5425
0.5	1.25	0.625	0.636	2.5425
0.75	1.875	0.625	0.636	2.5425
1	2.5	0.625	0.636	2.5425
1.25	3.125	0.625	0.636	2.5425
1.5	3.75	0.625	0.636	2.5425
1.75	4.375	0.625	0.636	2.5425
2	5	0.625	0.636	2.5425
2.25	5.75	0.75	0.763	3.051
2.5	6.5	0.75	0.763	3.051
2.75	7.25	0.75	0.763	3.051
3	8	0.75	0.763	3.051
3.25	9	1	1.017	4.068
3.5	10	1	1.017	4.068
3.75	11	1	1.017	4.068
4	12	1	1.017	4.068
4.25	13.5	1.5	1.526	6.102
4.5	15	1.5	1.526	6.102
4.75	17	2	2.034	8.136
5	19	2	2.034	8.136
5.25	22	3	3.051	12.204
5.5	25	3	3.051	12.204
5.75	37	12	12.204	48.816
6	70	33	33.561	134.244
6.25	74.5	4.5	4.577	18.306
6.5	79	4.5	4.577	18.306
6.75	81	2	2.034	8.136
7	83	2	2.034	8.136
7.25	84.5	1.5	1.526	6.102
7.5	86	1.5	1.526	6.102
7.75	87.5	1.5	1.526	6.102
8	89	1.5	1.526	6.102
8.25	89.875	0.875	0.890	3.5595
8.5	90.75	0.875	0.890	3.5595
8.75	91.625	0.875	0.890	3.5595
9	92.5	0.875	0.890	3.5595
9.25	93.375	0.875	0.890	3.5595
9.5	94.25	0.875	0.890	3.5595
9.75	95.125	0.875	0.890	3.5595
10	96	0.875	0.890	3.5595
10.25	96.5	0.5	0.509	2.034
10.5	97	0.5	0.509	2.034
10.75	97.5	0.5	0.509	2.034
11	98	0.5	0.509	2.034
11.25	98.5	0.5	0.509	2.034
11.5	99	0.5	0.509	2.034
11.75	99.5	0.5	0.509	2.034
12	100	0.5	0.509	2.034
		Sum:	**101.7**	

Total Rainfall Depth (mm): 120.6

24 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	0.25	0.25	0.302	1.206
0.5	0.5	0.25	0.302	1.206
0.75	0.75	0.25	0.302	1.206
1	1	0.25	0.302	1.206
1.25	1.25	0.25	0.302	1.206
1.5	1.5	0.25	0.302	1.206
1.75	1.75	0.25	0.302	1.206
2	2.2	0.45	0.543	2.1708
2.25	2.525	0.325	0.392	1.5678
2.5	2.85	0.325	0.392	1.5678
2.75	3.175	0.325	0.392	1.5678
3	3.5	0.325	0.392	1.5678
3.25	3.825	0.325	0.392	1.5678
3.5	4.15	0.325	0.392	1.5678
3.75	4.475	0.325	0.392	1.5678
4	4.8	0.325	0.392	1.5678
4.25	5.2	0.4	0.482	1.9296
4.5	5.6	0.4	0.482	1.9296
4.75	6	0.4	0.482	1.9296
5	6.4	0.4	0.482	1.9296
5.25	6.8	0.4	0.482	1.9296
5.5	7.2	0.4	0.482	1.9296
5.75	7.6	0.4	0.482	1.9296
6	8	0.4	0.482	1.9296
6.25	8.5	0.5	0.603	2.412
6.5	9	0.5	0.603	2.412
6.75	9.5	0.5	0.603	2.412
7	10	0.5	0.603	2.412
7.25	10.5	0.5	0.603	2.412
7.5	11	0.5	0.603	2.412
7.75	11.5	0.5	0.603	2.412
8	12	0.5	0.603	2.412
8.25	12.675	0.675	0.814	3.2562
8.5	13.35	0.675	0.814	3.2562
8.75	14.025	0.675	0.814	3.2562
9	14.7	0.675	0.814	3.2562
9.25	15.5	0.8	0.965	3.8592
9.5	16.3	0.8	0.965	3.8592
9.75	17.2	0.9	1.085	4.3416
10	18.1	0.9	1.085	4.3416
10.25	19.25	1.15	1.387	5.5476
10.5	20.4	1.15	1.387	5.5476
10.75	21.95	1.55	1.869	7.4772
11	23.5	1.55	1.869	7.4772
11.25	25.9	2.4	2.894	11.5776
11.5	28.3	2.4	2.894	11.5776
11.75	38.7	10.4	12.542	50.1696
12	66.3	27.6	33.286	133.1424
12.25	69.9	3.6	4.342	17.3664
12.5	73.5	3.6	4.342	17.3664
12.75	75.35	1.85	2.231	8.9244
13	77.2	1.85	2.231	8.9244
13.25	77.55	0.35	0.422	1.6884
13.5	77.9	0.35	0.422	1.6884
13.75	79.95	2.05	2.472	9.8892
14	82	2.05	2.472	9.8892
14.25	82.75	0.75	0.905	3.618
14.5	83.5	0.75	0.905	3.618
14.75	84.25	0.75	0.905	3.618
15	85	0.75	0.905	3.618
15.25	85.75	0.75	0.905	3.618
15.5	86.5	0.75	0.905	3.618
15.75	87.25	0.75	0.905	3.618
16	88	0.75	0.905	3.618
16.25	88.45	0.45	0.543	2.1708
16.5	88.9	0.45	0.543	2.1708
16.75	89.35	0.45	0.543	2.1708
17	89.8	0.45	0.543	2.1708
17.25	90.25	0.45	0.543	2.1708
17.5	90.7	0.45	0.543	2.1708
17.75	91.15	0.45	0.543	2.1708
18	91.6	0.45	0.543	2.1708
18.25	92.05	0.45	0.543	2.1708
18.5	92.5	0.45	0.543	2.1708
18.75	92.95	0.45	0.543	2.1708
19	93.4	0.45	0.543	2.1708
19.25	93.85	0.45	0.543	2.1708
19.5	94.3	0.45	0.543	2.1708
19.75	94.75	0.45	0.543	2.1708
20	95.2	0.45	0.543	2.1708
20.25	95.5	0.3	0.362	1.4472
20.5	95.8	0.3	0.362	1.4472
20.75	96.1	0.3	0.362	1.4472
21	96.4	0.3	0.362	1.4472
21.25	96.7	0.3	0.362	1.4472
21.5	97	0.3	0.362	1.4472
21.75	97.3	0.3	0.362	1.4472
22	97.6	0.3	0.362	1.4472
22.25	97.9	0.3	0.362	1.4472
22.5	98.2	0.3	0.362	1.4472
22.75	98.5	0.3	0.362	1.4472
23	98.8	0.3	0.362	1.4472
23.25	99.1	0.3	0.362	1.4472
23.5	99.4	0.3	0.362	1.4472
23.75	99.7	0.3	0.362	1.4472
24	100	0.3	0.362	1.4472
		Sum:	**120.6**	

City of Barrie SCS Storm Hyetographs
(Adjusted to Account for Climate Change)
100-yr Return Period

Total Rainfall Depth (mm): 106.5
6 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	1	1	1.065	4.26
0.5	2	1	1.065	4.26
0.75	3.5	1.5	1.598	6.39
1	5	1.5	1.598	6.39
1.25	6.5	1.5	1.598	6.39
1.5	8	1.5	1.598	6.39
1.75	10.5	2.5	2.663	10.65
2	13	2.5	2.663	10.65
2.25	16	3	3.195	12.78
2.5	19	3	3.195	12.78
2.75	34	15	15.975	63.9
3	73	39	41.535	166.14
3.25	78.5	5.5	5.858	23.43
3.5	84	5.5	5.858	23.43
3.75	86.5	2.5	2.663	10.65
4	89	2.5	2.663	10.65
4.25	91	2	2.130	8.52
4.5	93	2	2.130	8.52
4.75	94.5	1.5	1.598	6.39
5	96	1.5	1.598	6.39
5.25	97	1	1.065	4.26
5.5	98	1	1.065	4.26
5.75	99	1	1.065	4.26
6	100	1	1.065	4.26
		Sum:	**106.5**	

Total Rainfall Depth (mm): 112.5
12 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	0.625	0.625	0.703	2.8125
0.5	1.25	0.625	0.703	2.8125
0.75	1.875	0.625	0.703	2.8125
1	2.5	0.625	0.703	2.8125
1.25	3.125	0.625	0.703	2.8125
1.5	3.75	0.625	0.703	2.8125
1.75	4.375	0.625	0.703	2.8125
2	5	0.625	0.703	2.8125
2.25	5.75	0.75	0.844	3.375
2.5	6.5	0.75	0.844	3.375
2.75	7.25	0.75	0.844	3.375
3	8	0.75	0.844	3.375
3.25	9	1	1.125	4.5
3.5	10	1	1.125	4.5
3.75	11	1	1.125	4.5
4	12	1	1.125	4.5
4.25	13.5	1.5	1.688	6.75
4.5	15	1.5	1.688	6.75
4.75	17	2	2.250	9
5	19	2	2.250	9
5.25	22	3	3.375	13.5
5.5	25	3	3.375	13.5
5.75	37	12	13.500	54
6	70	33	37.125	148.5
6.25	74.5	4.5	5.063	20.25
6.5	79	4.5	5.063	20.25
6.75	81	2	2.250	9
7	83	2	2.250	9
7.25	84.5	1.5	1.688	6.75
7.5	86	1.5	1.688	6.75
7.75	87.5	1.5	1.688	6.75
8	89	1.5	1.688	6.75
8.25	89.875	0.875	0.984	3.9375
8.5	90.75	0.875	0.984	3.9375
8.75	91.625	0.875	0.984	3.9375
9	92.5	0.875	0.984	3.9375
9.25	93.375	0.875	0.984	3.9375
9.5	94.25	0.875	0.984	3.9375
9.75	95.125	0.875	0.984	3.9375
10	96	0.875	0.984	3.9375
10.25	96.5	0.5	0.563	2.25
10.5	97	0.5	0.563	2.25
10.75	97.5	0.5	0.563	2.25
11	98	0.5	0.563	2.25
11.25	98.5	0.5	0.563	2.25
11.5	99	0.5	0.563	2.25
11.75	99.5	0.5	0.563	2.25
12	100	0.5	0.563	2.25
		Sum:	**112.5**	

Total Rainfall Depth (mm): 133.6
24 Hour SCS Storm

Time	Ratio	Incr.	Depth (mm)	Intensity (mm/hr)
0.25	0.25	0.25	0.334	1.336
0.5	0.5	0.25	0.334	1.336
0.75	0.75	0.25	0.334	1.336
1	1	0.25	0.334	1.336
1.25	1.25	0.25	0.334	1.336
1.5	1.5	0.25	0.334	1.336
1.75	1.75	0.25	0.334	1.336
2	2.2	0.45	0.601	2.4048
2.25	2.525	0.325	0.434	1.7368
2.5	2.85	0.325	0.434	1.7368
2.75	3.175	0.325	0.434	1.7368
3	3.5	0.325	0.434	1.7368
3.25	3.825	0.325	0.434	1.7368
3.5	4.15	0.325	0.434	1.7368
3.75	4.475	0.325	0.434	1.7368
4	4.8	0.325	0.434	1.7368
4.25	5.2	0.4	0.534	2.1376
4.5	5.6	0.4	0.534	2.1376
4.75	6	0.4	0.534	2.1376
5	6.4	0.4	0.534	2.1376
5.25	6.8	0.4	0.534	2.1376
5.5	7.2	0.4	0.534	2.1376
5.75	7.6	0.4	0.534	2.1376
6	8	0.4	0.534	2.1376
6.25	8.5	0.5	0.668	2.672
6.5	9	0.5	0.668	2.672
6.75	9.5	0.5	0.668	2.672
7	10	0.5	0.668	2.672
7.25	10.5	0.5	0.668	2.672
7.5	11	0.5	0.668	2.672
7.75	11.5	0.5	0.668	2.672
8	12	0.5	0.668	2.672
8.25	12.675	0.675	0.902	3.6072
8.5	13.35	0.675	0.902	3.6072
8.75	14.025	0.675	0.902	3.6072
9	14.7	0.675	0.902	3.6072
9.25	15.5	0.8	1.069	4.2752
9.5	16.3	0.8	1.069	4.2752
9.75	17.2	0.9	1.202	4.8096
10	18.1	0.9	1.202	4.8096
10.25	19.25	1.15	1.536	6.1456
10.5	20.4	1.15	1.536	6.1456
10.75	21.95	1.55	2.071	8.2832
11	23.5	1.55	2.071	8.2832
11.25	25.9	2.4	3.206	12.8256
11.5	28.3	2.4	3.206	12.8256
11.75	38.7	10.4	13.894	55.5776
12	66.3	27.6	36.874	147.4944
12.25	69.9	3.6	4.810	19.2384
12.5	73.5	3.6	4.810	19.2384
12.75	75.35	1.85	2.472	9.8864
13	77.2	1.85	2.472	9.8864
13.25	77.55	0.35	0.468	1.8704
13.5	77.9	0.35	0.468	1.8704
13.75	79.95	2.05	2.739	10.9552
14	82	2.05	2.739	10.9552
14.25	82.75	0.75	1.002	4.008
14.5	83.5	0.75	1.002	4.008
14.75	84.25	0.75	1.002	4.008
15	85	0.75	1.002	4.008
15.25	85.75	0.75	1.002	4.008
15.5	86.5	0.75	1.002	4.008
15.75	87.25	0.75	1.002	4.008
16	88	0.75	1.002	4.008
16.25	88.45	0.45	0.601	2.4048
16.5	88.9	0.45	0.601	2.4048
16.75	89.35	0.45	0.601	2.4048
17	89.8	0.45	0.601	2.4048
17.25	90.25	0.45	0.601	2.4048
17.5	90.7	0.45	0.601	2.4048
17.75	91.15	0.45	0.601	2.4048
18	91.6	0.45	0.601	2.4048
18.25	92.05	0.45	0.601	2.4048
18.5	92.5	0.45	0.601	2.4048
18.75	92.95	0.45	0.601	2.4048
19	93.4	0.45	0.601	2.4048
19.25	93.85	0.45	0.601	2.4048
19.5	94.3	0.45	0.601	2.4048
19.75	94.75	0.45	0.601	2.4048
20	95.2	0.45	0.601	2.4048
20.25	95.5	0.3	0.401	1.6032
20.5	95.8	0.3	0.401	1.6032
20.75	96.1	0.3	0.401	1.6032
21	96.4	0.3	0.401	1.6032
21.25	96.7	0.3	0.401	1.6032
21.5	97	0.3	0.401	1.6032
21.75	97.3	0.3	0.401	1.6032
22	97.6	0.3	0.401	1.6032
22.25	97.9	0.3	0.401	1.6032
22.5	98.2	0.3	0.401	1.6032
22.75	98.5	0.3	0.401	1.6032
23	98.8	0.3	0.401	1.6032
23.25	99.1	0.3	0.401	1.6032
23.5	99.4	0.3	0.401	1.6032
23.75	99.7	0.3	0.401	1.6032
24	100	0.3	0.401	1.6032
		Sum:	**133.6**	

HURRICANE HAZEL RAINFALL DEPTHS

	Depth		Percent of
	mm	Inches	12 Hour
First 36 hours	73	2.90	-
37th hour	6	.25	3
38th hour	4	.17	2
39th hour	6	.25	3
40th hour	13	.50	6
41st hour	17	.66	8
42nd hour	13	.50	6
43rd hour	23	.91	11
44th hour	13	.50	6
45th hour	13	.50	6
46th hour	53	2.08	25
47th hour	38	1.49	18
48th hour	13	.50	6
	285	11.21	100

NOTE: For drainage areas 25 km^2 or less

HURRICANE HAZEL - AREAL REDUCTION

Drainage Area (km^2)	Percentage
0 to 25	100.0
26 to 45	99.2
46 to 65	98.2
66 to 90	97.1
91 to 115	96.3
116 to 140	95.4
141 to 165	94.8
166 to 195	94.2
196 to 220	93.5
221 to 245	92.7
246 to 270	92.0
271 to 450	89.4
451 to 575	86.7
576 to 700	84.0
701 to 850	82.4
851 to 1000	80.8
1001 to 1200	79.3
1201 to 1500	76.6
1501 to 1700	74.4
1701 to 2000	73.3
2001 to 2200	71.7
2201 to 2500	70.2
2501 to 2700	69.0
2701 to 4500	64.4
4501 to 6000	61.4
6001 to 7000	58.9
7001 to 8000	57.4

Note: A copy of the Hurricane Hazel storm file is available from the City of Barrie and is provided on the CD included with the *Storm Drainage and Stormwater Management Policies and Design Criteria* document.

Source: Technical Guidelines for Flood Plain Management in Ontario, Working Paper C, Rainfall Analysis, Report to MNR, Dillon Consulting, August 1985

Hurricane Hazel Rainfall Hyetograph

Time (min)	Intensity (mm/hr)
0	0
60	6
120	4
180	6
240	13
300	17
360	13
420	23
480	13
540	13
600	53
660	38
720	13

Note: To be used with AMC III conditions

TIMMINS - RAINFALL DEPTHS

Hour	Depth (mm)	Depth Inches	Percent of 12 Hour
1st	15	0.6	8
2nd	20	0.8	10
3rd	10	0.4	6
4th	3	0.1	1
5th	5	0.2	3
6th	20	0.8	10
7th	43	1.7	23
8th	20	0.8	10
9th	23	0.9	12
10th	13	0.5	6
11th	13	0.5	7
12th	8	0.3	4

TIMMINS - AREAL REDUCTION

Drainage Area (km^2)	Percentage
0 to 25	100
26 to 50	97
51 to 75	94
76 to 100	90
101 to 150	87
151 to 200	84
201 to 250	82
251 to 375	79
376 to 500	76
501 to 750	74
751 to 1000	70
1001 to 1250	68
1251 to 1500	66
1501 to 1800	65
1801 to 2100	64
2101 to 2300	63
2301 to 2600	62
2601 to 3900	58
3901 to 5200	56
5201 to 6500	53
6501 to 8000	50

Note: A copy of the Timmins Storm file is available from the City of Barrie and is provided on the CD included with the *Storm Drainage and Stormwater Management Policies and Design Criteria* document.

Source: Technical Guidelines for Flood Plain Management in Ontario, Working Paper C, Rainfall Analysis, Report to MNR, Dillon Consulting, August 1985

Timmins Storm Rainfall Hyetograph

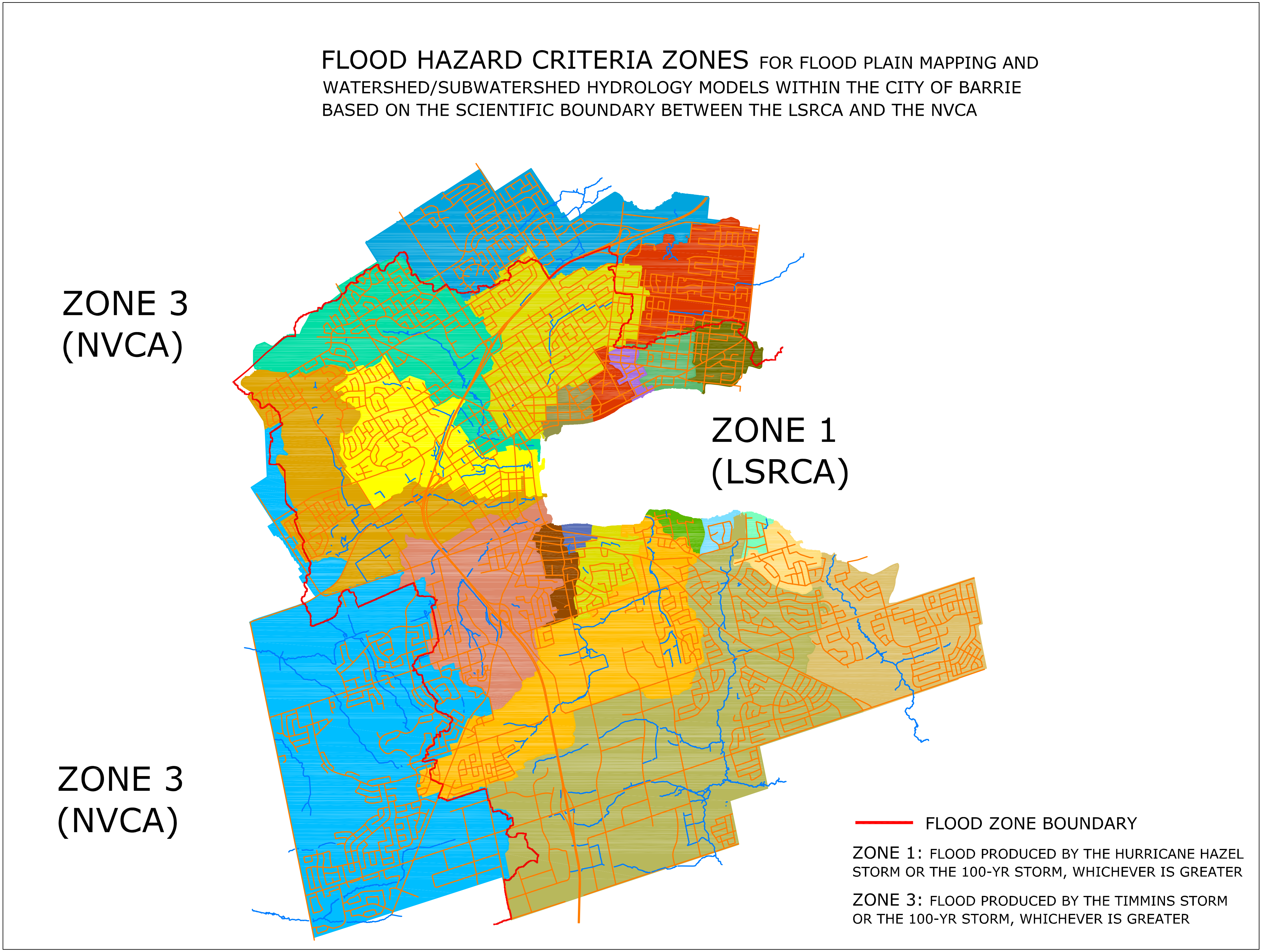
Time (min)	Intensity (mm/hr)
0	0
60	15
120	20
180	10
240	3
300	5
360	20
420	43
480	20
540	23
600	13
660	13
720	8

Note: To be used with AMC II conditions

CN Value Conversion Table (AMC I, II, and III)

AMC II	AMC I	AMC III	AMC II	AMC I	AMC III
100	100	100	60	40	78
99	97	100	59	39	77
98	94	99	58	38	76
97	91	99	57	37	75
96	89	99	56	36	75
95	87	98	55	35	74
94	85	98	54	34	73
93	83	98	53	33	72
92	81	97	52	32	71
91	80	97	51	31	70
90	78	96	50	31	70
89	76	96	49	30	69
88	75	95	48	29	68
87	73	95	47	28	67
86	72	94	46	27	66
85	70	94	45	26	65
84	68	93	44	25	64
83	67	93	43	25	63
82	66	92	42	24	62
81	64	92	41	23	61
80	63	91	40	22	60
79	62	91	39	21	59
78	60	90	38	21	58
77	59	89	37	20	57
76	58	89	36	19	56
75	57	88	35	18	55
74	55	88	34	18	54
73	54	87	33	17	53
72	53	86	32	16	52
71	52	86	31	16	51
70	51	85	30	15	50
69	50	84			
68	48	84	25	12	43
67	47	83	20	9	37
66	46	82	15	6	30
65	45	82	10	4	22
64	44	81	5	2	13
63	43	80	0	0	0
62	42	79			
61	41	78			

Source: Mishra, Surendra and Vijay P. Singh (2003). *Soil Conservation Service Curve Number (SCS-CN) Methodology*. Norwell, MA: Kluwer Acedemic Publishers, p103.


FLOOD HAZARD CRITERIA ZONES FOR FLOOD PLAIN MAPPING AND
WATERSHED/SUBWATERSHED HYDROLOGY MODELS WITHIN THE CITY OF BARRIE
BASED ON THE SCIENTIFIC BOUNDARY BETWEEN THE LSRCA AND THE NVCA
ZONE 3
(NVCA)
ZONE 1
(LSRCA)
ZONE 3
(NVCA)
FLOOD ZONE BOUNDARY
ZONE 1: FLOOD PRODUCED BY THE HURRICANE HAZEL STORM OR THE 100-YR STORM, WHICHEVER IS GREATER
ZONE 3: FLOOD PRODUCED BY THE TIMMINS STORM OR THE 100-YR STORM, WHICHEVER IS GREATER

APPENDIX C

SAMPLE CALCULATIONS AND EXAMPLES

CORPORATE ASSET MANAGEMENT

- Sample Calculations and Examples
  - Example 1 – Storm Sewer Design
  - Example 2 – Overland Flows
  - Example 3 – Flow Through Hydraulic Structures
  - Example 4 – Time of Concentration and Time to Peak
  - Example 5 – Infiltration Equations
  - Example 6 – Hydraulic Loss Calculations
  - Example 7 – Infiltration Trench
  - Example 8 – Soakaway Pit
  - Example 9 – Pre/Post-Development Runoff Calculations
  - Example 10 – Hydraulic Grade Line Analysis Using a Spreadsheet
  - Example 11 – Hydraulic Grade Line Analysis Using PCSWMM.NET
  - Example 12 – Storm Sewer Design Using a Storm Sewer Design Sheet
  - Example 14 – Culvert Design
  - Example 15 – Total Capture CB with Safety Factor

Example 1 – Storm Sewer Design

Design a storm sewer to convey the 5-yr design flow from a site with the following areas:
Landscaped Area (C=0.20) = 1.00 ha
Parking Area (C=0.95) = 0.50 ha
Time of Concentration = 10 min for the area, and the pipe is concrete at 2% slope.

Solution

(a) ***Flow to be Conveyed***

Total Area = 1.00 ha + 0.50 ha = 1.50 ha

$$\text{Composite Runoff Coefficient} = \frac{\sum (Area_i)(Coefficient_i)}{Total\ \ Area}$$

$$= \frac{(1.0\ ha)(0.20) + (0.5\ ha)(0.95)}{1.50\ \ ha}$$

Composite Runoff Coefficient = 0.450

Using **Table 3.1** to obtain A, B, C IDF parameters for the 5-yr storm,

A = 853.608
B = 4.699
C = 0.766

$$i = \frac{A}{(t_d + B)^C} = \frac{853.608}{(10 + 4.699)^{0.766}} = 108.92 \text{ mm/hr}$$

$$Q = \frac{(C)(i)(A)}{360} = \frac{(0.450)(108.92\ mm/hr)(1.5\ ha)}{360} = 0.2042 \text{ m}^3\text{/s}$$

Therefore, the sewer must be designed to convey 0.2042 m^3/s.

(b) ***Diameter of Pipe Required***

From ***Table 3.4***, n=0.013 for concrete pipe. Using the equation for pipe flow to solve for diameter,

$$Q = \left[\frac{0.312}{n}\right](D)^{\frac{8}{3}}(S)^{\frac{1}{2}}$$

$$0.2042\ m^3/s = \left[\frac{0.312}{0.013}\right](D)^{\frac{8}{3}}(0.02)^{\frac{1}{2}}$$

$$0.2042\ m^3/s = (3.394)(D)^{\frac{8}{3}}$$

$$\log\left[\frac{0.2042}{3.394}\right] = \left[\frac{8}{3}\right]\log(D)$$

$$D = 10^{\log\left[\frac{0.2042}{3.394}\right]\left[\frac{3}{8}\right]} = 0.349 \text{ m}$$

Therefore, the diameter of the pipe must be at least 0.349 m. Choosing the next standard pipe size up, the pipe should be 375 mm nominal diameter (381 mm actual).

(c) *Check Velocity of Pipe Flow (Min. = 0.75 m/s, Max = 4.0 m/s)*

$$A_{pipe} = \pi(r)^2 = \pi\left[\frac{0.3810\ m}{2}\right]^2 = 0.1140 \text{ m}^2$$

Check Full Flow Velocity

$$v_{full} = \frac{Q_{full}}{A}$$

$$Q_{capacity} = Q_{full}$$

$$Q_{full} = \left[\frac{0.312}{n}\right](D)^{8/3}(S)^{1/2} = \left[\frac{0.312}{0.013}\right](0.3810)^{8/3}(0.02)^{1/2} = 0.259 \text{ m}^3\text{/s}$$

$$v_{full} = \frac{Q_{full}}{A} = \frac{0.259\ m^3/s}{0.1140\ m^2} = 2.27 \text{ m/s}$$

Check Actual Velocity

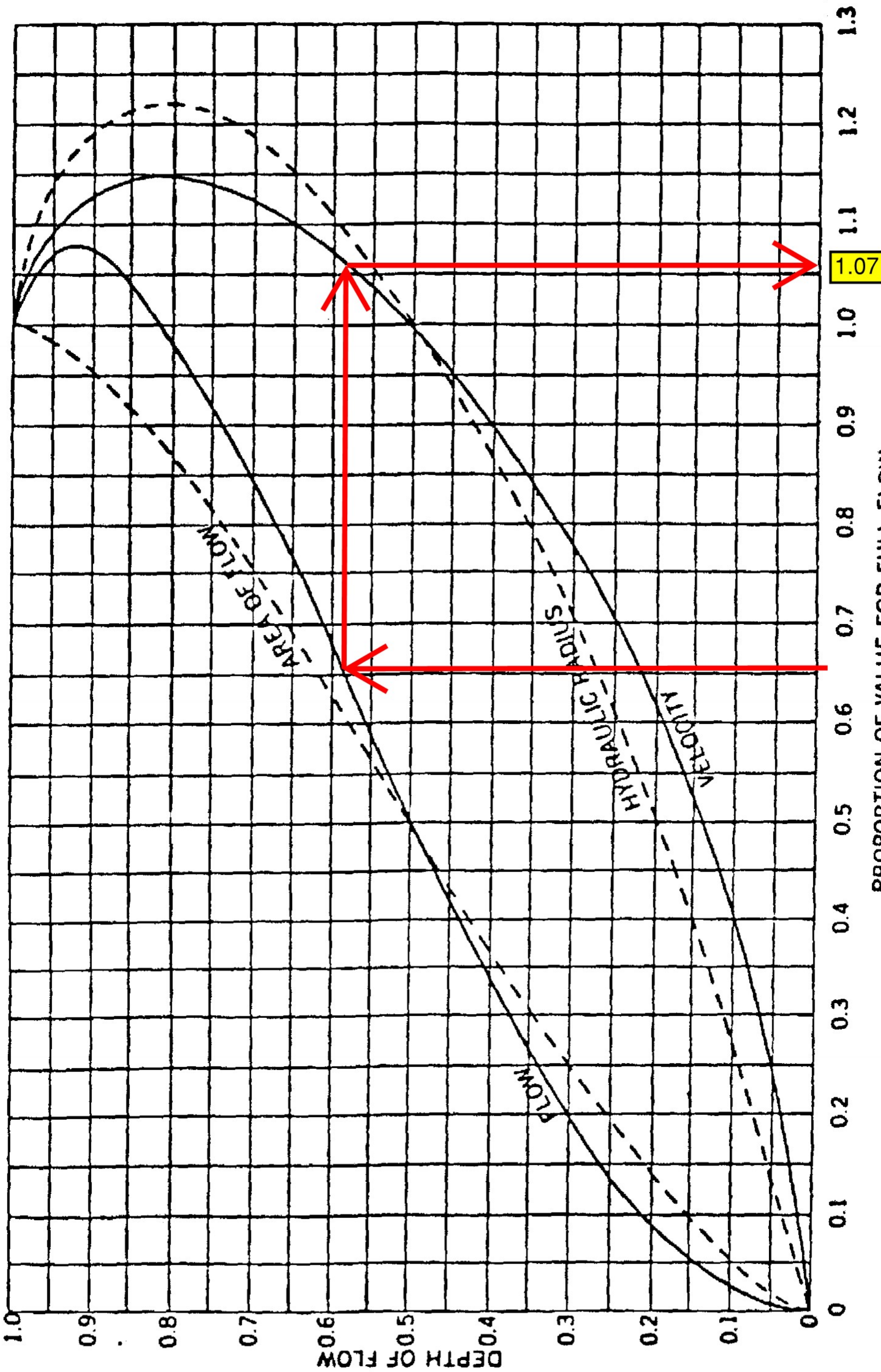
Calculate the ratio, $\frac{Q_{actual}}{Q_{full}} = \frac{0.1726\ m^3/s}{0.259\ m^3/s} = 0.6664$

From Figure 1.1, the ratio v_{actual} / v_{full} = 1.07

Therefore, $v_{actual} = (1.07)(v_{full}) = (1.07)(2.27 \text{ m/s}) = 2.43 \text{ m/s}$

Since the actual pipe velocity is greater than 0.75 m/s and less than 4.0 m/s, the pipe flow velocity is acceptable.

Figure 1.1
Hydraulic Properties of Circular Pipe



Reference: "Concrete Pipe Design Manual" ACPA, 1970

Example 2 – Overland Flows

(a) Overland Flow

Calculate the overland flow for a lawn with slope = 0.04 m/m and a flow depth of 1 cm and a flow width of 45 m.

Solution

From ***Table 3.8***, Manning's n for overland flow = 0.150 for short grass.

$$q_o = \left[\frac{1}{n}\right](S_o)^{\frac{1}{2}}(y_o)^{\frac{5}{3}} = \left[\frac{1}{0.150}\right](0.04\ m/m)^{\frac{1}{2}}(0.01\ m)^{\frac{5}{3}} = 0.00062\ \text{m}^3\text{/s/m}$$

Therefore, the shallow overland flow = (45.0 m)(0.00062 m^3/s/m) = 0.028 m^3/s.

(b) Channel Flow

Calculate the flow and velocity through a rectangular concrete channel with a width of 5 m, a flow depth of 25 cm, and a slope of 0.02 m/m.

Solution

From ***Table 3.7***, Manning's n = 0.013 for concrete channel.

Area of flow cross-section = A = (5 m)(0.25 m) = 1.25 m^2

Wetted Perimeter = 2(0.25 m) + 5 m = 5.50 m

$$\text{Hydraulic Radius} = \text{R} = \frac{Area}{Wetted\ Perimeter} = \frac{1.25\ m^2}{5.50\ m} = 0.227\ \text{m}$$

$$Q = \left[\frac{1}{n}\right](A)(R)^{\frac{2}{3}}(S_o)^{\frac{1}{2}} = \left[\frac{1}{0.013}\right](1.25\ m^2)(0.227\ m)^{\frac{2}{3}}(0.02\ m/m)^{\frac{1}{2}} = 5.06\ \text{m}^3\text{/s}$$

$$V = \left[\frac{1}{n}\right](R)^{\frac{2}{3}}(S)^{\frac{1}{2}} = \left[\frac{1}{0.013}\right](0.227)^{\frac{2}{3}}(0.02)^{\frac{1}{2}} = 4.05\ \text{m/s}$$

Therefore, the flow through the channel is 5.06 m^3/s, and the velocity of flow is 4.05 m/s.

Example 3 – Flow Through Hydraulic Structures

(a) Weir Flow – Sharp-Crested Weir with End Contractions

Calculate the flow through a sharp-crested weir with end contractions for a weir with a head of 0.25 m, and a crest length of 0.10 m.

Solution

From ***Table 7.2***, the coefficient for a sharp-crested weir is 1.837.

$$Q = C(L - 0.2H)(H)^{\frac{3}{2}} = 1.837[0.10\,m - 0.2(0.25\,m)](0.25\,m)^{\frac{3}{2}} = 0.0115 \text{ m}^3\text{/s} = 11.5 \text{ L/s}$$

(b) Weir Flow – Sharp-Crested Weir without End Contractions and Broad-Crested

Calculate the flow through a broad-crested weir on a SWM Pond with a head of 0.30 m and a crest length of 5.0 m.

Solution

From ***Table 7.2***, the coefficient for a SWM Pond broad-crested weir is 1.7.

$$Q = (C)(L)(H)^{\frac{3}{2}} = (1.7)(5.0\,m)(0.30\,m)^{\frac{3}{2}} = 1.40 \text{ m}^3\text{/s}$$

(c) Orifice Flow

Calculate the flow rate through a 500 mm diameter orifice if the upstream water level is 0.75 m above the invert of the orifice.

Solution

From ***Table 7.2***, the orifice coefficient is 0.63.

Area = A = $\pi (r)^2 = \pi \left[\frac{0.500\,m}{2}\right]^2 = 0.1963 \text{ m}^2$

Δh = height of water above centre of orifice
= 0.75 m – (0.5)(dia. of orifice)
= 0.75 m – (0.5)(0.50 m)
Δh = 0.50 m

$$Q = (C)(A)\sqrt{2g\Delta h} = (0.63)(0.1963\,m^2)\sqrt{2(9.81\,m/s^2)(0.50\,m)} = 0.387 \text{ m}^3\text{/s}$$

Example 4 – Time of Concentration and Time to Peak

(a) Airport Method

Calculate the time of concentration for an area with a runoff coefficient of 0.30, a slope of 1.0%, and a flow path length of 100 m.

Solution

Choose the Airport Method because C<0.40.

$$t_c = \frac{3.26(1.1-C)(L)^{0.5}}{S_w^{\ 0.33}} = \frac{3.26(1.1-0.30)(100\ m)^{0.5}}{(1.0)^{0.33}} = 26.08 \text{ min}$$

(b) Bransby-Williams Method

Calculate the time of concentration for and area with a flow path length of 150 m, a slope of 2%, an area of 3.0 ha, and a runoff coefficient of 0.70.

Solution

Choose the Bransby-Williams Method because C>0.40.

$$t_c = \frac{(0.057)(L)}{(S_w)^{0.2}(A)^{0.1}} = \frac{(0.057)(150\ m)}{(2.0)^{0.2}(3.0\ ha)^{0.1}} = 6.67 \text{ min}$$

(c) Uplands Method

Calculate the time of concentration using the Uplands Method for a paved area flowing onto short grass. The flow travels 30 m over the paved area with a slope of 0.02 m/m, and then 15 m over the grass area at a slope of 0.03 m/m.

Solution

From ***Table 7.3***, C_u = 6.1 for paved areas and C_u = 2.3 for short grass.

$$V_{paved} = (C_u)(S)^{0.5} = (6.1)(0.02)^{0.5} = 0.8627 \text{ m/s}$$

$$t_c(paved) = \frac{Length}{V_{paved}} = \frac{30\ m}{0.8627\ m/s} = 34.77 \text{ s}$$

$$V_{grass} = (C_u)(S)^{0.5} = (2.3)(0.03)^{0.5} = 0.3984 \text{ m/s}$$

$$t_c(grass) = \frac{Length}{V_{grass}} = \frac{15\ m}{0.3984\ m/s} = 37.65 \text{ s}$$

$$t_c(total) = t_c(paved) + t_c(grass) = 34.77 \text{ s} + 37.65 \text{ s} = 72.42 \text{ s} = 1.207 \text{ min}$$

(d) Time to Peak

Calculate the time to peak of flow for an area that has a time of concentration of 13 minutes.

<u>Solution</u>

$$T_p = 0.67(t_c) = 0.67(13\,\text{min}) = 8.71\ \text{min}$$

Example 5 – Infiltration Equations

(a) SCS Curve Number Infiltration Method

Calculate the runoff volume from a site with 0.75 ha of lawn (good condition). The hydrological soil group (HSG) is AB and the Antecedent Moisture Condition (AMC) is wet (AMC III). Precipitation depth is 25 mm.

Solution

Using ***Table 7.4***, the curve number for lawn (good condition) and soil type AB is 50 (AMC II-normal moisture condition). Under AMC III (wet conditions), a CN of 50 becomes 70 (using CN conversion table in ***Appendix B***).

$$S = \frac{25400}{CN} - 254 = \frac{25400}{70} - 254 = 108.9 \text{ mm}$$

Using the SCS equation for IA based on a CN of 70,

$$IA = (0.075)(S) = (0.075)(108.9\ mm) = 8.2 \text{ mm}$$

$$Q = \frac{(P - I_a)^2}{(P + S - I_a)} = \frac{(25 - 8.2)^2}{(25 + 108.9 - 8.2)} = 2.2 \text{ mm}$$

$$\text{Runoff Volume} = \left[\frac{2.2\ mm}{1000\ mm/m}\right](0.75\ ha \times 10000\ m^2/ha) = 16.5 \text{ m}^3$$

Therefore, the runoff from the site during a 25 mm rainfall event is 16.5 m^3

(b) Horton Infiltration Method

Calculate the infiltration rate at t=1hr for a soil in the hydrologic soil group (HSG) 'C' using the Horton Method.

Solution

From ***Table 7.7***, for soil group 'C', f_0 = 125 mm/hr
f_∞ = 5 mm/hr
k = 2 hr^{-1}

$$f_t = f_\infty + (f_o - f_\infty)(e)^{-kt} = 5\ mm/hr + \left[125\ mm/hr - 5\ mm/hr\right](e)^{-(2hr^{-1})(1hr)} = 21.24 \text{ mm/hr}$$

Therefore, the infiltration rate at 1 hour for a group 'C' soil is 21.24 mm/hr.

(c) Green-Ampt Infiltration Method

Calculate the infiltration capacity of a hydrologic soil group (HSG) 'B' soil using the parameters in ***Table 7.8*** *for a rainfall intensity of 50 mm/hr, after 40 mm has infiltrated.*

Solution

From ***Table 7.8***,

Initial Moisture Deficit = IMD = 0.32 mm/mm
Avg. Capillary Suction = S_u = 300 mm
Saturated Hydraulic Conductivity = K_s = 13 mm/hr

$$F_s = \frac{(S_u)(IMD)}{[i/K_s]-1} = \frac{(300\ mm)(0.32\ mm/mm)}{[50\ mm/hr\ /\ 13\ mm/hr]-1} = 33.73 \text{ mm}$$

Therefore, runoff will begin after 33.73 mm of rain has infiltrated and F > F_s.

Since F > F_s, the infiltration capacity,

$$f_p = K_s\left[1+\frac{(S_u)(IMD)}{F}\right] = (13mm/hr)\left[1+\frac{(300\ mm)(0.32mm/mm)}{40\ mm}\right] = 44.20 \text{ mm/hr}$$

After 40 mm of rain has infiltrated the infiltration capacity is 44.20 mm/hr.

Example 6 – Hydraulic Loss Calculations

Head Losses Through Pipes and Maintenance Holes Using Standard Equations

Calculate the total head loss (m) of water flowing through a concrete storm sewer pipe 50 m long and 300 mm nominal diameter at 1.50% slope, followed by a maintenance hole and connected downstream to a 30 m 375 mm pipe at 2.00% slope. The maintenance hole has a 45° lateral connection. Based on the results of a dual drainage analysis, the flow in the 300 mm pipe is 0.1236 m^3/s and the flow in the 375 mm pipe downstream of the maintenance hole is 0.2588 m^3/s.

Solution

Using ***Table 3.4***, Manning's n for concrete pipe is 0.013.

Converting nominal to actual pipe diameters, the 300 mm pipe becomes 304.8 mm, and the 375 mm pipe becomes 381 mm.

300 mm Pipe

$$f = 124\frac{n^2}{d^{1/3}} = 124\frac{(0.013)^2}{(0.3048\ m)^{1/3}} = 0.03113891$$

$$k = \frac{fL}{D} = \frac{(0.03113891)(50\ m)}{0.3048\ m} = 5.1080889$$

$$A_{pipe} = \pi(r)^2 = \pi\left[\frac{0.3048\ m}{2}\right]^2 = 0.07297\ \mathrm{m}^2$$

Average Velocity of Flow,

$$v_f = \frac{Q}{A_{pipe}} = \frac{0.1236\ m^3/s}{0.07297\ m^2} = 1.694\ \mathrm{m/s}$$

$$h_{300mm} = \frac{kV^2}{2g} = \frac{(5.1080889)(1.694\ m/s)^2}{2(9.81\ m/s^2)} = 0.7471\ \mathrm{m}$$

Maintenance Hole With 45° Lateral Connection

$$h_{MH} = \frac{(V_d)^2}{2g} - \frac{0.45(V_u)^2}{2g} = \frac{(2.270\ m/s)^2}{2(9.81\ m/s^2)} - \frac{0.45(1.694\ m/s)^2}{2(9.81\ m/s^2)} = 0.1968\ \mathrm{m}$$

375 mm Pipe

$$f = 124\frac{n^2}{d^{1/3}} = \frac{124(0.013)^2}{(0.381\ m)^{1/3}} = 0.028906803$$

$$k = \frac{fL}{D} = \frac{(0.028906803)(30\ m)}{0.381\ m} = 2.2761262$$

$$A_{pipe} = \pi(r)^2 = \pi\left[\frac{0.3810\ m}{2}\right]^2 = 0.1140\ \text{m}^2$$

Average Velocity of Flow,

$$v_f = \frac{Q}{A_{pipe}} = \frac{0.2588\ m^3/s}{0.1140\ m^2} = 2.270\ \text{m/s}$$

$$h_{375mm} = \frac{kV^2}{2g} = \frac{(2.2761262)(2.270\ m/s)^2}{2(9.81\ m/s^2)} = 0.5978\ \text{m}$$

Total Head Loss

$$h_{total} = h_{300mm} + h_{MH} + h_{375mm} = 0.7471\ \text{m} + 0.1968\ \text{m} + 0.5978\ \text{m} = 1.5417\ \text{m}$$

Example 7 – Infiltration Trench

Design an infiltration trench in loamy sand soil to contain and infiltrate the flow from a 0.50 ha parking area for a 5 mm rainfall event.

Solution

Using ***Table 3.2***, C = 0.95 for parking.
From ***Table 4.4***, in the ***MOE Stormwater Management Planning and Design Manual (2003)***, the percolation rate for loamy sand is 60 mm/hr.
The porosity of clear stone is 0.40 (***MOE Manual***).
Assume a drawdown time of 24 hours (24-48 hours typical – ***MOE Manual***).

$$Vol.\ Runoff = (C)(d_{rain})(A) = (0.95)\left[\frac{5\ mm}{1000\ mm/m}\right](0.50\ ha)(10000\ m^2/ha) = 23.75\ \text{m}^3$$

The maximum depth of the infiltration trench, according to ***Equation 4.2*** in the ***MOE Manual***, is:

$$d = \frac{(P)(T)}{1000}$$

Where,
d = maximum allowable depth (m)
P = percolation rate (mm/hr)
T = drawdown time (24-48 hours) (hours)

$$d = \frac{(P)(T)}{1000} = \frac{(60\ mm/hr)(24\ hr)}{1000} = 1.44\ \text{m}$$

The bottom area of the infiltration trench, according to ***Equation 4.3*** in the ***MOE Manual***, is:

$$A = \frac{1000(V)}{(P)(n)(\Delta t)}$$

Where,
A = bottom area of trench (m^2)
V=runoff volume to be infiltrated (m^3)
P = percolation rate (mm/hr)
n = porosity of storage media (0.4 for clear stone)
Δt = retention time (24-48 hours) (hours)

$$A = \frac{1000(V)}{(P)(n)(\Delta t)} = \frac{1000(23.75\ m^3)}{(60\ mm/hr)(0.4)(24\ hr)} = 41.2\ \text{m}^2$$

Therefore, the infiltration trench should have a depth of 1.44 m and a bottom area of 41.2 m^2 to infiltrate the runoff from the parking area within 24 hours.

Example 8 – Soakaway Pit

Design a soakaway pit in loam soil that will contain and infiltrate the runoff volume from a 10 mm rainfall event over a 125 m^2 roof.

Solution

From ***Table 3.2***, C=0.95 for impervious areas.
Using ***Table 4.4*** in the ***MOE Stormwater Management Planning and Design Manual (2003)***, the percolation rate for loam soil is 15 mm/hr.
Assume a drawdown time of 24 hours (24-48 hours typical).

$$\text{Runoff Volume } = (C)(d_{rain})(A) = (0.95)\frac{(10\ mm)}{(1000\ mm/m)}(125\ m^2)\ = 1.189\ \text{m}^3$$

Using ***Equation 4.2*** from the ***MOE Manual***, maximum depth is:

$$d = \frac{(P)(T)}{1000} = \frac{(15\ mm/hr)(24\ hr)}{1000} = 0.36\ \text{m}$$

To calculate the bottom area of the soakaway pit, using ***Equation 4.3*** in the ***MOE Manual***,

$$A = \frac{1000(V)}{(P)(n)(\Delta t)} = \frac{(1000)(1.189\ m^3)}{(15\ mm/hr)(0.4)(24\ hr)}\ = 8.26\ \text{m}^2$$

Therefore, the soakaway pit should have a depth of 0.36 m and a bottom area of 8.3 m^2 to contain and infiltrate the runoff.

Example 9 – Pre/Post-Development Runoff Calculations

Compare the 100-yr, 3-hr storm pre-development and post-development runoff and time to peak using the rational method for a square 15 ha area with hydrologic soil group (HSG) 'B'. The area has an average slope of 2% before and after development. Before development, the land is relatively flat pasture, and is developed to be 25% grass at a 2% grade, 50% heavy industrial area, and 25% impervious (buildings, roads, parking). Also, determine the required amount of storage to control the 100-yr post-development flow to pre-development conditions.

Solution

Using ***Table 3.2*** to find the 5-yr runoff coefficients and ***Table 3.3*** to adjust them to 100-yr, the runoff coefficients for each land use are as follows:

Table 9.1: Summary of Runoff Coefficients

Land Use	**Runoff Coefficient (C_5)**	**Adjusted Runoff Coefficient ($C_{100}=1.25C_5$)**
Pasture (0-5% slope)	0.28	0.35
Lawn (2-7% slope)	0.16	0.20
Industrial (heavy)	0.75	0.9375
Impervious	0.95	1.00

Sample Runoff Coefficient Adjustment (Pasture): $C_{100} = 1.25C_5 = 1.25(0.28) = 0.35$

Composite Runoff Coefficients

Pre-development composite runoff coefficient = 0.35

$$\text{Post-development composite runoff coefficient} = \frac{\sum (Area_i)(Coefficient_i)}{Area_{total}}$$

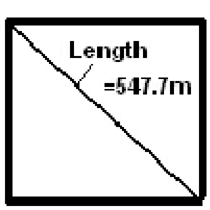
$$= \frac{(Area_{lawn})(C_{lawn}) + (Area_{industrial})(C_{industrial}) + (Area_{impervious})(C_{impervious})}{Area_{total}}$$

$$= \frac{(3.75\ ha)(0.20) + (7.50\ ha)(0.9375) + (3.75\ ha)(1.00)}{15\ ha}$$

Post-development composite runoff coefficient = 0.7688

Time of Concentration and Rainfall Intensity

To find watershed length, measure the longest path of flow for the runoff.



Watershed Length = L = 547.7 m

Using ***Table 3.1*** to obtain A,B,C IDF parameters for the 100-yr storm,

A = 1426.408
B = 5.273
C = 0.759

Pre-Development Time of Concentration and Rainfall Intensity

Since the composite runoff coefficient is less than 0.40, choose the Airport Method for calculating time of concentration.

$$t_c = \frac{3.26(1.1 - C)(L)^{0.5}}{S_w{}^{0.33}} = \frac{3.26(1.1 - 0.35)(547.7\ m)^{0.5}}{(2.0)^{0.33}} = 45.52 \text{ min}$$

Assume $t_d = t_c$ = 45.52 min

Rainfall intensity is calculated using the equation:

$$i = \frac{A}{(t_d + B)^C} = \frac{1426.408}{(45.52 + 5.273)^{0.759}} = 72.37 \text{ mm/hr}$$

Post-Development Time of Concentration and Rainfall Intensity

Since the composite runoff coefficient is greater than 0.40, choose the Bransby-Williams Method for calculating time of concentration.

$$t_c = \frac{(0.057)(L)}{(S_w)^{0.2}(A)^{0.1}} = \frac{(0.057)(547.7\ m)}{(2.0)^{0.2}(15\ ha)^{0.1}} = 20.73 \text{ min}$$

Assume $t_d = t_c$ = 20.73 min

Rainfall intensity is calculated using the equation:

$$i = \frac{A}{(t_d + B)^C} = \frac{1426.408}{(20.73 + 5.273)^{0.759}} = 120.29 \text{ mm/hr}$$

Time to Peak – Pre-Development

$$t_p = 0.67(t_c) = 0.67(45.52 \text{ min}) = 30.50 \text{ min}$$

Time to Peak – Post-Development

$$t_p = 0.67(t_c) = 0.67(20.73 \text{ min}) = 13.89 \text{ min}$$

Peak Flow from Pre-Development Site

$$Q = \frac{(C)(i)(A)}{360} = \frac{(0.35)(72.37\ mm/hr)(15\ ha)}{360} = 1.055 \text{ m}^3\text{/s}$$

Peak Flow from Post-Development Site

$$Q = \frac{(C)(i)(A)}{360} = \frac{(0.7688)(120.29\ mm/hr)(15\ ha)}{360} = 3.853\ \text{m}^3/\text{s}$$

See the storage calculations spreadsheet following this example for the calculation of the required stormwater management pond volume. To control the developed peak flow down to pre-development flow, the required pond volume is 3592 m^3.

Storage Volume Calculations - Modified Rational Method
100-year Chicago Storm - Barrie

TITLE: **SWM Pond Design Example**

Total Area (ha)	15
100 yr Runoff Coefficient	0.7688
Maximum Discharge Through Orifice (L/s)	1055.0
Discharged Volume per 5 min Interval (cu.m)	316.5

Time (min)	Intensity (mm/hr)	Runoff Volume (cu.m)	Discharged Volume (cu.m)	Storage Volume (cu.m)
0	0.0	0.000	0.000	0.000
5	7.74	74.381	74.381	0.000
10	8.38	80.532	80.532	0.000
15	9.16	88.028	88.028	0.000
20	10.14	97.445	97.445	0.000
25	11.38	109.362	109.362	0.000
30	13.03	125.218	125.218	0.000
35	15.35	147.514	147.514	0.000
40	18.86	181.245	181.245	0.000
45	24.83	238.616	238.616	0.000
50	37.46	359.991	316.500	43.491
55	82.72	794.939	316.500	478.439
60	243.43	2339.362	316.500	2022.862
65	105.36	1012.510	316.500	696.010
70	60.19	578.426	316.500	261.926
75	42.26	406.119	316.500	89.619
80	32.74	314.631	314.631	0.000
85	26.86	258.125	258.125	0.000
90	22.87	219.781	219.781	0.000
95	19.98	192.008	192.008	0.000
100	17.79	170.962	170.962	0.000
105	16.06	154.337	154.337	0.000
110	14.68	141.075	141.075	0.000
115	13.53	130.023	130.023	0.000
120	12.57	120.798	120.798	0.000
125	11.75	112.918	112.918	0.000
130	11.04	106.094	106.094	0.000
135	10.42	100.136	100.136	0.000
140	9.88	94.947	94.947	0.000
145	9.39	90.238	90.238	0.000
150	8.96	86.106	86.106	0.000
155	8.57	82.358	82.358	0.000
160	8.22	78.994	78.994	0.000
165	7.89	75.823	75.823	0.000
170	7.60	73.036	73.036	0.000
175	7.33	70.441	70.441	0.000
180	7.08	68.039	68.039	0.000

Total Storage Volume Required (cu.m) **3592.3**

Note: Chicago Storm Hyetograph Calculated Using Method Described in
"Technical Guidelines for Flood Plain Management in Ontario, Working Paper C, Rainfall Analysis" (Dillon, 1985)

Example 10 – Hydraulic Grade Line Analysis Using a Spreadsheet

An existing street and storm sewer are to be extended and an existing field will be developed. The section of the sewer being modeled begins upstream of EX.MH5 and continues to a proposed MH2. There is a total captured flow of 0.301 m^3/s at EX.MH5. Model the storm sewer Hydraulic Grade Lines for a 25-yr event using a spreadsheet.

Solution

Given

Based on a dual drainage analysis using PCSWMM.NET, the total captured flow in the storm sewer at EX.MH5 for the 25-yr design storm is 0.301 m^3/s.

Sample Spreadsheet Calculation – EX.MH5 → MH1

Pipe diameter = 525 mm (nominal) = 533.4 mm (actual)

$$A_{pipe} = \pi(r)^2 = \pi\left[\frac{0.5334\ m}{2}\right]^2 = 0.2235\ \text{m}^2$$

Hydraulic Radius, $R = \frac{dia.}{4} = \frac{0.5334\ m}{4} = 0.133$ m

Pipe Length / Diameter, $\frac{L}{D} = \frac{74.0\ m}{0.5334\ m} = 138.73$

Friction Factor, $f = \frac{124(n)^2}{(d)^{1/3}} = \frac{124(0.013)^2}{(0.5334\ m)^{1/3}} = 0.0258$

Average Velocity of Flow, $V_f = \frac{Q}{A_{pipe}} = \frac{0.301\ m^3/s}{0.2235\ m^2} = 1.347$ m/s

Velocity Head, $\frac{V^2}{2g} = \frac{(1.347\ m/s)^2}{2(9.81\ m/s^2)} = 0.0925$ m

Full Flow Capacity,

$$Q_{capacity} = \left[\frac{0.312}{n}\right](D)^{\frac{8}{3}}(S)^{\frac{1}{2}} = \left[\frac{0.312}{0.013}\right](0.5334\ m)^{\frac{8}{3}}(0.0160)^{\frac{1}{2}} = 0.568\ \text{m}^3\text{/s}$$

Pipe Losses, $h_{pipe} = \frac{k(V)^2}{2g} = (f)\left[\frac{L}{D}\right]\left[\frac{(V)^2}{2g}\right] = (0.0258)(138.73)(0.0925\ m) = 0.332$ m

Manhole Losses, $h_{MH} = \frac{k(V)^2}{2g} = (0.05)(0.0925\ m) = 0.005$ m

Total Losses, $h_{total} = h_{pipe} + h_{MH}$ = 0.332 m + 0.005 m = 0.336 m (accounting for rounding)

Upstream HGL = Downstream HGL + Head Loss
= 250.62 m + 0.336 m
= 250.95 m

Note: If the upstream pipe obvert is higher than the downstream HGL plus head loss, the upstream HGL should be set to the upstream pipe obvert.

HYDRAULIC GRADELINE ANALYSIS

File: Example
Job#: HGL Example
User: PA

Project Name: 25-yr HGL Example
Location: City of Barrie

Note: Total flow in pipe determined from dual drainage analysis calculations

LOCATION/	PIPE	MANHOLES		INVERT ELEV		Slope	GROUND	COVER	BASEMENT	Circular Pipe Parameters			TOTAL	Qcap	Qin/	Surch.	OBV(U/S)	HGL(U/S)	HGL(D/S)	Dist	
DESCRIPTION	NUMBER	U/S	D/S	U/S	D/S		U/S	U/S	U/S	Diameter	Length	'n'	FLOW		Qcap	(U/S)	(m)	(m)	(m)	(m)	MH Loss
				(m)	(m)	(m/m)	(m)	(m)	(m)	(mm)	(m)		(cms)	(m^3/s)		(m)					Factor
Proposed STM Sewer																					
	7	EX.MH1	EX.MH11	248.48	248.16	0.0246	250.80	n/a	n/a	914.4	13.0	0.013	2.063	2.966	0.70	0.00	249.39	249.39	249.07	n/a	0.05
	6	EX.MH2	EX.MH1	248.83	248.48	0.0123	251.37	1.5	249.30	914.4	28.5	0.013	2.063	2.095	0.98	0.01	249.74	249.76	249.39	-0.46	0.05
	5	EX.MH3	EX.MH2	249.22	248.83	0.0073	252.44	1.5	249.87	914.4	53.5	0.013	2.063	1.614	1.28	0.28	250.13	250.42	249.76	-0.55	0.05
	4	EX.MH4	EX.MH3	249.68	249.59	0.0072	252.42	1.5	250.94	533.4	12.5	0.013	0.301	0.381	0.79	0.27	250.21	250.48	250.42	0.46	0.05
	3	EX.MH5	EX.MH4	249.91	249.74	0.0058	252.74	1.5	250.92	533.4	29.5	0.013	0.301	0.341	0.88	0.17	250.44	250.62	250.48	0.30	0.05
	2	MH1	EX.MH5	250.19	249.96	0.0031	253.14	1.5	251.24	533.4	74.0	0.013	0.301	0.250	1.20	0.23	250.72	250.95	250.62	0.29	0.05
	1	MH2	MH1	251.00	250.26	0.0160	253.53	1.5	251.64	533.4	46.3	0.013	0.301	0.568	0.53	0.00	251.53	251.53	250.95	0.11	0.05

Head Loss Calculations

Pipe Cross Sectional Area	**Hydraulic Radius**	**Pipe Length / Pipe Diam.**	**Friction Factor**	**Average Velocity of Flow**	**Velocity Head**	**Pipe Losses**	**MH Losses**	**Total Head Loss**
						HI Pipe	HI MH	HI TOTAL
A (m^2)	R (m)	L/D	f	Vf (m/s)	$V^2/2g$	(m)	U/S (m)	(m)
0.657	0.229	14.2	0.022	3.141	0.503	0.154	0.025	0.180
0.657	0.229	31.2	0.022	3.141	0.503	0.338	0.025	0.364
0.657	0.229	58.5	0.022	3.141	0.503	0.635	0.025	0.661
0.223	0.133	23.4	0.026	1.347	0.092	0.056	0.005	0.061
0.223	0.133	55.3	0.026	1.347	0.092	0.132	0.005	0.137
0.223	0.133	138.7	0.026	1.347	0.092	0.332	0.005	0.336
0.223	0.133	86.8	0.026	1.347	0.092	0.207	0.005	0.212

Sample Calculations (row 0.223 / 0.133 / 138.7)

Example 11 –Hydraulic Grade Line Analysis Using PCSWMM.NET

An existing street and storm sewer are to be extended and an existing farm will be developed. The section of the sewer being modeled begins upstream at MH2 and continues to an existing storm sewer at EX.MH11. There is a total flow of 2.063 m^3/s at EX.MH3. Model the storm sewer Hydraulic Grade Lines for a 25-yr event using PCSWMM.NET.

Solution

- Create a new project in PCSWMM.NET.
- To add maintenance holes, in the Project panel on the left of the screen, select 'Junctions'
- Click the 'Add Shape' button on the top menu, and click on the project map space to add junctions.
- Click on 'Conduits' in the Project panel, click the 'Add Shape' button, and connect the junctions by clicking on them.
- Enter the junction inverts and maximum depth (distance to ground) in the attributes panel by clicking on each junction.
- Enter conduit lengths, inlet/outlet offsets, diameters and roughness coefficients in the attributes panel
- Draw subcatchments by clicking the option in the Project panel.
- Click on 'Rain Gauges' in the Project panel and enter the rainfall information.
- Create the major system (road network) by clicking 'Tools' and 'Dual Drainage Creator'.
- Create a road cross section to match the width and slope of the road being used.
- Delete any of the created roads that are not needed.
- Create and select rating curves for inlet flow to the minor system by clicking on the outlets between the major and minor system.
- Adjust the length of time to run the simulation for and the time step under 'Options' in the Project window.
- Run the model by clicking the 'Run Simulation' button.
- View the water profile by holding shift while clicking on node and then another on the map, and clicking the 'Profile' tab.
- Output the Hydraulic Grade Line to file by clicking the 'Graph' tab, selecting 'Nodes', 'Head', and then selecting the desired junctions to output. Right click on the list and select 'Export Selected Time Series…' and save the output file.

A copy of the model schematic is provided in Figure 11.1. Copies of the HGL profile and output data are provided in Figures 11.2 and 11.3, respectively.

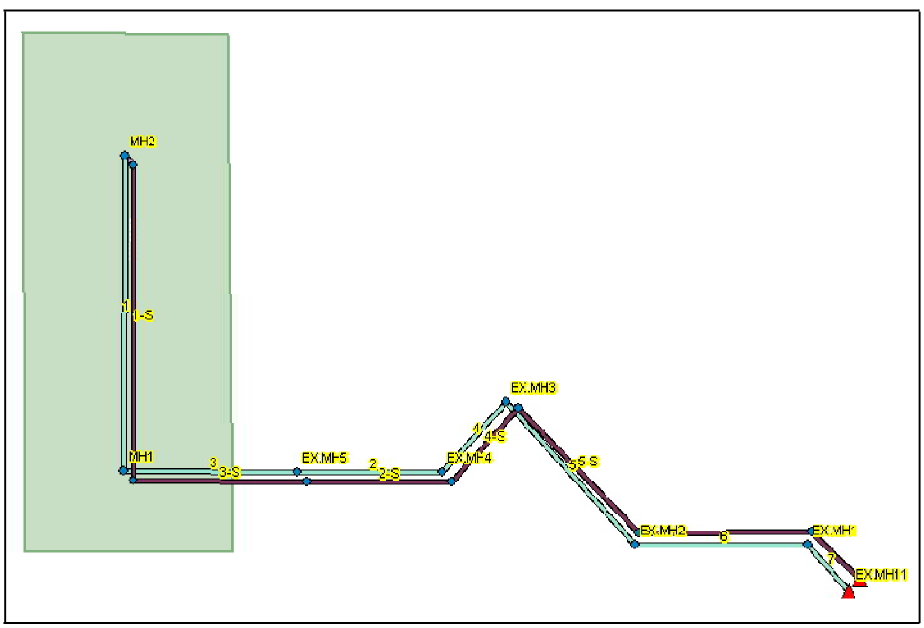


Figure 11.1: PCSWMM.NET Model Schematic

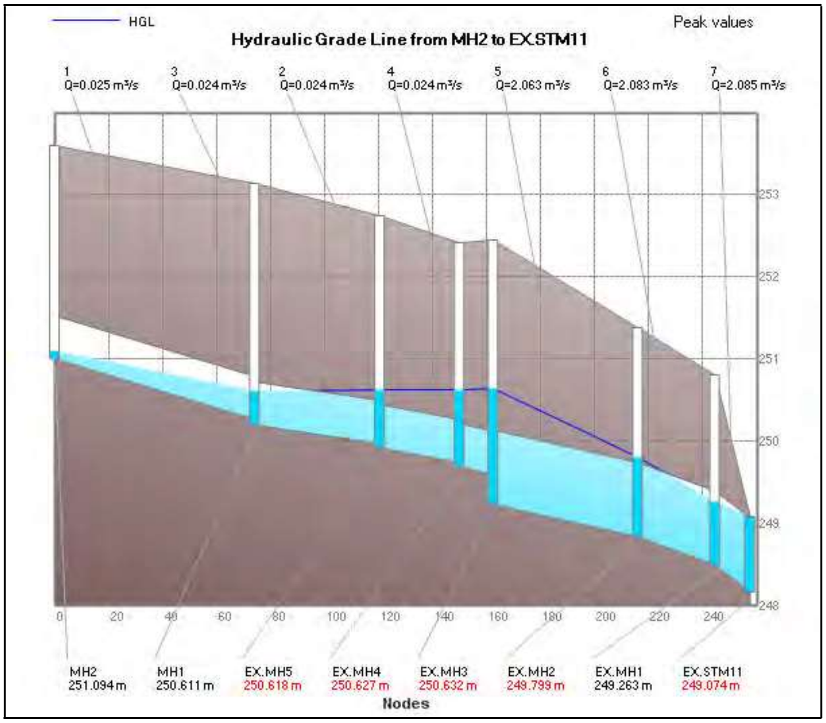


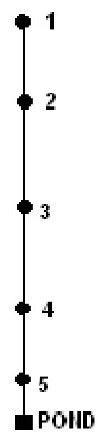
Figure 11.2: PCSWMM.NET Hydraulic Grade Line Profile

IDs:	EX.MH1	EX.MH2	EX.MH3	EX.MH4	EX.MH5	EX.STM11	MH1	MH2
Date/Time	Head	Head	Head	Head	Head	Head	Head	Head
M/d/yyyy	m	m	m	m	m	m	m	m
6/3/2009 0:15	249.2520	249.7487	250.5793	250.5795	250.5783	249.0744	250.5813	251.0030
6/3/2009 0:30	249.2527	249.7537	250.5866	250.5868	250.5830	249.0744	250.5900	251.0087
6/3/2009 0:45	249.2543	249.7509	250.5700	250.5671	250.5621	249.0744	250.5854	251.0122
6/3/2009 1:00	249.2432	249.7895	250.5934	250.5847	250.5833	249.0744	250.5894	251.0233
6/3/2009 1:15	249.2555	249.7528	250.5997	250.5987	250.6021	249.0744	250.6086	251.0943
6/3/2009 1:30	249.2573	249.7504	250.6094	250.6129	250.6175	249.0744	250.6111	251.0895
6/3/2009 1:45	249.2582	249.7477	250.6020	250.6056	250.6110	249.0744	250.5997	251.0806
6/3/2009 2:00	249.2576	249.7445	250.5884	250.5901	250.5879	249.0744	250.5952	251.0730
6/3/2009 2:15	249.2578	249.7574	250.6001	250.5981	250.5947	249.0744	250.5966	251.0670
6/3/2009 2:30	249.2585	249.7491	250.5951	250.5960	250.5933	249.0744	250.5939	251.0613
6/3/2009 2:45	249.2585	249.7488	250.5945	250.5953	250.5927	249.0744	250.5926	251.0569
6/3/2009 3:00	249.2415	249.7992	250.6321	250.6266	250.6055	249.0744	250.5933	251.0522
6/3/2009 3:15	249.2596	249.7448	250.5840	250.5833	250.5865	249.0744	250.5917	251.0453
6/3/2009 3:30	249.2628	249.7500	250.5827	250.5796	250.5693	249.0744	250.5892	251.0351
6/3/2009 3:45	249.2465	249.7582	250.5862	250.5798	250.5807	249.0744	250.5802	251.0236
6/3/2009 4:00	249.2576	249.7464	250.5717	250.5716	250.5786	249.0744	250.5807	251.0130
6/3/2009 4:15	249.2579	249.7467	250.5781	250.5779	250.5807	249.0744	250.5830	251.0065
6/3/2009 4:30	249.2565	249.7509	250.5810	250.5830	250.5837	249.0744	250.5857	251.0044
6/3/2009 4:45	249.2545	249.7527	250.5903	250.5895	250.5797	249.0744	250.5855	251.0035
6/3/2009 5:00	249.2549	249.7577	250.5891	250.5879	250.5843	249.0744	250.5840	251.0030
6/3/2009 5:15	249.2486	249.7586	250.5876	250.5860	250.5813	249.0744	250.5846	251.0027
6/3/2009 5:30	249.2546	249.7524	250.5927	250.5936	250.5869	249.0744	250.5826	251.0025
6/3/2009 5:45	249.2496	249.7584	250.5990	250.6048	250.6096	249.0744	250.5792	251.0023
6/3/2009 6:00	249.2548	249.7454	250.5833	250.5827	250.5881	249.0744	250.5855	251.0023

Figure 11.3: PCSWMM.NET Hydraulic Grade Line Output File

Example 12: Storm Sewer Design Using a Storm Sewer Design Sheet

Design a storm sewer using a spreadsheet for a street with 5 maintenance holes that outlet to a pond with a normal water elevation of 298.250 m (see schematic below).



The areas contributing runoff into each manhole are as follows:

MH Number	Area (ha)	Runoff Coefficient
1	0.65	0.65
2	0.04	0.55
3	0.02	0.55
4	0.25	0.55
5	1.75	0.55
POND	-	-

Solution

Sample Spreadsheet Calculation for Maintenance Hole 1 to 2

(a) 5-Year Design Storm Intensity and Flow

5-Year IDF Parameters:
A = 853.608
B = 4.699
C = 0.766

Using the IDF parameters and the minimum allowable time of concentration of 10 minutes,

$$i = \frac{A}{(t_c + B)^C} = \frac{853.608}{(10 + 4.699)^{0.766}} = 108.92 \text{ mm/hr}$$

$$Q = \frac{(C)(i)(A)}{360} = \frac{(0.65)(108.92\ mm/hr)(0.65\ ha)}{360} = 0.13 \text{ m}^3\text{/s}$$

(b) Full Flow Pipe Capacity

Try pipe size = 250 mm (nominal) or 254.0 mm (actual) diameter.

$$Q=\left[\frac{0.312}{n}\right](D)^{\frac{8}{3}}(S)^{\frac{1}{2}}=\left[\frac{0.312}{0.013}\right](0.2540\ m)^{\frac{8}{3}}(0.025)^{\frac{1}{2}}=0.098\ \text{m}^3/\text{s}$$

Since the capacity of a 250 mm diameter pipe is less than 0.13 m^3/s, a larger pipe must be used. Try the next largest size of 300 mm (304.8 mm actual).

$$Q=\left[\frac{0.312}{n}\right](D)^{\frac{8}{3}}(S)^{\frac{1}{2}}=\left[\frac{0.312}{0.013}\right](0.3048\ m)^{\frac{8}{3}}(0.025)^{\frac{1}{2}}=0.160\ \text{m}^3/\text{s}$$

Therefore, a 300 mm diameter pipe has sufficient capacity.

(c) Full Flow Velocity

$$A_{pipe}=\pi(r)^2=\pi\left[\frac{0.3048\ m}{2}\right]^2=0.07297\ \text{m}^2$$

$$v_{full}=\frac{Q}{A_{pipe}}=\frac{0.160\ m^3/s}{0.07297\ m^2}=2.193\ \text{m/s}$$

(d) Time in Section

$$t=\frac{length}{v_{full}}=\left[\frac{43.9\ m}{2.193\ m/s}\right]\left[\frac{1\ \text{min}}{60\ s}\right]=0.33\ \text{min}$$

Total time = time of concentration + time in section = 10 min + 0.33 min = 10.33 min

Example 14 – Culvert Design

Size a culvert for an urban local road crossing using the Nomograph Method. Based on the Barrie guidelines, the culvert shall be sized to convey the 25-year peak flow. Based on a separate analysis, the 25-year peak flow was determined to be 3.70 m^3/s.

Given:
Culvert Length (L) = 35.20 m
Upstream Invert = 195.60 m
Downstream Invert = 195.25 m
Culvert Slope (S)= 1.0% or 0.01 m/m
Road Deck Elevation = 197.85 m
Tailwater Depth (TW) = 0.50 m

Solution

(a) *Flow to be conveyed*

$$Q_{25-year} = 3.70\ m^3/s$$

(b) Determine the culvert type

Determine the material (e.g. concrete, CSP or PVC), type (e.g. headwall, projecting or mitered), shape (e.g. circular, box, arch, or ellipse) of the culvert according to the target flow, site topo, embankment and possible cover.

For example, a projecting CSP circular culvert was recommended in this case because of the cost effectiveness (see **Figure 14.1** for detail).

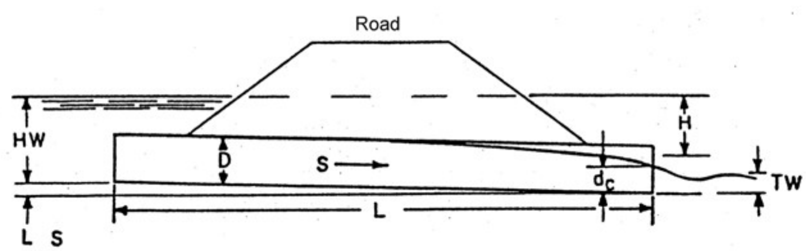


Figure 14.1: Schematic of Proposed Culvert Crossing

(c) Using the appropriate nomograph, complete the calculation assuming inlet control

Step 1: To begin, let's assume the culvert diameter, D = 1200 mm:

Based on the appropriate nomograph in the **MTO Drainage Management Manual** (see **Figure 14.2)**,

$$\frac{HW}{D} = 2.20 \text{, hence } HW = 2.20(D) = 2.20(1.20\ m) = 2.64\ m\ .$$

The maximum upstream water surface elevation (WSEL) = 195.60 m + 2.64 m = 198.24 m which is higher than the road deck elevation, 197.85 m. Therefore, the 1200 mm CSP culvert is **NOT** adequately sized to convey the 25-year peak flow assuming the culvert is operating under inlet control.

Step 2: Therefore, let's increase the culvert diameter to D = 1350 mm (next largest standard size):

Based on the appropriate nomograph in the **MTO Drainage Management Manual** (see **Figure 14.2**),

$$\frac{HW}{D} = 1.50 \text{, hence } HW = 1.50(D) = 1.50(1.35\ m) = 2.025\ m\ .$$

The maximum upstream water surface elevation (WSEL) = 195.60 m + 2.025 m = 197.63 m, which is lower than the road deck elevation, 197.85 m. Therefore, the 1350 mm CSP culvert is adequately sized to convey the 25-year peak flow assuming the culvert is operating under inlet control.

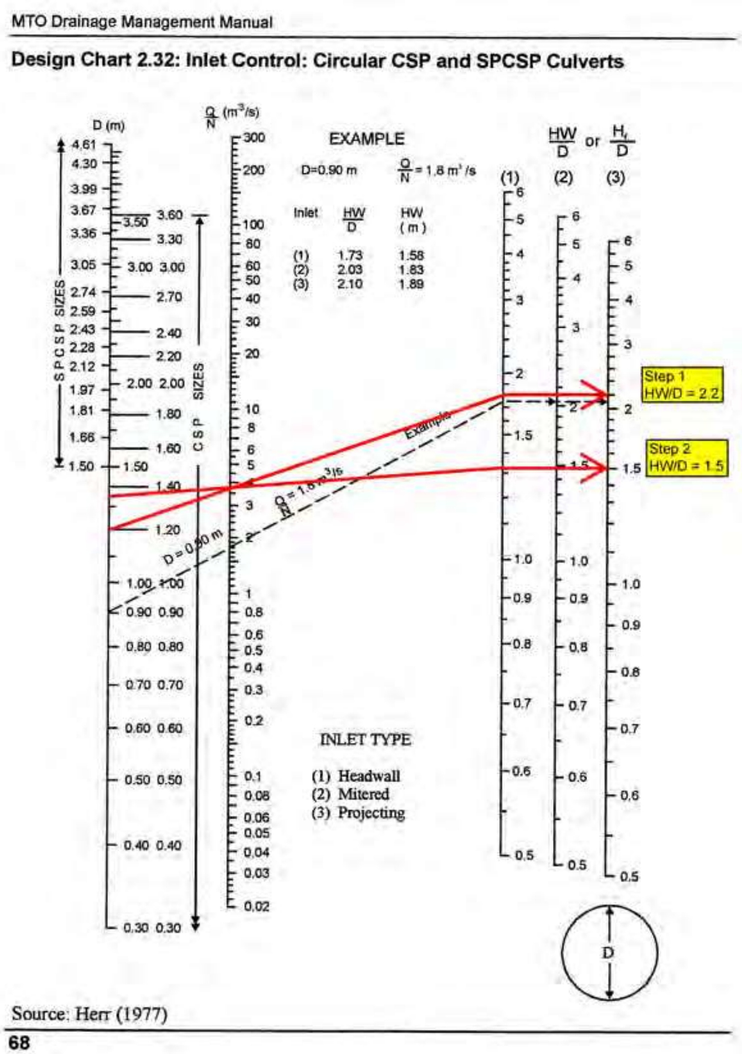


Figure 14.2: Nomograph for Inlet Control - Circular CSP Pipe (MTO, 1997)

(d) Using the Nomograph check the result assuming outlet control

Step 3: Now, let's check the culvert assuming outlet control with D = 1350 mm:

Based on the appropriate nomograph in the **MTO Drainage Management Manual** (see **Figure 14.3**)

$$H = 1.25\ m$$

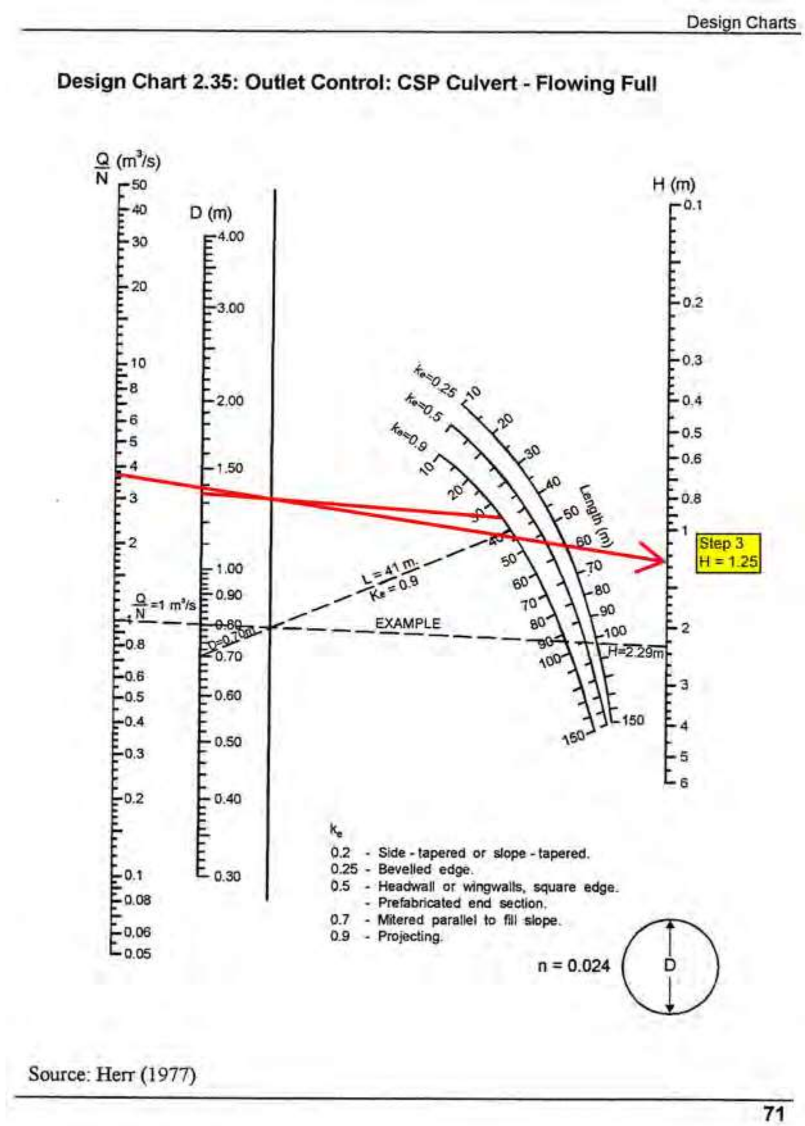


Figure 14.3: Nomograph for Outlet Control – Circular CSP Pipe (MTO, 1997)

As per the **MTO Drainage Management Manual** for outlet control conditions (see **Figure 14.4**),

$$HW = H + h_o - (L)(S)$$

where,
HW = headwater depth (m);
H = head as per MTO chart (m)
h_o = greater of the following:

TW, or
$(d_c + D)/2$
where,
d_c = critical depth (m) and d_c not greater than D;
D = diameter of culvert (m); and
TW = tailwater depth (m).

L = length of culvert (m)
S = slope of culvert (m/m)

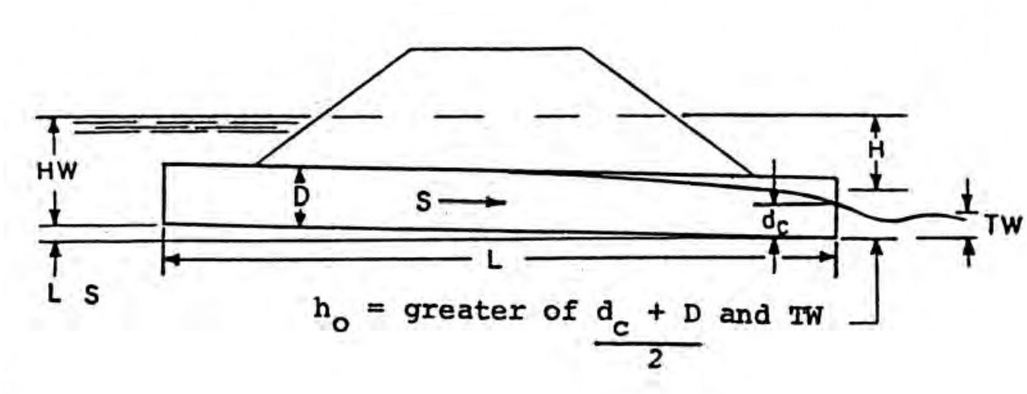


Figure 14.4: Determination of h_o for Tailwater below Top of Opening (MTO, 1997)

Using MTO Design Chart 2.37 (MTO, 1997) (see **Figure 14.5**), the critical depth (d_c) is determined to be 1.02 m.

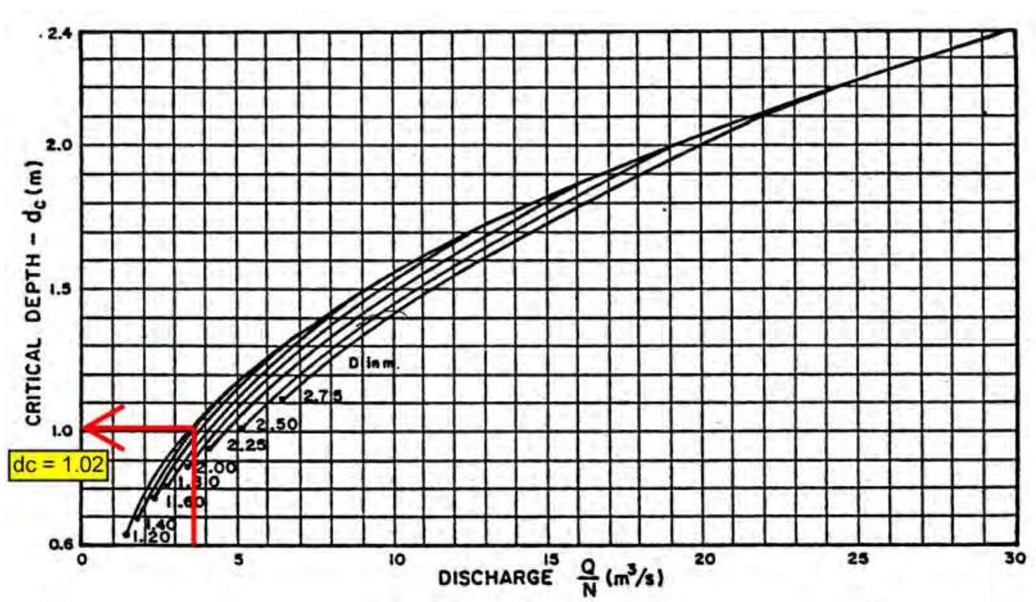


Figure 14.5: Critical Depth – Circular Pipe (MTO, 1997)

$$TW = 0.50\ (given)$$

$$\frac{d_c + D}{2} = \frac{1.02 + 1.350}{2} = 1.185\ m$$

Therefore, h_o = 1.185 m.

$$HW = 1.25\ m + 1.185\ m - (35.2\ m)(0.01\ m/m) = 2.083\ m$$

Therefore, the maximum upstream water surface elevation (WSEL) = 195.60 m + 2.083 m = 197.68 m, which is lower than the road deck elevation, 197.85 m. As such, a 1350 mm diameter CSP culvert is also adequately sized to convey the 25-year peak flow assuming the culvert is operating under outlet control.

(e) Determine the governing headwater elevation and required culvert size based on the larger of inlet and outlet control conditions

Repeat **Step 2** and **Step 3** until the culvert size is adequate to satisfy both inlet and outlet control conditions to convey the target flow. For this example, a 1350 mm diameter CSP culvert is calculated to be sufficient to convey the 25-yr peak flow without overtopping the road.

Example 15 – Total Capture CB with Safety Factor

Size a total capture catch basin at a sag location with the required safety factor. Based on the Barrie guidelines, the safety factor shall be 2.0 (i.e. 50% blockage). Based on a separate analysis, the peak flow to be captured was determined to be 0.37 m^3/s.

Solution

(a) *Flow to be conveyed*

$$Q_{total} = 0.37\ m^3/s$$

(b) *Calculate the flow capacity of the CB selected*

Determine the CB type and calculate the opening area for the proposed CB type based on the appropriate OPSD standard drawing. For this example, single "square opening" CB's (**OPSD 400.100**) with approximately a 40% grate opening area are proposed. The flow for each CB can be calculated using the orifice equation:

$$Q_{CB} = (c)(A_o)(2gh)^{0.5}$$

where,
c = orifice coefficient (based on the City guidelines); and
A_o = total opening area of the CB (m^2).

$$A_o = 0.6\ m \times 0.6\ m \times 0.4 = 0.144\ m^2$$

where,
g = acceleration due to gravity (9.81 m/s^2); and
h = water head (m) (based on the City guidelines, the maximum depth is 0.3 m).

$$Q_{CB} = (c)(A_o)(2gh)^{0.5} = (0.63)(0.144\ m^2)(2 \times 9.81\ m/s^2 \times 0.3\ m)^{0.5} = 0.22\ m^3/s$$

(c) Calculate the number of CB's required including the safety factor:

$$N = \frac{(F)(Q_{total})}{Q_{CB}}$$

where,
F = safety factor (based on the City guidelines, *F* is 2.0).

$$N = \frac{(F)(Q_{total})}{Q_{CB}} = \frac{(2.0)(0.37\ m^3/s)}{0.22\ m^3/s} = 3.36$$

Hence, 4 single "square opening" CB's are required.

(d) Check the lead to confirm adequate conveyance capacity (can quickly approximate assuming inlet control operating as an orifice):

$$Q_{lead} = (c)(A_{lead})(2gh)^{0.5}$$

where,
c = orifice coefficient (based on the City guidelines); and
A_o = lead pipe area (m^2).

Assuming a 250 mm PVC pipe per CB with 1.2 m of cover,

$$A = \frac{(\pi)(D)^2}{4} = \frac{(3.14)(0.250\ m)^2}{4} = 0.049\ m^2$$

g = acceleration due to gravity (9.81 m/s^2); and
h = water head (m).

$$h = 0.3\ m + 1.2\ m + \frac{0.250\ m}{2} = 1.625\ m$$

$$Q_{lead} = (c)(A_{lead})(2gh)^{0.5} = (0.63)(0.049\ m^2)(2 \times 9.81\ m/s^2 \times 1.625\ m)^{0.5} = 0.174\ m^3/s$$

Hence, a 250 mm lead pipe exceeds the CB inlet capacity (assuming 50% blockage).

APPENDIX D

SUMMARY OF RECOMMENDATIONS FROM MDPS FOR CITY OF BARRIE WATERSHEDS

CORPORATE ASSET MANAGEMENT

- Summary of Recommendations from the Approved Master Drainage Plans for the City of Barrie Watersheds

Summary of Recommendations from Approved Master Drainage Plans for City of Barrie Watersheds

Watershed	Approved MDP Document	Summary of Recommendations
Bayshore	None approved	
Bear Creek	None approved	
Bunkers Creek	*Bunkers Creek Master Drainage Plan Update* (Giffels Associates, June 2004)	• A number of infrastructure upgrades were recommended for implementation including channel, culvert and storm sewer construction and improvements. • SWM Facility proposed for R.A. Archer Operations Centre • SWM Pond Outlet improvements proposed for Milligan's Pond. • Summary of the Implementation Program is provided in Table 15 of MDP report.
Dyments Creek	*Master Drainage Plan, Municipal Class EA, Dyments Creek* (Jones Consulting Group, June 2006)	• A number of infrastructure upgrades were recommended for implementation including flood proofing and channel, culvert and storm sewer construction and improvements. • SWM facility proposed west of Anne Street. • SWM facility proposed west of Victoria Street. • SWM facility proposed north of Dunlop Street and west of Ferndale Industrial Drive (Pond 1). • Summary of the proposed works for implementation is provided in Section 5.3.1 of the MDP report.
Georgian	None approved	
Gray Lane	None approved	
Hewitts Creek	*Lovers Creek and Hewitts Creek Master Watershed Plans* (Cumming Cockburn, December 1995)	The following recommendations were provided in the MWP report regarding flood storage, erosion and water quality: • Promote maintenance and vegetation of valley corridors • Continue to apply flood and fill regulations; extend and update. • Maintain flood storage in St. Paul's Swamp. • Maintain flood storage by BMP's. • Promote agricultural activities which maintain infiltration and reduce surface erosion. • Promote application of rural BMP's for erosion control. • Reduce livestock access to watercourses. • Require erosion control BMP's during and after development. • Maintain / reestablish vegetation / ground cover. • Implement water quality education programs. • Promote urban and agricultural BMP's for water quality. • Reduce phosphorus loading by 25%. • Continue to control sediment from construction sites. • Reduce fertilizer application.
Holgate Creek	None approved	
Hotchkiss Creek	*Hotchkiss Creek Master Drainage Plan Update, Environmental Assessment Document* (R.G. Robinson and Associates, October 2000)	• A number of infrastructure upgrades were recommended for implementation including the construction of SWM facilities within the creek corridor as well as increased hydraulic conductivity of culverts and channels and the discharge of major system flow directly to Kempenfelt Bay.
Huronia Creek	None approved	
Johnson	None approved	

Kidd's Creek	*Kidd's Creek Master Drainage Plan, Class Environmental Assessment, Addendum* (City of Barrie, January 2005)	• The watershed is fully developed and no additional SWM facilities are proposed within the watershed. • Recommended solutions are to eliminate spill to the adjacent watersheds and to improve conveyance including channel and culvert improvements and flood proofing. • As feasible, flow restrictions within the flood plain should be removed or minimized to reduce the effect of flooding during the regulatory storm (Hurricane Hazel).
Little Lake (Willow Creek)	*Willow Creek Subwatershed Plan* (NVCA, December 2001)	• SWM ponds constructed within the Willow Creek Subwatershed must provide Level 1 (Enhanced) protection for water quality. • The minimum erosion requirement shall consist of the 25 mm post-development peak flow released over a 24-hour period. • The minimum level of quantity control shall be post-to-pre flow control for the 2-yr through 100-yr design storms. • Where feasible, temperature impacts to the receiving waters should be minimized by incorporating measures such as littoral plantings and bottom draw outlet structures into the overall design of SWM facilities.
Lovers Creek	*Lovers Creek and Hewitts Creek Master Watershed Plans* (Cumming Cockburn, December 1995)	The following recommendations were provided in the MWP report regarding flood storage, erosion and water quality: • Mitigate the loss of natural flood storage in developed areas by use of BMP's and the maintenance of valley corridors and flood plains. • Extend fill lines to significant headwater tributary areas. • The storage capacity of Lovers Creek Swamp should be maintained. • Rehabilitate the erosion scars downstream from HWY 11 to improve aesthetics and to accelerate recovery. • Utilize naturalized / bio-engineering techniques wherever possible where stabilization is required (to accelerate stabilization). • Promote measures to minimize livestock access to streams. • Encourage the implementation of urban and rural BMP's regarding erosion control. • Retrofit existing SWM ponds in urban areas, where feasible, for quality control. • Encourage the use of BMP's for all future SWM systems. • Continue to control sediment from construction sites. • Promote and encourage the use of agricultural BMP's for water quality. • Phosphorus loadings should be reduced by 25%. • Encourage the reduction of fertilizers in rural and urban areas. • Maintain groundwater quality by development controls in recharge areas.
Minets	None approved	
Mulcaster	None approved	
Nelson	None approved	
Rodney	None approved	
Royal Oak	None approved	

Sophia Creek	*Sophia Creek Watershed Master Drainage Plan* (Skelton, Brumwell & Associates, February 2002)	The following recommendations were developed to reduce the magnitude and frequency of flooding within Sophia Creek: • It is recommended that two SWM ponds should be constructed. One should have a storage volume of 14,000 m^3 and be located on City owned lands along the east branch of the watercourse between MacMorrison Park and St. Vincent Street. Another pond should have a volume of 9,900 m^3 and be located within what is currently private property along the north branch (properties identified as #28 Currie St. and #364 St. Vincent St.). • Culvert and storm sewers should be enlarged to convey the peak flow from the 25-yr storm and open channel section should also be reconstructed to maximize the channel capacity within the available property limits. These improvements will eliminate frequent flooding and of private properties and ensure that runoff from major storms does not damage buildings. • Additional details are provided in Table 10 of the MDP report. The following recommendations were developed to improve water quality within Sophia Creek: • Provide vegetation buffers where feasible adjacent the creek. • Provide natural channel design improvements to degraded reaches within the creek. • Implement water quality structural improvements by incorporating quality control structures in storm sewer reconstruction projects, redevelopment proposals, and the construction of sediment basins in storage ponds. • Additional details regarding water quality recommendations are provided in Section 4.2 of the MDP report.
St. Vincent	None approved	
Whiskey Creek	*Whiskey Creek Master Drainage Plan Update, Environmental Assessment Document* (R.G. Robinson and Associates, September 2004)	DRAFT report – check with City for final recommendations
Williams	None approved	

APPENDIX E

SUMMARY OF APPLICABLE LEGISLATIONS, ACTS AND REGULATIONS

CORPORATE ASSET MANAGEMENT

- Applicable Legislation – Summary of Local, Provincial and Federal Acts and Regulations

LEGISLATION – SUMMARY OF ACTS AND REGULATIONS

1 Provincial Acts and Regulations

1.1 Conservation Authorities Act

The Ontario "Conservation Authorities Act" was first passed in 1946 with the objectives of ensuring the conservation, restoration and responsible management of our water, land and natural habitat. The programs in which the Conversation Authorities you be engaged must incorporate a balance between human, environmental and economic needs.

For the purposes of accomplishing its objects, the act has provided Conservation Authorities with several powers including the authority:

- to control the flow of surface waters in order to prevent floods or pollution or to reduce the adverse effects thereof;
- to alter the course of any river, canal, brook, stream or watercourse, and divert or alter, as well temporarily as permanently, the course of any river, stream, road, street or way, or raise or sink its level in order to carry it over or under, on the level of or by the side of any work built or to be built by the authority, and to divert or alter the position of any water-pipe, gas-pipe, sewer, drain or any telegraph, telephone or electric wire or pole;

Subject to the approval of the Minister, an authority may make regulations applicable in the area under its jurisdiction:

- restricting and regulating the use of water in or from rivers, streams, inland lakes, ponds, wetlands and natural or artificially constructed depressions in rivers or streams;
- prohibiting, regulating or requiring the permission of the authority for straightening, changing, diverting or interfering in any way with the existing channel of a river, creek, stream or watercourse, or for changing or interfering in any way with a wetland;
- prohibiting, regulating or requiring the permission of the authority for development if, in the opinion of the authority, the control of flooding, erosion, dynamic beaches or pollution or the conservation of land may be affected by the development;

1.1.1 Regulation of Development, Interface with Wetlands and Alternations to Shorelines and Watercourses

The following regulations are designed to protect life and property from natural hazards such as flooding, erosion and pollution, barring permission granted otherwise from the Conservation Authority:

No person shall *undertake development* or permit another person to undertake development in or on the areas within the jurisdiction of the Conservation Authority that are:

- river or stream valleys that have depressional features associated with a river or stream, whether or not they contain a watercourse, the limits of which are determined in accordance with the following rules:
    - where the river or stream valley is apparent and has stable slopes, the valley extends from the stable top of bank, plus 15 meters, to a similar point on the opposite side,
    - where the river or stream valley is apparent and has unstable slopes, the valley extends from the predicted long term stable slope, projected from the existing stable slope or, if the toe of the slope

is unstable, from the predicted location of the toe of the slope as a result of stream erosion over a projected 100-year period, plus 15 meters, to a similar point on the opposite side,

  - where the river or stream valley is not apparent, the valley extends the greater of:

    - the distance from a point outside the edge of the maximum extent of the flood plain under the applicable flood event standard, plus 15 meters, to a similar point on the opposite side, or

    - the distance from the predicted meander belt of a watercourse, expanded as required to convey the flood flows under the applicable flood event standard, plus 15 meters, to a similar point on the opposite side;

- hazardous lands;

- wetlands; or

- other areas where development could interfere with the hydrologic function of a wetland, including areas within 120 meters of all provincially significant wetlands and 30 meters of all other wetlands, but not including those where development has been approved pursuant to an application made under the Planning Act or other public planning or regulatory process.

No person shall *straighten, change, divert or interfere* in any way with the existing channel of a river, creek, stream or watercourse or change or interfere in any way with a wetland.

The applicable *flood event standards* used to determine the maximum susceptibility to flooding of lands or areas within the watersheds in the area of jurisdiction of the Authorities are the Hazel or Timmins Flood Event Standard and the 100 Year Flood Event Standard.

Hazardous lands, wetlands, watercourses, shorelines and areas susceptible to flooding, and associated allowances within the watersheds, in the area of jurisdiction of the Authority are delineated by the *Regulation Limit* shown on the map *Ontario Regulation 97/04: Regulation for Development, Interference with Wetlands and Alterations to Shorelines and Watercourses*.

1.2 <u>Drainage Act</u>

The Ontario Drainage Act defines legal agreements that can be made regarding drainage works, requirements for construction and engineering assessment of drains, and prohibits the discharges.

Except as authorized by a by-law of the initiating municipality approved by the Ministry of the Environment, no person shall discharge or deposit or permit to be discharged or deposited into any drainage works any liquid, material or substance other than unpolluted drainage water.

Two or more owners may enter into a written agreement to construct or improve a drain on their land. The agreement should describe the land affected, the location of the drainage works, and the proportion of the work each person is expected to pay for and maintain.

When the agreement is drawn up, it may be registered against the land for the protection of owners. The Drainage Act gives Mutual Agreement Drains formal status, and registration makes the agreement binding on future owners of the land. Agreements should be made each time a main drain leaves an owner's property and should be registered in the appropriate registry office. Enforcement of the Agreement must be made through court action.

The Drainage Act provides an elaborate procedure for the construction, improvement and maintenance of drainage works. The maintenance of the drainage works is carried out by the municipality at the expense of all the upstream lands and roads assessed by the Engineer's report. Any person whose property is injured, may give the Clerk 45 days notice to repair the drainage works. If an owner obstructs a drain, the obstruction may be removed at his expense. A municipality with an approved drainage superintendent may receive a grant for maintenance work.

Repair and Improvement can be made by Council especially for minor improvements of deepening, widening or extending a drain to an outlet, providing the cost does not exceed $4500. The cost must be assessed over all the lands and roads affected by the drain regardless of the location of the work. The Council can improve a drain on the report of an Engineer, without a petition. An owner can make a written request to Council for the improvements of a drain, or, Council can initiate the improvements. The procedure follows that for a petition drain as much as possible starting at step 3 in the Order of Procedure.

The Act also outlines procedure for Abandonment of a Drain or Part of a Drain. A drain may be abandoned by petition of 3/4 of the owners of land assessed for benefit who own not less than 3/4 of the area assessed for benefit. Council may also initiate abandonment of a drain. The Engineer may recommend abandonment of a drain which is no longer useful. The Act provided a procedure for petitions.

The Tile Drainage Act makes loans available for the drainage work done on a farm. A loan is obtained from the provincial government through the township council. After the township has passed the necessary borrowing by-law, an assessed owner may make application for a loan. The application is made prior to the work commencing. The loan cannot exceed 75% of the total cost of the drainage system. The approval of a loan application lies within the discretion of Council. Council may request such information as they require to arrive at a decision. Written notice of the Council's decision is given to each applicant. After Council's approval of the loan, the work may commence. When the work has been completed, an inspector employed by the Council files an inspection and completion certificate with the township clerk which states that the work is either done, or not done, to his satisfaction.

1.3 Provincial Policy Statement

1.3.1 Natural Hazard Land Policies

Section 3.1 of the the Provincial Policy Statement outlines policies associated with development within hazard lands. Hazard lands are defined as areas susceptible to flooding and erosion events. The objectives of these policies are to prevent damages to developments from hazardous events and to minimize erosion through restricting development. The preventative approach of these policies "supports provincial and municipal financial well-being over the long term, protects public health and safety, and minimizes cost, risk and social disruption." (PPS, 2005)

Development will generally be directed to areas outside of:

- hazardous lands adjacent to the shorelines of the Great Lakes - St. Lawrence River System and large inland lakes which are impacted by flooding, erosion, and/or dynamic beach hazards;
- hazardous lands adjacent to river and stream systems which are impacted by flooding and/or erosion hazards; and
- hazardous sites.

Development and site alteration will not be permitted within:

- defined portions of the dynamic beach;
- defined portions of the one hundred year flood level along connecting channels (the St. Mary's, St. Clair, Detroit, Niagara and St. Lawrence Rivers); and
- a floodway (except in those exceptional situations where a Special Policy Area has been approved).

Except as provided in the above policies, development and site alteration may be permitted in hazardous lands and hazardous sites, provided that all of the following can be achieved:

- the hazards can be safely addressed, and the development and site alteration is carried out in accordance with established standards and procedures;

- new hazards are not created and existing hazards are not aggravated;
- no adverse environmental impacts will result;
- vehicles and people have a way of safely entering and exiting the area during times of flooding, erosion and other emergencies; and
- the development does not include institutional uses or essential emergency services or the disposal, manufacture, treatment or storage of hazardous substances.

1.3.2 Water Quality and Quantity Policies

Planning authorities shall protect, improve or restore the quality and quantity of water by:

- using the watershed as the ecologically meaningful scale for planning;
- minimizing potential negative impacts, including cross-jurisdictional and cross-watershed impacts;
- identifying surface water features, ground water features, hydrologic functions and natural heritage features and areas which are necessary for the ecological and hydrological integrity of the watershed;
- implementing necessary restrictions on development and site alteration to:
    - protect all municipal drinking water supplies and designated vulnerable areas; and
    - protect, improve or restore vulnerable surface and ground water, sensitive surface water features and sensitive ground water features, and their hydrologic functions;
- maintaining linkages and related functions among surface water features, ground water features, hydrologic functions and natural heritage features and areas;
- promoting efficient and sustainable use of water resources, including practices for water conservation and sustaining water quality; and
- ensuring stormwater management practices minimize stormwater volumes and contaminant loads, and maintain or increase the extent of vegetative and pervious surfaces.

Development and site alteration shall be restricted in or near sensitive surface water features and sensitive ground water features such that these features and their related hydrologic functions will be protected, improved or restored.

Mitigative measures and/or alternative development approaches may be required in order to protect, improve or restore sensitive surface water features, sensitive ground water features, and their hydrologic functions.

1.4 Lakes and Rivers Improvement Act

The Lakes and Rivers Improvement Act applies to construction in watercourses (e.g. dams). The purposes of the Act are to provide for:

- the management, protection, preservation and use of the waters of the lakes and rivers of Ontario and the land under them;
- the protection and equitable exercise of public rights in or over the waters of the lakes and rivers of Ontario;
- the protection of the interests of riparian owners;
- the management, perpetuation and use of the fish, wildlife and other natural resources dependent on the lakes and rivers; and

- the protection of the natural amenities of the lakes and rivers and their shores and banks.

1.5 Environmental Protection Act

The Ontario Environmental Protection Act was created to provide for the protection and conservation of the natural environment. Under the act, regulations can be made to prevent or reducing the growth of aquatic vegetation that is caused by the release of nutrients in waters and is interfering with the functioning of an ecosystem.

1.6 Ontario Water Resources Act

The Ministry should be notified of all discharges not occurring in the normal course of events, or from control material into any waters that may impair the water quality.

The Director may order the relevant authority of a sewage works, water works or other facility discharging material into a water or watercourse to do any one or more of the following:

- to have available at all times, or during the periods specified in the order, the equipment, material and personnel specified in the order at the locations specified in the order to prevent, reduce or alleviate any impairment of the quality of the water or the effects of any impairment of the quality of the water.
- to obtain, construct and install or modify the devices, equipment and facilities specified in the order at the locations and in the manner specified in the order.
- to implement the procedures specified in the order.
- to take all steps necessary to ensure that the procedures specified in the order will be implemented in the event that a water or watercourse becomes impaired or may become impaired.
- to monitor and record the quality and quantity of any water specified in the order and to report to the Director.
- to study and to report to the Director about:
    - measures to control the discharge into a water or watercourse of a material specified in the order;
    - the effects of the discharge into a water or watercourse of a material specified in the order; and
    - the water or watercourse into which a material specified in the order may be discharged.

An area may be defined by a Director that includes a source of public water supply where:

- no person shall swim or bathe;
- no material of any kind that may impair the quality of water therein shall be placed, discharged or allowed to remain; or
- no act shall be done and no water shall be taken that may unduly diminish the amount of water available in such area as a public water supply.

1.6.1 Ontario Regulation 219/09 Made Under the Lake Simcoe Protection Act

The Lake Simcoe Protection Regulation defines responsibilities and imposes limits on sewage treatment plants which discharge into surface waters which drain into Lake Simcoe. The overall goal of this regulation was to limit nutrient discharge into Lake Simcoe to mitigate observed ecological impacts.

The regulation defines total phosphorus discharge limits, sampling requirements, required calculations to be reported monthly, and prohibits new sewage treatment plants unless strict requirements are met. For new sewage works such as stormwater management ponds to be approved it must be shown that the SWM pond will comply with Enhanced Protection level specified in Chapter 3 of the Ministry of Environment's "Storm Water Management Planning and Design Manual 2003".

1.7 Planning Act

In considering a draft plan of subdivision, health, safety, convenience, accessibility for persons with disabilities and welfare of the present and future inhabitants of the municipality and to conservation of natural resources and flood control should be considered. Furthermore, zoning by-laws may be passed of the council of municipalities:

- for prohibiting the erection of any class or classes of buildings or structures on land that is subject to flooding or on land with steep slopes, or that is rocky, low-lying, marshy, unstable, and hazardous, subject to erosion or to natural or artificial perils.
- for prohibiting any use of land and the erecting, locating or using of any class or classes of buildings or structures within any defined area or areas, that is:
  - a significant wildlife habitat, wetland, woodland, ravine, valley or area of natural and scientific interest,
  - a significant corridor or shoreline of a lake, river or stream, or
  - a significant natural corridor, feature or area.

1.8 Public Land Act

No person shall deposit or cause to be deposited any material, substance or thing on public lands, whether or not the lands are covered with water or ice, except with the written consent of the Minister or an officer authorized by the Minister.

1.9 Municipal Act

A municipality may enter into an agreement with any person to construct, maintain and operate a private road or a private water or sewage (includes stormwater and other drainage from land) works.

A municipality may enter on land, at reasonable times, to inspect the discharge of any matter into the sewage system of the municipality or into any other sewage system the contents of which ultimately empty into the municipal sewage system and may conduct tests and take samples for this purpose.

1.10 MTO Drainage Management Policy

The objective of the MTO drainage policy is to ensure that water conveyed through highway drainage works will not infringe upon the riparian rights of landowners (See Section 2.19 - *Element of Common Law*) located upstream or downstream of the highway right-of-way. Accordingly, the proponent must recognize that MTO will not approve a land development proposal if the riparian rights of any landowner may be infringed upon by the proposed land development.

1.11 Lake Simcoe Protection Plan (June 2009)

The provincial government has recently put in place new environmental, land use planning, and growth management frameworks through the Clean Water Act 2006, the Safeguarding and Sustaining Ontario's Water Act 2007, the Nutrient Management Act 2002, the Greenbelt Plan, the Growth Plan for the Greater Golden Horseshoe 2006, the Provincial Policy Statement 2005, and reforms to the Planning Act. The government has developed a Lake Simcoe Protection Strategy that builds on these existing frameworks to protect the health of the lake and ensure that future growth in the Lake Simcoe watershed occurs in a sustainable manner.

The objectives of the Protection Plan include:

- to protect, improve or restore the elements that contribute to the ecological heat of Lake Simcoe watershed, including, water quality, hydrology, key natural heritage features and their functions;
- reduce loadings of phosphorus and other nutrients of concern to Lake Simcoe and its tributaries;
- reduce the discharge of pollutants to Lake Simcoe and its tributaries;
- respond to adverse effects related to invasive species and, where possible, to prevent invasive species from entering the Lake Simcoe watershed;
- improve the Lake Simcoe watershed's capacity to adapt to climate change;
- Promote environmentally sustainable land and water uses, activities and development practices.
- Build on the protections for the Lake Simcoe watershed that are provided by provincial plans that apply in all or part of the Lake Simcoe watershed, including the Oak Ridges Moraine Conservation Plan and the Greenbelt Plan, and provincial legislation, including the Clean Water Act, 2006, the Conservation Authorities Act, the Ontario Water Resources Act, and the Planning Act.

The objectives were developed through the identification of several existing and potential stresses on the Lake Simcoe watershed including human activities, phosphorus loading, invasive species, and climate change. The plan recognizes the need for the economies and communities in the watershed to grow, but indicates that they must do so in a manner which sustains a health ecosystem.

1.12 Element of Common Law (e.g. Riparian Rights)

Common law is a matter of precedents that are modified by court rulings. Common law governs unless it is superseded by statute law. Common law is founded on the principle that water flows naturally and should be permitted thus to flow, and can be divided into three main categories:

- Natural Watercourses;
- Surface or Sheet Flow; and

- Subsurface Flow.

1.12.1 <u>Natural Watercourses</u>

Aspects of common law that pertain to *Natural Watercourses* include the following:

- *Riparian Rights and Obligations:* A riparian owner is one whose land is in actual contact with a natural watercourse. Specific riparian rights include:
    - the right to drain that land into the watercourse;
    - where it traverses that land, the right to benefit from the water flowing through the watercourse in its natural state;
    - obligations to receive it even if it becomes a nuisance due to flooding, erosion or other reasons;
    - the owner has no legal ground to complaint if upstream riparian owners reasonable use the watercourse as an outlet, even though the result could be an increase in the amount of water; and
    - person's not riparian owners who obtain an outlet to the stream are liable to a downstream riparian owner whose land is damaged by the increased amount of water.
- *Use of Water:* a riparian owner has the right to have the water flow in its natural state with regard to both quantity and quality, subject to certain qualifications, and may put the water from the natural watercourse to any reasonable use. Reasonable use of a stream has been defined as a use up to the capacity of the banks of the stream.
- *Interference with Natural Watercourses:* anyone who interferes with a natural watercourse, must ensure that the works are adequate to carry the flow of water, even that resulting from an extraordinary rainfall.

1.12.2 <u>Surface or Sheet Flow</u>

An owner who paves the surface of their land and thereby increases the rate of surface runoff is not normally liable under common law, even though his/her action may aggravate previously existing flooding problems. Such lack of liability does not absolve the owner from assessing the environmental implications of increasing the runoff.

If a ditch, pipe or curb and gutter is constructed to collect surface water, it is then necessary to provide a sufficient outlet for the collected water. An owner does not have the right to collect surface water in this fashion and discharge it onto the lands of other riparian landowners.

1.12.3 <u>Subsurface Flow</u>

Subterranean flowing streams that have definite courses may be treated for all practical purposes, as natural watercourses on the surface. An owner is entitled to put an underground stream to any reasonable use.

2 Federal Acts and Regulations

2.1 Federal Fisheries Act

The Federal Fisheries Act provides for the protection of fish habitat, which is defined as: "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes".

Under the Fisheries Act, no one may carry out any work or undertaking that results in the harmful alteration, disruption or destruction (HADD) of fish habitat, unless this HADD has been authorized by the Minister of Fisheries and Oceans Canada. Where adverse effects to fish habitat cannot be avoided through project relocation, redesign or mitigation, habitat compensation options may be required and a subsection 35(2) Fisheries Act authorization issued. Where the HADD is not acceptable, the authorization may be refused.

DFO, Ontario - Great Lakes Area, Fish Habitat Management Program has the mandate for administering the habitat provisions of the Fisheries Act in Ontario. The Fisheries Act sets out some general habitat and pollution protection provisions that are binding on all levels of government and the public, in areas such as:

- The prohibition against the harmful alteration, disruption or destruction (HADD) of fish habitat unless authorized by DFO;
- Passage of fish around migration barriers;
- Provision of sufficient water flows;
- Screening of water intakes;
- Prohibition against the destruction of fish by means other than fishing unless authorized by DFO; and
- Prohibition to deposit deleterious substances unless by regulation (administered by Environment Canada, with the exception of subsection 36(3) with respect to sediment).

2.2 Species at Risk Act (SARA)

The Act is a key federal government commitment to prevent wildlife species from becoming extinct and secure the necessary actions for their recovery. It provides for the legal protection of wildlife species and the conservation of their biological diversity. The Species at Risk Act resulted from the implementation of the Canadian Biodiversity Strategy. The Act provides legislation to prevent endangered wildlife from becoming extinct and to encourage their recovery. Furthermore, the Act encourages the management of other species in order to prevent them from becoming at risk. More specifically SARA contains policies including:

- prohibitions to protect listed threatened and endangered species and their critical habitat;
- recognition that compensation may be needed to ensure fairness following the imposition of the critical habitat prohibitions;

the Act requires:

- the establishment of a Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as an independent body of experts responsible for assessing and identifying species at risk;
- that the best available knowledge be used to define long and short-term objectives in a recovery strategy and action plan;

- prohibitions to protect listed threatened and endangered species and their critical habitat;
- that compensation may be needed to ensure fairness following the imposition of the critical habitat prohibitions;
- the development of a public registry to assist in making documents under the Act more accessible to the public; and
- consistency with Aboriginal and treaty rights and respect the authority of other federal ministers and provincial governments.

2.3 Navigable Waters Protection Act

The Navigable Waters Protection Act provides for the protection of the public right to navigate waters and to protect the environment. Specifically the NWPA:

- approves any works built or placed in, on, over, under, through or across navigable water in Canada prior to construction of the work(s);
- removes obstructions to navigation including unauthorized works or other obstructions such as sunken or wrecked vessels;
- regulates the provision and maintenance of lights, markers, etc. required for safe navigation during and/or on completion of the construction of certain works;

3 Local Regulations

3.1 City of Barrie Watercourse By-law 90-92 (LC)

The primary purpose of the By-law 90-92 is to prohibit the obstruction of drains and watercourses, to require the repair and maintenance of drains and watercourses, and to regulate the altering of drains and watercourses in the City of Barrie (the Corporation).

General policies state that:

- the Corporation will continue to undertake drainage projects including erosion protection for drains and watercourses, grading, alignment, retention or detention systems, storm sewers and culverts, and ongoing maintenance based on the recommendation of the current Drainage and Storm Sewer Policies and Criteria and the Master Drainage Plans.
- the Corporation will continue to progressively acquire land or an interest therein (easements) for drains, watercourses and storage areas crossing or upon private lands, where it is considered to be in the Corporation's interest to do so.
- local sewers and stormwater from land development shall discharge to the nearest appropriate and sufficient drain or watercourse within the natural watershed at a rate acceptable to Engineering.
- works on watercourses and drains such as realignment, widening and control structures may be required to the satisfaction of Engineering under the subdivider's agreement or as conditions for site plan development plans.
- watercourses and drains shall be kept open wherever possible except at points crossing under roads, highways, railways and other rights-of-way and entrances at which piping of sufficient capacity (as deemed by Engineering) will be installed by the Owner of the land upon which the watercourse or drain is located.

Alteration policies state:

- no person shall straighten, change, divert or obstruct in any way existing drains, watercourses or storage areas, except in accordance with this by-law.
- owners or contractors proposing to straighten, divert or in any way change or obstruct a drain, watercourse or storage area shall file with Engineering plans as prepared by a qualified registered Professional Engineer licensed to practice in the Province of Ontario showing existing conditions, proposed conditions, profiles, cross-sections, construction dates along with any other supplementary documentation as requested by Engineering. No work shall proceed until Engineering has sufficient plans and documentation showing that the proposed works will not obstruct drainage. Construction of proposed works shall be supervised by the Professional Engineer who designed the works. The Professional Engineer shall prepare and submit "as built" drawings of the works to Engineering upon completion.
- no permit for any building or structure requiring a building permit shall be issued for a building or structure proposed within a drain or watercourse.

3.2 City of Barrie Site Alteration By-law 2006-101 (LC)

No person shall cause or permit Site Alteration within the City of Barrie:

- without a permit (conditions outlined in the By-law);
- in breach of a condition in the permit or of the Sediment and Erosion Control Plan (to be prepared as per Code in the By-Law);

Further, no person shall cause or permit Site Alteration within the City of Barrie where:

- stormwater or snowmelt reaches a protected area without passing through a final control device;
- stormwater or snowmelt downgradient of a final control device contains more than 100 mg/L of suspended solids, except during or within 30 minutes of precipitation of more than 12 mm in an hour, or
- sedimentation occurs in a protected area.

3.3 City of Barrie Zoning By-law 85-95 (LC)

Unless otherwise shown, a street, lane or railway right-of-way, electrical transmission line right-of-way or watercourse shall be included within the zone of the adjoining property on either side and where such street, lane, right-of-way or watercourse serves as a boundary between two or more different zones, the centre line of such street, lane, right-of-way or water course and extending in the general direction of the long dimension shall be deemed to be the boundary between zones.

APPENDIX F

EMERGING TECHNOLOGIES IN STORMWATER MANAGEMENT

CORPORATE ASSET MANAGEMENT

- Emerging Technologies in Stormwater Management

EMERGING TECHNOLOGIES IN STORMWATER MANAGEMENT

Greenroofs

A green rooftop is a thin layer of vegetation installed on top of a flat or sloped roof (up to 30%). A green rooftop typically consists of several layers, including a waterproofing membrane, insulation, protection layer, drainage layer, filter mat, soil layer, and vegetation. The vegetation can range from turfgrass to shrubs or even trees, depending on the climate and the load-bearing capacity of the roof. Green rooftops may have an internal drainage network that directs an overflow away from the roof to inhibit ponding.

Rooftop area, as a percent of total impervious area, generally ranges from 30 to 35% in suburban development to as much as 70 to 75% in downtown business districts, and maybe as high as 80% in some warehouse/semi-industrial districts. Even partial control of these areas can reduce the annual runoff volume by up to 50%.

In addition, green rooftops offer public benefits including: aesthetics, waste diversion (less refuse from re-roofs), reductions in urban heat island effect, improved air quality, improved quality of life and local job creation. Private owner benefits of green roofs include: improved energy efficiency, increased membrane durability, fire retardation, noise reduction, and marketability of green roof amenities.

The following general design guidelines may be followed in the design of a green rooftop (Adapted from the Portland Stormwater Manual for Ecoroofs):

- Consultation with a structural engineer is required for all green roof designs;
- The system should include a 150 mm soil bed, with a silt loam texture;
- The soil bed should be underlain with a 50 mm gravel layer, and these two layers should be separated by a layer of filter fabric;
- An impermeable layer should be placed between the rooftop and the gravel layer.
- The roof should have a maximum slope of 25%;
- The roof should be designed to hold an additional 122 kg/m^2 weight, beyond minimum structural design criteria;
- Vegetation should be established within two growing seasons;
- Vegetation should require minimal fertilization, watering and pesticides;
- A 50 mm mulch layer should be immediately placed above the soil layer to prevent erosion; and
- The vegetation and mulch layer shall be maintained at least quarterly, removing dead vegetation and eroded mulch.

Infiltration

<u>*Subsurface Infiltration Tanks*</u>

An innovative stormwater management technology that maximizes on-site stormwater detention and infiltration is a modular system that consists of small basket-like modules that can be stacked horizontally and vertically to form subsurface tanks or channels. These systems can provide more effective collection and storage volumes than that provided by conventional methods, including concrete chambers or pipe.

Module walls may consist of intermolded rods that give the finished structure more than double the strength needed for traffic loads, yet allow the finished structure to provide 95% water detention volume per structure volume and more than 50% of open exfiltration surface. The system's exterior can be wrapped with permeable geotextile to keep the soil and silt out, while allowing water to exfiltrate with minimum resistance through the bottom and sides. If exfiltration is not desired, then the system can be wrapped with an impermeable plastic liner. The system does not require gravel or stone for structural support, thereby reducing the amount of labor required to install the system, as well as the size of the excavation volume to just above the desired detention volume.

Stormwater is collected through catch basins or central stormwater filters and then sent into the system through pipes that connect to the side of the system through cut-to-fit openings in the system's wall.

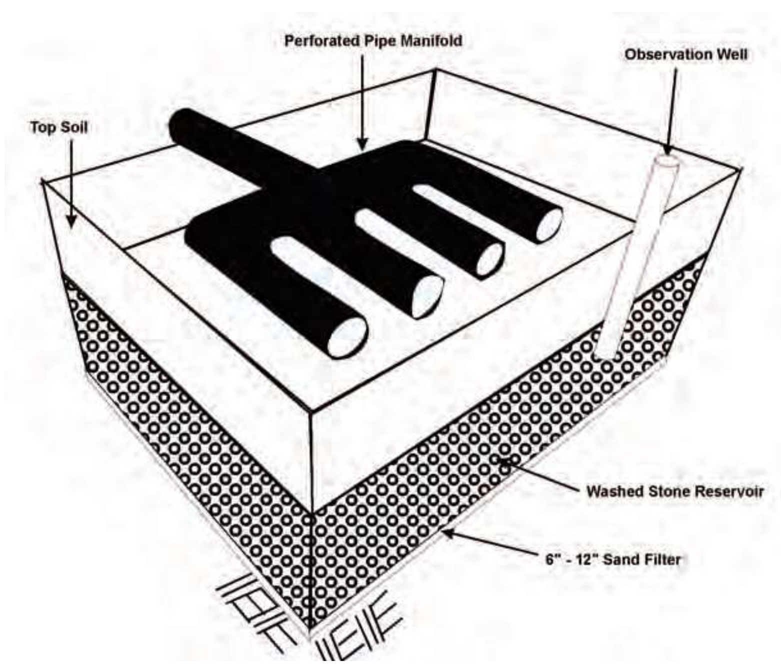
Infiltration Drainfields

Infiltration drainfields are innovative technologies that are specially designed to promote stormwater infiltration into subsoils. These drainfields help to control runoff and prevent the contamination of local watersheds. The system is usually composed of a pretreatment structure, a manifold system, and a drainfield.

Runoff is first diverted into a storm sewer system that passes through a pretreatment structure such as an oil and grit separator. Oil and grit chambers can effectively remove coarse sediment, oils, and grease from the runoff. The stormwater runoff then continues through a manifold system into the infiltration drainfield (see **Figure 1**). The manifold system consists of a perforated pipe which distributes the runoff evenly throughout the infiltration drainfield. The runoff then percolates through an underlying aggregate sand filter and filter fabric into the subsoils.

Infiltration drainfields are most applicable on sites with a relatively small drainage area (< 5 ha). They can be used to control runoff from parking lots, rooftops, impervious storage areas, or other land uses. Infiltration drainfields should not be used in locations that receive a large sediment load that could clog the pretreatment system, which in turn would plug the infiltration drainfield and reduce its effectiveness.

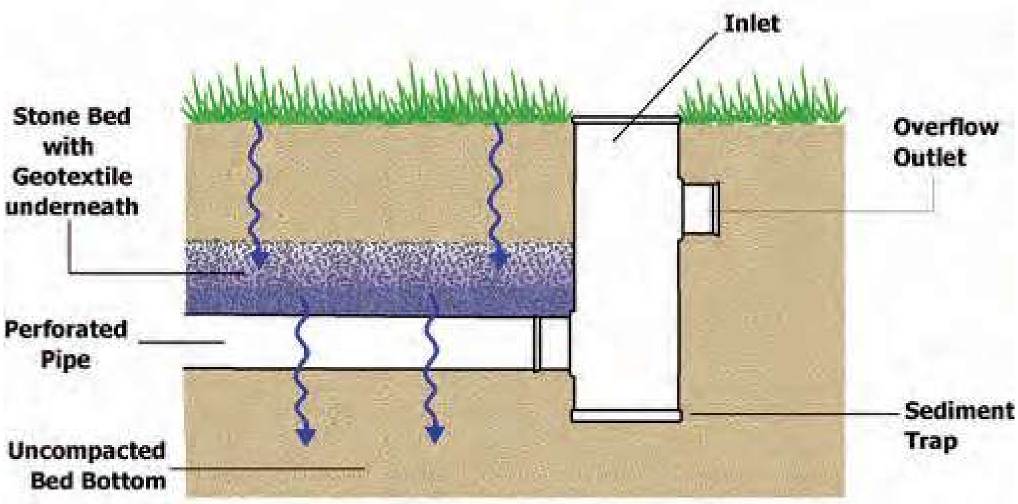
FIGURE 1
SCHEMATIC OF INFILTARION DRAINFIELD



Subsurface Infiltration Bed

Large athletic fields and play areas present ideal opportunities for stormwater storage/infiltration by placing a stone storage infiltration bed used for porous pavement under a soil or vegetated cover. Stormwater can be infiltrated into the aquifer, while the area can still be used for recreation or open space (see **Figure 2**).

FIGURE 2
SUBSURFACE INFILTRATION BED



Phosphorus Removal

One of the main contaminants of concern for stormwater discharge is phosphorus which has been implicated in the eutrophication of lakes and wetlands. Suspended solids are highly correlated with other contaminants, but phosphorus usually has a sediment-related component and a dissolved component.

Dead Storage/Quiescent Treatment Ponds

Although most pond designs remove some phosphorus when they remove TSS, a quiescent settling pond can be designed with additional phosphorus removal as its primary objective. Dead storage or quiescent treatment ponds tend to be large pond designs and are often constructed with little consideration of temperature and aesthetics problems. This type of pond often appears to be an easy fix because once treatment volume is selected there is no need for additional calculation of outflow rate and balance. However, failure to address these issues may lead to loss of vegetation or downstream flow-control problems. Dead storage ponds can be adapted to serve multiple purposes quite well, but this often requires additional design information.

SAV Dominated Treatment Wetlands

The use of treatment wetlands holds considerable promise for controlling phosphorus loads in stormwater runoff in a cost-effective manner. Submerged aquatic vegetation (SAV) in treatment wetlands have been reported to have higher phosphorus removal performance than wetlands dominated by rooted, emergent plants in relatively small-scale mesocosms (5–2000 m^2) and on larger scale treatment wetlands (148 ha) (Treatment Wetlands, 1996; Wetlands Ecol. Mgmt., 1997).

SAV-dominated lakes and rivers typically remove phosphorus from the water column. The likely long-term sink for this phosphorus is newly accreted sediment. Phosphorus removals in SAV-dominated systems are influenced by inlet phosphorus loading rates, with removal rates positively correlated to both phosphorus inlet concentration and hydraulic loading rate.

Phoslock™

Phoslock™ is a modified clay product which is capable of efficiently removing phosphorus (up to 99% reduction of phosphate) from natural and industrial waterways, process waters and waste water streams. Phoslock™ can be applied to water systems as a slurry, powder or granules and works by absorbing phosphorus from the water column as it settles to the bottom. Once it has passed through the water column, Phoslock™ forms a stable sediment on the bed of the water body which effectively traps the phosphorus that has already been absorbed as well as that released from underlying sediments.

Phoslock™ is considered to be several times more effective in phosphorus uptake than other products currently in use to remove phosphorus from water systems. This, combined with the stability of the spent clay/phosphorus complex over a broad range of environmental conditions (salinity, pH levels and dissolved oxygen), clearly distinguishes Phoslock™ from competitive products in the marketplace.

The major features and benefits of Phoslock™ are:

- Ability to bind phosphorus under both aerobic and anaerobic conditions and over a broad range of pH and salinity conditions;
- Phoslock™ does not readily re-release phosphorus when physical and chemical conditions change;
- Simple and easy delivery to the target site and its ability to bind phosphorus onto a clay matrix that rapidly settles in water;
- Relatively high affinity for phosphorus compared with conventional treatments; and

Low toxicity, resulting in safe handling, application and disposal.

Low Impact Development (LID)

Low Impact Development (LID) is a stormwater management approach and set of practices that can be used to reduce runoff and pollutant loadings by managing the runoff as close to its source(s) as possible.

LID principles are based on controlling stormwater at the source by the use of microscale controls that are distributed throughout the site. A set or system of small-scale practices, linked together on the site, is often used. LID approaches can be used to reduce the impacts of development and redevelopment activities on water resources. In the case of new development, LID is typically used to achieve or pursue the goal of maintaining or closely replicating the predevelopment hydrology of the site.

In areas where development has already occurred, LID can be used as a retrofit practice to reduce runoff volumes, pollutant loadings, and the overall impacts of existing development on the affected receiving waters.

In general, implementing integrated LID practices can result in enhanced environmental performance while at the same time reducing development costs when compared to traditional stormwater management approaches. LID techniques promote the use of natural systems, which can effectively remove nutrients, pathogens, and metals from stormwater. Cost savings are typically seen in reduced infrastructure because the total volume of runoff to be managed is minimized through infiltration and evapotranspiration.

These multifunctional site designs incorporate alternative stormwater management practices such as functional landscape that act as stormwater facilities, flatter grades, depression storage and open drainage swales. This system of controls can reduce or eliminate the need for a centralized facility for the control of stormwater runoff. LID practices offer an additional benefit in that they can be integrated into the infrastructure and are more cost effective and aesthetically pleasing than traditional, structural stormwater conveyance systems.

Today many urban centres are facing the issue of urban sprawl, which puts pressure on environmentally sensitive areas. "Smart growth" strategies are designed to reconfigure development in a more eco-efficient and community-oriented style. LID addresses many of the environmental practices that are essential to smart growth strategies including the conservation of open green space. It should be pointed out that LID does not address the subject of availability of public transportation.

LID provides many opportunities to retrofit existing highly urbanized areas with pollution controls, as well as address environmental issues in newly developed areas. LID techniques such as rooftop retention, permeable pavements, bioretention and disconnecting rooftop rain gutter spouts are valuable tools that can be used in urban areas. For example, stormwater flows can easily be directed into rain barrels, cisterns or across vegetated areas in high-density urban areas. Further, opportunities exist to implement bioretention systems in parking lots with little or no reduction in parking space. The use of vegetated rooftops and permeable pavements are two ways to reduce impervious surfaces in highly urbanized areas. LID practices, such as the examples listed below, offer great potential to help our region manage development and stormwater runoff more effectively. Low impact development can be used in new sites or as part of a re-development project. **Table 1** outlines some LID practices:

TABLE 1
EXAMPLES OF LID PRACTICES

Low Impact Landscaping	Filtration Practices	Runoff Conveyance Practices	Runoff Storage Practices	Infiltration Practices
• Planting native, drought tolerant plants • Converting turf areas to shrubs and trees • Reforestation • Encouraging longer grass length • Planting wildflower meadows rather than turf along medians and in open space • Amending soil to improve infiltration	• Bioretention • Vegetated swales • Vegetated filter strips and/or • buffers	• Eliminating curbs and gutters • Creating grassed swales and grass-lined channels • Roughening surfaces • Creating long flow paths over landscaped areas • Installing smaller culverts, pipes and inlets • Creating terraces and check dams	• Parking lot, street, and sidewalk storage • Rain barrels and cisterns • Depressional storage in landscape islands and in tree, shrub, or turf depressions • Green roofs	• Infiltration basins and trenches • Porous pavement • Disconnected downspouts • Rain gardens and other vegetated treatment systems

An outline of selected examples is provided below.

Bioretention

Bioretention systems are designed based on soil types, site conditions and land uses. A bioretention area can be composed of a mix of functional components, each performing different functions in the removal of pollutants and attenuation of stormwater runoff. Six typical components found in bioretention cells:

- Grass buffer strips reduce runoff velocity and filter particulate matter.
- Sand bed provides aeration and drainage of the planting soil and assists in the flushing of pollutants from soil materials.
- Ponding area provides storage of excess runoff and facilitates the settling of particulates and evaporation of excess water.

- Organic layer performs the function of decomposition of organic material by providing a medium for biological growth (such as microorganisms) to degrade petroleum-based pollutants. It also filters pollutants and prevents soil erosion.
- Planting soil provides the area for stormwater storage and nutrient uptake by plants. The planting soils contain some clays which adsorb pollutants such as hydrocarbons, heavy metals and nutrients.
- Vegetation (plants) functions in the removal of water through evapotranspiration and pollutant removal through nutrient cycling.

Grass Swales

Grass swales or channels are adaptable to a variety of site conditions, are flexible in design and layout, and are relatively inexpensive. Generally open channel systems are most appropriate for smaller drainage areas with mildly sloping topography. Their application is primarily along residential streets and highways. They function as a mechanism to reduce runoff velocity and as filtration/infiltration devices. Sedimentation is the primary pollutant removal mechanism, with additional secondary mechanisms of infiltration and adsorption. In general grass channels are most effective when the flow depth is minimized and detention time is maximized. The stability of the channel or overland flow is dependant on the erodibility of the soils in which the channel is constructed. Decreasing the slope or providing dense cover will aid in both stability and pollutant removal effectiveness.

Permeable Pavements

The use of permeable pavements is an effective means of reducing the percent of imperviousness in a drainage basin. Stream, lake and wetland quality is reduced sharply when impervious cover is added in an upstream watershed. Porous pavements are best suited for low traffic areas, such as parking lots and sidewalks. The most successful installations of alternative pavements are found in areas with sandy soils and flatter slopes. Permeable pavements allow stormwater to infiltrate into underlying soils promoting pollutant treatment and recharge, as opposed to producing large volumes of rainfall runoff requiring conveyance and treatment.

APPENDIX G

ANALYSIS OF DRAINAGE AREA SIZE LIMITATIONS FOR APPLICATION OF THE RATIONALE METHOD

CORPORATE ASSET MANAGEMENT

- Analysis of Drainage Area Size Limitations for the Application of the Rational Method

Analysis to Determine the Maximum Recommended Drainage Area for Peak Flow Calculations Using the Rational Method for Sizing Storm Sewers (Rational Method vs. Hydrology Computer Modeling)

1. Introduction

Based on certain municipal SWM design criteria/guidelines, a maximum allowable site area is sometimes specified regarding the use of the Rational Method to design storm sewer systems. The site area limitation for using the Rational Method has been specified in some hydrology text books as well. However, these standards are generally based on experience and not well supported with proper research. This analysis is intended to carry out a simplified study to determine the area limitation for applying the Rational Method for sizing storm sewers and when it is more appropriate to use a hydrology model (such as VO2) for the City of Barrie.

2. Methodology

In general, the method compares the unit peak runoff flow for a 5-year storm (i.e., $m^3/s/ha$) calculated using the Rational Method to those simulated using the VO2 program. The parameters for the Rational Method and the VO2 model are set equivalent. The premise is that the threshold drainage area for using the Rational Method can be determined at the point where the calculated flow using the Rational Method and the VO2 model are equal. In other words, the Rational Method predicts a higher peak flow for smaller drainage areas while the VO2 model predicts higher peak flows for larger drainage areas. The point at which the Rational Method becomes less conservative (*i.e.* when the drainage area exceeds a certain size) is considered to be the threshold drainage area above which the use of the Rational Method is not recommended for sizing storm sewers due to limitations in the assumptions for this method.

Site size

A total of 19 site drainage areas (1.0 ha to 200.0 ha) (see **Table 1** for details) were examined.

Design Storm

The 5-year, 4-hr Chicago storm was used for the Rational Method calculations and the VO2 modeling as per City of Barrie standards. The a, b and c values were derived from the City IDF curve.

Rational Method and VO2 Parameters

In order to ensure that the two methods are compatible, equivalent parameter settings were used. Specifically, the C-value was set to 0.6 for the Rational Method (a typical value for subdivision design as per City standards), and the equivalent imperviousness and XIMP (directly connected imperviousness) were calculated to be 0.57 and 0.34, respectively, for the VO2 model. The CN number and initial abstractions were set as 80 and 5mm, respectively, which is typical for subdivision design and consistent with the NVCA guidelines.

Flow Path and Pipe Length

In completing the analysis for this study, the shape of the site was assumed to be square. Peak flows calculated using VO2 were routed by an equivalent pipe length set equal to the length of the diagonal line between the two corners of the square. In calculating peak flows using the Rational Method, the total length of the sewer pipe (used to calculate the t_c and subsequently the rainfall intensity) was estimated based on an analysis of detailed subdivision designs completed recently by Valdor Engineering to determine a range of unit sewer pipe length (*i.e.* from 60 m/ha up to 90 m/ha typically encountered for municipal subdivisions. The drainage area of the projects used to determine the typical range of unit sewer pipe length ranged from 2 hectares to over 43 ha and the t_c ranged from 10 minutes to over 23 minutes).

Sensitivity Analysis

Regarding the selection of VO2 model parameter values, such as CN number and IA, which are not utilized with the Rational Method, conservative values were applied. In order to ensure that the analysis is reasonable, a sensitivity analysis was completed whereby three scenarios were calculated for a range of CN and IA values typically encountered and based on the NVCA guidelines assuming grassed pervious areas. The scenarios calculated for the range of drainage areas included (1)_ CN = 80 and IA = 5.0 mm; (2) CN = 80 and IA = 2.5 mm; and (3) CN = 85 and IA = 5.0 mm.

3. Results and Analysis

The results of the VO2 and Rational Method calculations were tabulated and plotted (see **Table 1, Table 2** and **Figure 1** attached).

Based on the analysis, the unit peak runoff flow decreases as the site drainage area increases for both the Rational Method and the VO2 method for calculating peak flow. However, the unit peak runoff flow based on the Rational Method declines faster than that of the VO2 model. Furthermore, the Rational Method results are conservative when the site drainage area is relatively small, and the VO2 model generated larger unit peak runoff when the site area is relatively large. The threshold is around 50 ha to 160 ha depending on the t_c estimated by the unit length of the storm sewer pipe and the range of CN and IA values used.

Based on this analysis, the primary variables affecting the determination of the threshold area above which the Rational Method is not recommended include the unit sewer pipe length and the CN and IA. In order to be conservative, the recommended threshold above which the Rational Method is not recommended was determined using the highest curve calculated using the VO2 model and the lowest curve using the Rational Method. The point at which the two curves crossed was considered to be a conservative estimate of the threshold drainage area (see **Figure 1**).

4. Summary and Conclusions

A detailed analysis using City of Barrie design criteria was completed to determine what a reasonable threshold is above which the Rational Method should not be used. Please see **Figure 1**, attached. The analysis was completed for a range of drainage area sizes based on actual subdivision designs in Southern Ontario which included a sensitivity check for key parameter values (*e.g.* curve number [CN], initial abstraction [IA], and time of concentration [t_c]). The analysis included peak flow calculations using the Rational Method and a computer model (Visual OTTHYMO – VO2) using standard accepted parameter values as per the updated City of Barrie *Storm Drainage and Stormwater Management Policies and Design Criteria* document. Based on the analysis and a conservative estimate using worst case sensitivity limits, the Rational Method produced higher peak flows than the model for drainage areas less than approximately 50 ha. The Rational Method produced lower peak flows than the model for drainage areas greater than approximately 50 ha. Based on this conservative estimate, it appears that the Rational Method is an acceptable methodology for drainage areas up to approximately 50 ha in size (based on Southern Ontario data and City of Barrie design criteria).

Recommendation

While the exact maximum threshold for permissible use of the Rational Method varies somewhat from one municipality/region to another, there does not appear to be any current detailed evidence to preclude the use of the Rational Method above 20 ha. Based on our analysis and a general review of the literature, we would suggest that using the Rational Method up to a drainage area of approximately 50 ha is both practical and conservative. We would recommend that the design of storm sewers with a drainage area greater than 50 ha be based on a computer model and also be verified with the Rational Method (*i.e.* the design for drainage areas above 50 ha should be based on the largest flow calculated using both the Rational Method and a computer model).

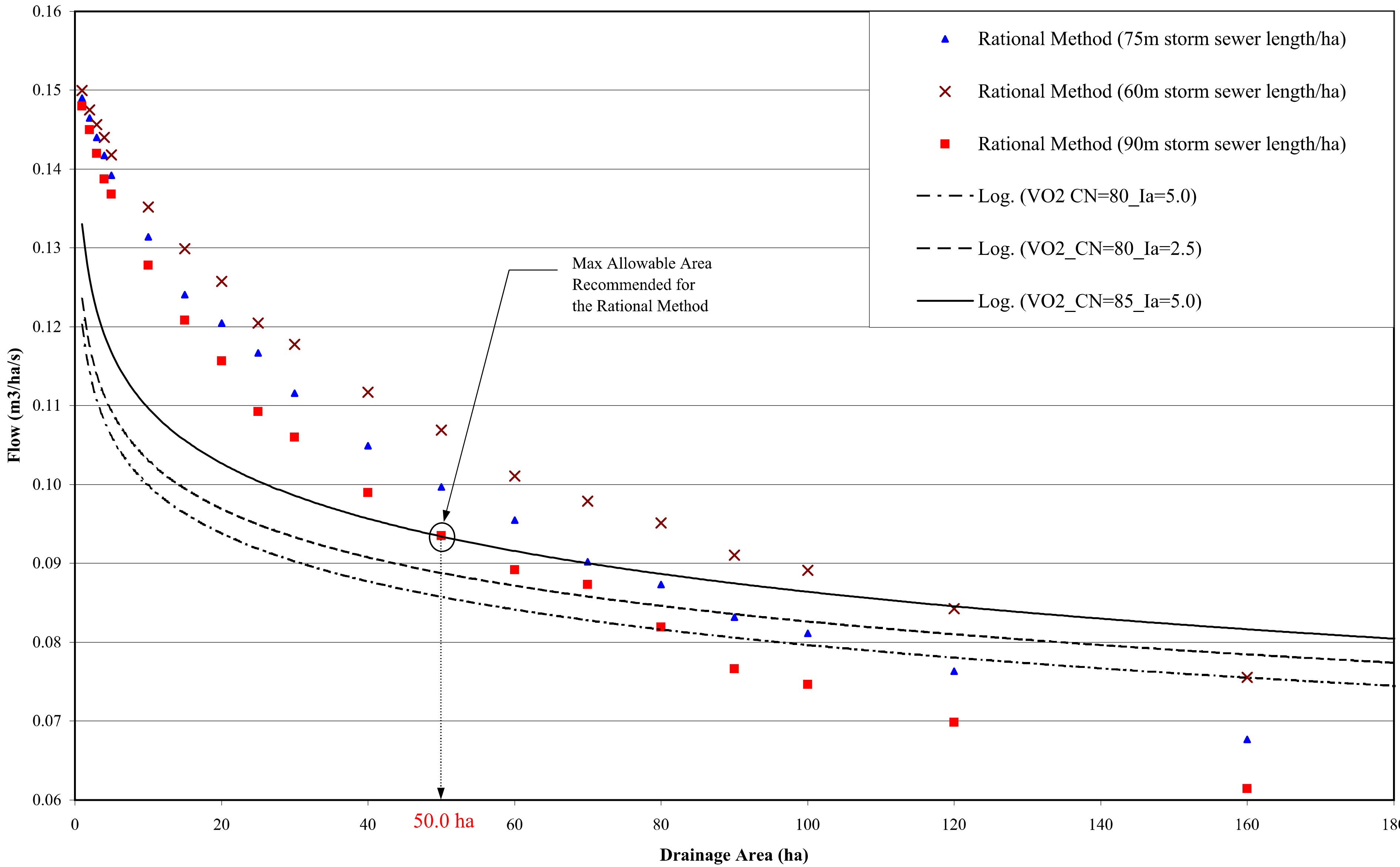
Table 1: Summary of Unit Flow Calculations Using the Rational Method Based on the 5-year Chicago Storm

Drainage Area (ha)	Storm Sewer Pipe Length = 75 m/ha			Storm Sewer Pipe Length = 60 m/ha			Storm Sewer Pipe Length = 90 m/ha		
	Pipe Length (m)	Unit Flow (m^3/ha/s)	Peak Flow (m^3/s)	Pipe Length (m)	Unit Flow (m^3/ha/s)	Peak Flow (m^3/s)	Pipe Length (m)	Unit Flow (m^3/ha/s)	Peak Flow (m^3/s)
1.0	75	0.1490	0.149	60	0.1500	0.15	90	0.1480	0.148
2.0	150	0.1465	0.293	120	0.1475	0.295	180	0.1450	0.29
3.0	225	0.1440	0.432	180	0.1457	0.437	270	0.1420	0.426
4.0	300	0.1418	0.567	240	0.1440	0.576	360	0.1388	0.555
5.0	375	0.1392	0.696	300	0.1418	0.709	450	0.1368	0.684
10.0	750	0.1314	1.314	600	0.1352	1.352	900	0.1278	1.278
15.0	1125	0.1241	1.861	900	0.1299	1.949	1350	0.1209	1.813
20.0	1500	0.1205	2.41	1200	0.1258	2.515	1800	0.1157	2.314
25.0	1875	0.1167	2.918	1500	0.1205	3.012	2250	0.1092	2.731
30.0	2250	0.1116	3.347	1800	0.1178	3.534	2700	0.1060	3.181
40.0	3000	0.1049	4.197	2400	0.1117	4.469	3600	0.0990	3.959
50.0	3750	0.0997	4.986	3000	0.1069	5.346	4500	0.0935	4.676
60.0	4500	0.0955	5.731	3600	0.1011	6.064	5400	0.0892	5.351
70.0	5250	0.0902	6.313	4200	0.0979	6.851	6300	0.0873	6.112
80.0	6000	0.0874	6.988	4800	0.0951	7.611	7200	0.0819	6.554
90.0	6750	0.0832	7.485	5400	0.0911	8.196	8100	0.0767	6.899
100.0	7500	0.0812	8.117	6000	0.0891	8.91	9000	0.0747	7.467
120.0	9000	0.0763	9.157	7200	0.0843	10.112	10800	0.0699	8.382
160.0	12000	0.0677	10.828	9600	0.0755	12.086	14400	0.0614	9.83
200.0	15000	0.0614	12.285	12000	0.0691	13.817	18000	0.0554	11.087

Table 2: Summary of Unit Flow Calculations Using the VO2 Model Based on the 5-year Chicago Storm

Drainage Area (ha)	CN = 85, Ia = 5.0		CN = 80, Ia = 2.5		CN = 80, Ia = 5.0	
	Unit Flow (m^3/ha/s)	Peak Flow (m^3/s)	Unit Flow (m^3/ha/s)	Peak Flow (m^3/s)	Unit Flow (m^3/ha/s)	Peak Flow (m^3/s)
1.0	0.141	0.141	0.117	0.117	0.114	0.114
2.0	0.123	0.245	0.118	0.236	0.115	0.229
3.0	0.119	0.358	0.115	0.346	0.112	0.336
4.0	0.117	0.468	0.113	0.452	0.110	0.440
5.0	0.115	0.574	0.111	0.555	0.108	0.538
10.0	0.108	1.080	0.105	1.046	0.102	1.016
15.0	0.104	1.562	0.100	1.496	0.097	1.450
20.0	0.103	2.064	0.098	1.956	0.094	1.888
25.0	0.102	2.550	0.097	2.419	0.093	2.333
30.0	0.101	3.027	0.096	2.874	0.092	2.774
40.0	0.099	3.942	0.094	3.748	0.091	3.620
50.0	0.093	4.626	0.088	4.391	0.085	4.242
60.0	0.091	5.438	0.086	5.172	0.083	4.999
70.0	0.089	6.209	0.085	5.915	0.082	5.723
80.0	0.087	6.997	0.083	6.654	0.080	6.425
90.0	0.087	7.802	0.082	7.391	0.079	7.136
100.0	0.086	8.612	0.081	8.114	0.078	7.833
120.0	0.085	10.197	0.080	9.608	0.077	9.276
160.0	0.083	13.267	0.078	12.511	0.075	11.945
200.0	0.081	16.213	0.077	15.306	0.074	14.772

Figure 1: Comparison of Unit Peak Flow vs. Drainage Area Using the Rational Method and Visual OTTHYMO (VO2) Model to Determine the Max. Recommended Drainage Area for Peak Flow Calculations Using the Rational Method



APPENDIX H

ANALYSIS OF DESIGN STORM DURATIONS (SCS AND CHICAGO STORM DISTRIBUTIONS)

CORPORATE ASSET MANAGEMENT

- Analysis of Design Storm Durations (SCS and Chicago Storm Distributions)

Table 1: Analysis of Critical Storm Duration Based on Peak Flow (Undeveloped/Rural Areas)

Drainage Area (ha)	2-yr Peak Flow (cms) for Various Storm Distributions and Durations						100-yr Peak Flow (cms) for Various Storm Distributions and Durations					
	1-hr Chicago	2-hr Chicago	4-hr Chicago	6-hr SCS	12-hr SCS	24-hr SCS	1-hr Chicago	2-hr Chicago	4-hr Chicago	6-hr SCS	12-hr SCS	24-hr SCS
0.1	0.001	0.002	0.002	0.003	0.003	0.003	0.007	0.008	0.010	0.024	0.021	0.017
0.5	0.005	0.006	0.007	0.011	0.012	0.012	0.029	0.033	0.038	0.094	0.081	0.066
1	0.009	0.011	0.013	0.020	0.021	0.022	0.052	0.060	0.068	0.166	0.143	0.117
2	0.017	0.020	0.023	0.035	0.037	0.038	0.093	0.107	0.122	0.293	0.255	0.208
3	0.024	0.028	0.033	0.049	0.052	0.053	0.131	0.151	0.172	0.410	0.357	0.291
4	0.030	0.036	0.042	0.062	0.066	0.068	0.167	0.192	0.218	0.519	0.450	0.367
5	0.037	0.043	0.050	0.075	0.079	0.081	0.201	0.231	0.263	0.623	0.543	0.442
10	0.065	0.078	0.090	0.133	0.140	0.144	0.355	0.413	0.468	1.101	0.958	0.782
15	0.090	0.110	0.127	0.185	0.195	0.201	0.491	0.579	0.655	1.532	1.337	1.090
20	0.112	0.140	0.161	0.234	0.247	0.254	0.618	0.737	0.831	1.937	1.693	1.380
25	0.134	0.169	0.195	0.281	0.296	0.305	0.736	0.887	1.001	2.323	2.027	1.654
30	0.155	0.197	0.227	0.325	0.343	0.353	0.851	1.031	1.164	2.690	2.354	1.921
40	0.194	0.251	0.288	0.411	0.433	0.446	1.065	1.310	1.477	3.396	2.973	2.427
45	0.213	0.278	0.318	0.453	0.477	0.492	1.169	1.447	1.628	3.735	3.271	2.673
50	0.230	0.304	0.348	0.493	0.518	0.536	1.268	1.578	1.776	4.068	3.559	2.909
75	0.315	0.425	0.487	0.686	0.720	0.745	1.734	2.209	2.480	5.634	4.943	4.046
100	0.394	0.538	0.619	0.866	0.909	0.940	2.165	2.797	3.146	7.100	6.234	5.109
500	1.343	1.943	2.366	3.207	3.332	3.395	7.390	10.088	11.844	25.872	22.736	18.533
1000	2.270	3.326	4.208	5.633	5.848	5.955	12.488	17.281	20.950	45.105	39.698	32.337
5000	7.635	11.388	15.406	20.604	21.476	22.067	42.021	59.148	76.497	162.582	144.141	119.009
Precip total (mm)	22.65	27.18	32.12	37.40	41.31	45.92	51.98	63.52	76.36	125.00	125.71	123.02
Max Intensity (mm/h)	99.91	99.91	99.91	58.34	54.52	50.67	211.69	211.69	211.69	195.00	165.92	135.79

Notes:

1. Calculations completed using Visual OTTHYMO (VO2) and the NASHYD command.
2. Critical flows are shaded.

Table 2: Analysis of Critical Storm Duration Based on Peak Flow (% IMP=25%)

Drainage Area (ha)	2-yr Peak Flow (cms) for Various Storm Distributions and Durations						100-yr Peak Flow (cms) for Various Storm Distributions and Durations					
	1-hr Chicago	2-hr Chicago	4-hr Chicago	6-hr SCS	12-hr SCS	24-hr SCS	1-hr Chicago	2-hr Chicago	4-hr Chicago	6-hr SCS	12-hr SCS	24-hr SCS
0.1	0.005	0.005	0.005	0.006	0.006	0.006	0.014	0.016	0.017	0.038	0.032	0.028
0.5	0.022	0.023	0.024	0.030	0.029	0.029	0.066	0.076	0.085	0.185	0.156	0.141
1	0.039	0.039	0.041	0.039	0.039	0.038	0.101	0.126	0.143	0.349	0.294	0.234
2	0.075	0.075	0.077	0.077	0.077	0.076	0.198	0.214	0.285	0.690	0.581	0.462
3	0.108	0.109	0.113	0.114	0.114	0.112	0.290	0.318	0.365	1.026	0.864	0.686
4	0.140	0.142	0.144	0.151	0.151	0.149	0.381	0.424	0.485	1.358	1.143	0.908
5	0.172	0.174	0.176	0.188	0.187	0.184	0.469	0.529	0.604	1.687	1.420	1.008
10	0.317	0.322	0.327	0.366	0.365	0.359	0.900	1.051	1.200	3.302	2.777	1.969
15	0.451	0.460	0.467	0.538	0.536	0.528	1.349	1.572	1.790	4.878	3.643	2.905
20	0.577	0.590	0.600	0.653	0.649	0.638	1.797	2.089	2.377	5.678	4.796	3.823
25	0.694	0.715	0.727	0.806	0.814	0.804	2.243	2.604	2.960	7.025	5.932	4.727
30	0.810	0.836	0.850	0.968	0.969	0.957	2.688	3.117	3.539	8.355	7.053	5.618
40	0.935	0.974	1.031	1.272	1.273	1.257	3.572	4.134	4.689	10.973	9.258	7.369
45	1.034	1.079	1.143	1.423	1.423	1.405	4.011	4.639	5.259	12.263	10.344	8.231
50	1.132	1.182	1.218	1.571	1.571	1.551	4.449	5.142	5.826	13.543	11.421	9.086
75	1.598	1.676	1.731	2.298	2.296	2.265	6.613	7.626	8.626	19.805	16.689	13.263
100	2.035	2.143	2.217	3.002	2.998	2.957	8.323	9.523	10.706	25.887	21.801	18.083
500	7.326	7.972	8.544	12.099	12.095	11.952	36.110	41.052	45.866	109.712	92.242	75.558
1000	12.906	14.364	15.857	21.964	21.957	21.656	64.182	76.856	85.891	214.952	167.101	132.160
5000	46.194	53.736	59.436	81.055	80.833	79.743	244.089	284.173	314.426	761.495	640.392	483.353
Precip total (mm)	22.65	27.18	32.12	37.40	41.31	45.92	51.98	63.52	76.36	125.00	125.71	123.02
Max Intensity (mm/h)	99.91	99.91	99.91	58.34	54.52	50.67	211.69	211.69	211.69	195.00	165.92	135.79

Notes:

1. Calculations completed using Visual OTTHYMO (VO2) and the STANDHYD command.
2. Assumed Impervious Values: TIMP = 25%, XIMP = 15%, where TIMP is total imperviousness and XIMP is directly connected imperviousness.
3. Critical flows are shaded.

Table 3: Analysis of Critical Storm Duration Based on Peak Flow (% IMP=55%)

Drainage	2-yr Peak Flow (cms) for Various Storm Distributions and Durations						100-yr Peak Flow (cms) for Various Storm Distributions and Durations					
	1-hr	2-hr	4-hr	6-hr	12-hr	24-hr	1-hr	2-hr	4-hr	6-hr	12-hr	24-hr
Area (ha)	Chicago	Chicago	Chicago	SCS	SCS	SCS	Chicago	Chicago	Chicago	SCS	SCS	SCS
0.1	0.010	0.011	0.012	0.009	0.009	0.008	0.030	0.033	0.035	0.047	0.040	0.032
0.5	0.044	0.045	0.047	0.044	0.043	0.041	0.147	0.158	0.169	0.233	0.197	0.159
1	0.078	0.079	0.082	0.073	0.071	0.068	0.207	0.221	0.234	0.421	0.355	0.285
2	0.150	0.151	0.157	0.144	0.140	0.134	0.403	0.430	0.456	0.833	0.703	0.564
3	0.217	0.220	0.223	0.214	0.207	0.200	0.592	0.632	0.670	1.241	1.047	0.840
4	0.281	0.285	0.289	0.283	0.274	0.264	0.776	0.829	0.879	1.645	1.387	1.113
5	0.344	0.349	0.354	0.324	0.314	0.302	0.956	1.021	1.084	2.046	1.725	1.383
10	0.635	0.647	0.657	0.632	0.612	0.587	1.674	1.939	2.060	4.019	3.385	2.711
15	0.904	0.922	0.938	0.930	0.899	0.863	2.418	2.550	2.686	5.952	5.008	3.691
20	1.157	1.184	1.204	1.221	1.180	1.131	3.132	3.306	3.485	7.853	6.604	4.863
25	1.399	1.435	1.459	1.506	1.419	1.366	3.821	4.038	4.259	9.729	7.501	6.016
30	1.633	1.677	1.707	1.739	1.688	1.625	4.491	4.750	5.013	11.583	8.925	7.155
40	1.868	1.941	1.992	2.286	2.218	2.133	5.784	6.128	6.473	13.933	11.728	9.393
45	2.067	2.150	2.208	2.555	2.479	2.384	6.412	6.798	7.191	15.580	13.109	10.495
50	2.262	2.356	2.420	2.822	2.737	2.447	7.028	7.457	7.959	17.213	14.479	11.588
75	3.191	3.339	3.437	3.843	3.720	3.576	10.008	10.892	11.724	25.216	21.183	16.928
100	4.063	4.267	4.398	5.022	4.857	4.667	14.159	15.456	16.629	32.995	27.691	21.819
500	14.154	15.227	16.105	20.650	18.886	18.148	52.654	62.973	67.756	136.206	114.028	90.597
1000	24.520	26.558	28.268	34.678	33.519	32.193	98.944	108.642	117.170	257.430	215.007	161.796
5000	84.824	92.192	98.663	125.532	121.628	116.919	355.057	391.110	423.139	953.780	758.234	579.812
Precip total (mm)	22.65	27.18	32.12	37.40	41.31	45.92	51.98	63.52	76.36	125.00	125.71	123.02
Max Intensity (mm/h)	99.91	99.91	99.91	58.34	54.52	50.67	211.69	211.69	211.69	195.00	165.92	135.79

Notes:

1. Calculations completed using Visual OTTHYMO (VO2) and the STANDHYD command.
2. Assumed Impervious Values: TIMP = 55%, XIMP = 30%, where TIMP is total imperviousness and XIMP is directly connected imperviousness.
3. Critical flows are shaded.

Table 4: Analysis of Critical Storm Duration Based on Peak Flow (% IMP=90%)

Drainage Area (ha)	2-yr Peak Flow (cms) for Various Storm Distributions and Durations						100-yr Peak Flow (cms) for Various Storm Distributions and Durations					
	1-hr Chicago	2-hr Chicago	4-hr Chicago	6-hr SCS	12-hr SCS	24-hr SCS	1-hr Chicago	2-hr Chicago	4-hr Chicago	6-hr SCS	12-hr SCS	24-hr SCS
0.1	0.020	0.025	0.025	0.015	0.014	0.013	0.054	0.055	0.055	0.053	0.045	0.037
0.5	0.120	0.120	0.121	0.075	0.071	0.066	0.267	0.269	0.270	0.263	0.224	0.183
1	0.231	0.231	0.231	0.149	0.140	0.130	0.523	0.526	0.528	0.525	0.446	0.364
2	0.440	0.441	0.442	0.297	0.278	0.259	1.017	1.023	1.028	1.049	0.891	0.724
3	0.638	0.640	0.641	0.443	0.414	0.385	1.493	1.501	1.509	1.571	1.335	1.083
4	0.828	0.831	0.832	0.587	0.549	0.510	1.955	1.966	1.977	2.093	1.767	1.441
5	1.011	1.016	1.018	0.730	0.682	0.634	2.406	2.420	2.433	2.596	2.205	1.798
10	1.866	1.881	1.884	1.428	1.332	1.237	4.494	4.514	4.531	5.159	4.375	3.560
15	2.652	2.680	2.685	2.105	1.951	1.811	6.481	6.515	6.539	7.690	6.513	5.293
20	3.393	3.437	3.444	2.753	2.560	2.375	8.381	8.429	8.462	10.195	8.625	7.000
25	4.102	4.162	4.172	3.395	2.979	2.762	10.213	10.279	10.318	12.676	10.713	8.868
30	4.783	4.862	4.874	3.801	3.521	3.264	11.991	12.075	12.122	15.134	12.779	10.352
40	5.308	5.423	5.446	4.946	4.577	4.241	15.417	15.543	15.605	19.993	16.857	13.635
45	5.870	6.005	6.032	5.505	5.092	4.718	17.077	17.226	17.295	22.395	18.871	15.254
50	6.420	6.575	6.608	6.057	5.601	5.189	18.705	18.878	18.956	24.782	20.869	16.859
75	9.041	9.302	9.362	8.727	8.059	7.461	26.486	26.795	26.910	36.507	30.667	24.717
100	11.495	11.868	11.959	11.279	10.355	9.580	30.287	30.808	31.003	47.938	40.195	30.284
500	37.041	38.975	39.815	41.198	37.915	35.035	108.589	112.277	113.442	194.886	161.068	122.101
1000	61.345	61.974	66.869	70.881	65.147	59.918	193.141	201.422	204.329	343.342	283.735	225.620
5000	214.015	227.984	237.167	264.487	242.843	223.265	614.746	652.514	672.938	1227.585	959.724	759.711
Precip total (mm)	22.65	27.18	32.12	37.40	41.31	45.92	51.98	63.52	76.36	125.00	125.71	123.02
Max Intensity (mm/h)	99.91	99.91	99.91	58.34	54.52	50.67	211.69	211.69	211.69	195.00	165.92	135.79

Notes:
1. Calculations completed using Visual OTTHYMO (VO2) and the STANDHYD command.
2. Assumed Impervious Values: TIMP = 90%, XIMP = 90%, where TIMP is total imperviousness and XIMP is directly connected imperviousness.
3. Critical flows are shaded.

Table 5: Analysis of Critical Storm Duration Based on Required SWM Pond Storage

Drainage Area (ha)	100-yr Required Storage (ha.m) for Various Storm Distributions and Durations					
	1-hr Chicago	2-hr Chicago	4-hr Chicago	6-hr SCS	12-hr SCS	24-hr SCS
1	0.0170	0.0165	0.0165	0.0224	0.0192	0.0188
5	0.0880	0.0932	0.0930	0.1092	0.0927	0.1004
10	0.1790	0.1851	0.1850	0.2140	0.1810	0.1960
25	0.4400	0.4540	0.4570	0.6050	0.5162	0.4290
50	0.8681	0.8890	0.8990	1.0580	0.8960	0.8490
75	1.2300	1.2700	1.2550	1.5500	1.3700	1.2500
100	1.7190	1.7885	1.7850	2.1400	1.8100	1.6750
500	8.4000	8.7000	8.7900	10.6500	9.0000	7.7500
1000	17.1100	16.8000	16.8500	20.5000	19.6000	15.3500
5000	77.1000	84.0000	86.0000	> 100	87.2000	76.4000

Precip total (mm)	51.98	63.52	76.36	125.00	125.71	123.02
Max Intensity (mm/h)	211.69	211.69	211.69	195.00	165.92	135.79

Notes:

1. Calculations completed using Visual OTTHYMO (VO2) and the STANDHYD command.
2. Critical required storage volumes are shaded.
3. Assumed Impervious Values: TIMP = 70%, XIMP = 45%, where TIMP is total imperviousness and XIMP is directly connected imperviou

Table 6: Analysis of Critical Storm Duration Based on Peak Flow (% IMP=90%)

Time Step: 1 min

Area (ha)	2-yr Storm			100-yr Storm		
	1-hr	2-hr	4-hr	1-hr	2-hr	4-hr
0.1	0.025	0.026	0.026	0.056	0.056	0.057
0.5	0.118	0.118	0.118	0.268	0.269	0.270
1	0.223	0.224	0.224	0.516	0.518	0.521
2	0.400	0.421	0.422	0.986	0.991	0.996
3	0.605	0.607	0.608	1.437	1.444	1.451
4	0.782	0.785	0.786	1.872	1.881	1.891
5	0.953	0.957	0.959	2.296	2.307	2.319
10	1.766	1.776	1.780	4.283	4.306	4.327
15	2.492	2.511	2.517	6.174	6.209	6.241
20	3.155	3.185	3.193	7.990	8.037	8.077
25	3.782	3.825	3.835	9.765	9.826	9.874
30	4.369	4.424	4.438	11.491	11.567	11.625
40	5.524	5.609	5.629	14.632	14.738	14.808
45	6.042	6.140	6.164	16.226	16.350	16.428
50	6.612	6.725	6.754	17.610	17.754	17.846
75	9.025	9.222	9.273	24.794	25.041	25.168
100	11.273	11.555	11.634	31.150	31.517	31.685
500	37.183	38.704	39.425	112.007	114.768	115.799
1000	61.301	64.217	65.845	189.580	195.757	198.265
5000	216.922	229.197	237.971	625.537	655.858	673.486

Time Step: 2 min

Area (ha)	2-yr Storm			100-yr Storm		
	1-hr	2-hr	4-hr	1-hr	2-hr	4-hr
0.1	0.027	0.027	0.027	0.060	0.060	0.060
0.5	0.123	0.123	0.124	0.281	0.283	0.284
1	0.232	0.232	0.233	0.538	0.541	0.543
2	0.433	0.434	0.435	1.018	1.022	1.027
3	0.620	0.622	0.623	1.476	1.483	1.489
4	0.798	0.801	0.803	1.918	1.927	1.935
5	0.970	0.974	0.976	2.346	2.357	2.367
10	1.763	1.776	1.779	4.357	4.380	4.400
15	2.455	2.477	2.483	6.202	6.233	6.257
20	3.142	3.179	3.185	7.971	8.016	8.047
25	3.706	3.759	3.770	9.671	9.730	9.769
30	4.321	4.390	4.404	11.316	11.391	11.438
40	5.433	5.530	5.550	14.419	14.538	14.610
45	6.002	6.116	6.140	15.974	16.113	16.193
50	6.560	6.691	6.719	17.500	17.660	17.749
75	8.861	9.081	9.135	24.306	24.555	24.683
100	11.128	11.407	11.487	30.687	31.099	31.272
500	37.128	38.704	39.427	110.269	113.157	114.222
1000	61.208	64.220	65.877	187.073	193.481	196.067
5000	216.500	229.137	238.045	623.784	656.047	674.338

Time Step: 3 min

Area (ha)	2-yr Storm			100-yr Storm		
	1-hr	2-hr	4-hr	1-hr	2-hr	4-hr
0.1	0.024	0.024	0.025	0.054	0.054	0.054
0.5	0.114	0.115	0.115	0.259	0.260	0.261
1	0.219	0.220	0.220	0.502	0.504	0.507
2	0.416	0.417	0.418	0.968	0.972	0.978
3	0.600	0.601	0.603	1.416	1.422	1.430
4	0.777	0.780	0.781	1.850	1.859	1.869
5	0.949	0.953	0.955	2.274	2.285	2.297
10	1.750	1.761	1.765	4.283	4.306	4.330
15	2.488	2.510	2.516	6.124	6.154	6.182
20	3.186	3.219	3.228	7.916	7.959	7.996
25	3.715	3.765	3.776	9.647	9.703	9.749
30	4.331	4.396	4.410	11.328	11.399	11.454
40	5.376	5.465	5.490	14.571	14.675	14.747
45	5.942	6.048	6.077	16.143	16.265	16.346
50	6.498	6.619	6.653	17.687	17.828	17.917
75	8.841	9.055	9.117	24.199	24.446	24.559
100	10.999	11.285	11.381	30.873	31.247	31.400
500	36.539	38.107	38.966	109.859	112.610	113.806
1000	60.487	63.165	65.082	185.954	192.238	195.233
5000	216.779	228.610	238.414	624.747	653.438	672.695

Time Step: 4 min

Area (ha)	2-yr Storm			100-yr Storm		
	1-hr	2-hr	4-hr	1-hr	2-hr	4-hr
0.1	0.027	0.027	0.027	0.058	0.059	0.059
0.5	0.124	0.124	0.125	0.280	0.282	0.284
1	0.234	0.235	0.235	0.535	0.537	0.539
2	0.439	0.440	0.440	1.025	1.028	1.032
3	0.629	0.632	0.633	1.490	1.496	1.501
4	0.811	0.814	0.816	1.938	1.946	1.953
5	0.985	0.990	0.992	2.373	2.383	2.392
10	1.786	1.802	1.804	4.414	4.436	4.453
15	2.515	2.546	2.550	6.309	6.345	6.369
20	3.051	3.092	3.101	8.106	8.159	8.191
25	3.699	3.756	3.768	9.831	9.903	9.943
30	4.325	4.399	4.414	11.499	11.591	11.638
40	5.524	5.634	5.656	14.698	14.837	14.899
45	6.102	6.231	6.258	16.179	16.322	16.376
50	6.397	6.558	5.693	17.685	17.853	17.914
75	8.940	9.205	9.263	24.256	24.558	24.679
100	11.015	11.356	11.447	31.081	31.532	31.696
500	36.908	38.767	39.592	109.413	113.166	114.381
1000	59.415	62.786	64.610	184.457	192.434	195.435
5000	211.764	224.911	234.043	608.746	640.814	660.533

Time Step: 5 min

Area (ha)	2-yr Storm			100-yr Storm		
	1-hr	2-hr	4-hr	1-hr	2-hr	4-hr
0.1	0.020	0.025	0.025	0.054	0.055	0.055
0.5	0.120	0.120	0.121	0.267	0.269	0.270
1	0.231	0.231	0.231	0.523	0.526	0.528
2	0.440	0.441	0.442	1.017	1.023	1.028
3	0.638	0.640	0.641	1.493	1.501	1.509
4	0.828	0.831	0.832	1.955	1.966	1.977
5	1.011	1.016	1.018	2.406	2.420	2.433
10	1.866	1.881	1.884	4.494	4.514	4.531
15	2.652	2.680	2.685	6.481	6.515	6.539
20	3.393	3.437	3.444	8.381	8.429	8.462
25	4.102	4.162	4.172	10.213	10.279	10.318
30	4.783	4.862	4.874	11.991	12.075	12.122
40	5.308	5.423	5.446	15.417	15.543	15.605
45	5.870	6.005	6.032	17.077	17.226	17.295
50	6.420	6.575	6.608	18.705	18.878	18.956
75	9.041	9.302	9.362	26.486	26.795	26.910
100	11.495	11.868	11.959	30.287	30.808	31.003
500	37.041	38.975	39.815	108.589	112.277	113.442
1000	61.345	61.974	66.869	193.141	201.422	204.329
5000	214.015	227.984	237.167	614.746	652.514	672.938

Notes:

1. Calculations completed using Visual OTTHYMO (VO2) and the STANDHYD command.
2. Assumed Impervious Values: TIMP = 90%, XIMP = 90%,
   where TIMP is total imperviousness and XIMP is directly connected imperviousness.

APPENDIX I

CD WITH SUPPORTING DOCUMENTATION AND FILES

CORPORATE ASSET MANAGEMENT

- CD with Supporting Documentation and Files
  - Digital Copy of Storm Drainage and Stormwater Management Policies and Design Guidelines Document
  - Design Storm Files (Chicago and SCS Distributions adjusted to account for climate change, Hurricane Hazel and Timmins Storm)
  - Storm Sewer Design Sheet
  - Barrie Rainfall Data in NCDC Format for PCSWMM for Stormceptor for Sizing Oil/Grit Separators
  - Native Plan Species of Simcoe County (Riley, 1989 and NVCA) and LSRCA Planting Guidelines

APPENDIX J

MEMORANDUM OF UNDERSTANDING (MOU) BETWEEN THE CITY AND THE LSRCA

CORPORATE ASSET MANAGEMENT

- Memorandum of Understanding (MOU) between the City and the LSRCA

MEMORANDUM OF UNDERSTANDING

Agreement made in duplicate this 23 day of June, 2009

BETWEEN: The Corporation of the City of Barrie
(Hereinafter referred to as the "City")

OF THE FIRST PART

- And -

Lake Simcoe Region Conservation Authority
(Hereinafter referred to as the "LSRCA")

OF THE SECOND PART

WHEREAS the LSRCA and the City have agreed that it would be beneficial to streamline the circulation and review procedures for site plan applications as defined under the *Planning Act*, and WHEREAS the purpose of this Memorandum of Understanding is to:

- Establish a framework for streamlining the review and approval of site plan applications;
- Verify the circulation procedures for site plan applications to the Conservation Authority;
- Create efficiencies by reducing duplication of service;
- Provide the City with increased decision making autonomy; and
- Provide LSRCA staff to be in attendance at City Hall to meet with City staff and the general public and attend site plan meetings as required.

Introduction

In 2008, the City, through consultation with the Conservation Authorities and the Barrie Land Developer's Association, felt that the process of circulation and the review of site plan applications needed to be reviewed and revamped to increase the efficiency and ease of use of the current process. As a result, representatives of the noted parties underwent an extensive and exhaustive mapping procedure to indentify where problems existed, and how the process could be improved. As a result of this work, the finished document was presented to the Executive Management Team which included the detailed mapping process for circulation, review procedures and a number of action items to be undertaken by various members of the mapping group. One (1) of the action items was to streamline the circulation and review procedures for site plan applications which included the elimination of duplication of effort and improved communication between the City and Conservation Authorities.

Legislative Contexts

Section 41 of the *Planning Act* establishes the framework for site plan control areas and the requirements or approvals of plans and associated conditions including the ratification of agreements. While certain Ontario Regulations under the *Act* require that the Conservation Authorities receive notice of applications such as plans of subdivision, there is no regulatory requirement of a municipality to circulate site plans to the Conservation Authorities. This partnership reflects this lack of a requirement for giving notice.

Section 28 of the *Conservation Authorities Act* allows for the passage of regulations to control development within environmental areas such as lands susceptible to flooding and erosion, and wetlands. As a result, LSRCA administers Ontario Regulation 179/06 in accordance with the *Act*. The regulations and associated mapping will assist in the streamlining procedures of this Memorandum of Understanding.

Principles

This Memorandum of Understanding is based upon the following principles:

- Continued cooperation between the City and LSRCA;
- Effective communication; and
- Direct consultation between the City and the LSRCA.

Jurisdiction

This Memorandum of Understanding applies to those lands within the current boundary of the City of Barrie and any expansions thereto.

Roles and Responsibilities

City of Barrie

1. The City will determine whether a site falls within a regulated area of the LSRCA based on screening maps supplied and updated by LSCRA which have been established by Ontario Regulation 179/06.

2. The City will circulate site plan applications under the *Planning Act* to the LSRCA in a manner as follows:

    - If the proposed development or associated infrastructure is partially or wholly located within a regulated area under Ontario Regulation 179/06 which govern such areas as flood plain, erosion hazards and wetlands;

    - In non-regulated areas, the City, will circulate site plans to the Conservation Authority for properties which host natural heritage lands.

3. The City in its review and approval, will undertake stormwater reviews (including the review of associated landscaping plans) for all site plans, and will ensure that the standards established in the following documents will be met:

    - Enhanced standards as described in the Stormwater Management Planning and Design Manual (March 2003), prepared by the Ministry of the Environment or any updates to this manual;

    - Stormwater Management Policies and Design Criteria for the City of Barrie and LSRCA or any updates to these criteria.

    - LSRCA landscaping standards for stormwater ponds (e.g. requirement for indigenous, non-invasive plant species) (Refer to Appendix A which is attached for a copy of these standards)

4. The City will provide the applicant with the current fee schedule of LSRCA and collect the base site plan review fee (applicable at the time of the application), on behalf of the LSRCA. This fee will be paid by the applicant under separate cheque, payable to the LSRCA and is to be attached to the applications when they are circulated to the LSRCA for review. The LSRCA will contact the developer or owner directly should additional fees be required to complete the site plan review. Copies of the LSRCA Fees Policies are attached in Appendix B. It should be noted that the LSRCA will consider an application to be incomplete if it is not accompanied by the base review fee.

5. For those site plans that are circulated to the LSRCA for review, in accordance with Condition 2 of this Memorandum of Understanding, the City shall provide the LSRCA with a package of information which includes:

   a. A copy of the Site Plan Application,
   b. The base site plan review fee of,
   c. A copy of all site plan drawings submitted,
   d. Reports and studies which pertain to natural heritage and hazard features in accordance with the Provincial Policy Statement.

6. The City shall provide the LSRCA with copies of all Site Plan Applications which do not satisfy Condition 2 of this Memorandum of Understanding as part of the monitoring protocol. The package provided the LSRCA will include:

   a. A copy of the Site Plan Application
   b. A copy of all site plan drawings submitted

Conservation Authority

7. The LSRCA will provide the City with the necessary mapping and information including updates related to Ontario Regulation 179/06.

8. The LSRCA will review the site plan application and provide conditions of site plan approval or comments pertaining to the application within ten (10) business days of the receipt of the application (recognizing that stormwater review will be carried out by the City). If the LSRCA cannot issue conditions of approval due to lack of information or concerns with regard to the proposed development, detailed comments will be provided within the 10 business days, of the receipt of the application outlining the concerns and request for additional information. If the LSRCA has no objection to the development concept and no further review is required, conditions of approval will not be provided, and comments would indicate that no further review is required by the LSRCA.

9. The LSRCA review and approval of site plans will focus on conformity with the *Provincial Policy Statement* under the *Planning Act* and in accordance with the regulations under the *Conservation Authorities Act.* These will include natural heritage resources and natural hazard land management related to areas of valley and streams, wetlands and woodlands, flood plains, watercourse alteration, erosion, steep slope, and hazardous sites (e.g. unstable soils).

10. When the LSRCA staff member is present at City Hall, this staff member will attend pre-consultation and technical site plan review meetings, as required, in order to promote cost-effective, proactive service delivery. The LSRCA will respond in writing to the City of Barrie within 10 business days of the pre-consultation meeting to any unanswered questions.

11. Staff of the LSRCA with expertise in environmental planning or engineering (prior request required for engineering staff to attend for specific items or meetings), will be present at City Hall the 2nd and 4th Thursday of each month to attend meetings, and be available as a resource to City staff in all departments and the public to address issues, improve communications and provide effective and efficient service delivery. An office or meeting room space will be made available to the LSRCA staff in order that they can continue to undertake Conservation Authority business during that time when City business is not always required.

12. The LSRCA will issue permits under their regulations in a timely manner upon the submission of a complete application which satisfies the Conservation Authority's development policies. Permits will specify as a condition of approval, that storm water management will be subject to approval by the City in accordance with the provisions and standards of this Memorandum of Understanding.

Implementation and Transition

This Memorandum of Understanding will take effect on the date to be agreed between the City, and the LSRCA. To promote effective implementation, consultation between the City and the LSRCA is strongly encouraged.

Monitoring and Cancellation

This Memorandum of Understanding will be reviewed annually on or about January 1st of each calendar year, to evaluate its effectiveness. This Memorandum of Understanding may be amended by mutual agreement from time to time in order to reflect any changing policies or programs at the Provincial, Conservation Authority, or Municipal level. At any time, the City or the Conservation Authority (upon 30 days notice) may terminate this Memorandum of Understanding.

City of Barrie:

Richard Forward, MBA, M.Sc., P.Eng.
General Manager of Infrastructure, Development & Culture

LSRCA:

D. Gayle Wood, CMMIII
Chief Administrative Officer/Secretary-Treasurer

LSRCA STORMWATER MANAGEMENT PONDS PLANTING GUIDELINES

- 2008 -

The following guidelines are to be used to develop stormwater management planting plans. SWM facilities perform many function; they receive runoff from developed lands, hold excess water during storm events, reduce the exchange of sediments and toxins into creeks and rivers, contribute to groundwater recharge, etc. Vegetation around SWM ponds helps to control erosion and the input of sediment, removes toxins from the water and decreases water temperatures. Appropriate species selection for these areas is critical for long-term survivability of the vegetation and function of the pond.

General Standards:

- Drawings should include a plan view showing planting locations, species and numbers, a detail showing the installation, and a note listing the species, size, and condition. Botanical names must be listed for all species.
- Include a key plan including location, project name, address and applicant and owner's name(s), etc.
- Signage in SWM pond area is recommended, indicating the purpose of the pond, safety considerations (i.e. no swimming/wading) and no mowing.
- To reduce thermal warming, shade southern exposure of pond, inflow and outflow channels whenever possible.
- Ground cover must include no-maintenance, non-invasive species with a minimum of 70% regionally native flowers and grasses, though we encourage the use of 100% regionally native due to the ready availability of these mixes.
- Species should be chosen with consideration given to environmental conditions specific to the site (e.g. moisture regime, shade, soil type, etc.).
- TIP: Geese use water as an escape route from predators. Planting dense shrubs around the perimeter of the pond will deter geese from the area, as their line of sight to the water will be obstructed.

Trees and Shrubs:

- All specified trees and shrub material is to be entirely native, non-invasive species and indigenous to the region. Cultivars are not acceptable.
- Plantings should be no fewer than 4-6 tree species and 4-6 shrub species.
- Planting plan layout should be random and natural.
- Proposed tree density after planting must be at least 5-7/100m^2. Trees spacing should be no closer than 2.5m on centre and shrubs should be planted 0.75m - 1.5m apart. The shrub to tree ratio should be approximately 5:1.
- Plant material with consideration for the moisture regime, water levels, etc.
- Consider soil bioengineering measures, as appropriate, eg. live staking on steep slopes.

Aquatic (when timing and conditions permit):

- Provide 4 - 6 aquatic species.
- Provide a minimum one species considered as submergent and floating, and one from robust, broadleaved and one from narrowleaved emergent plants.
- Use on-site wetland/wet meadow seedmix, as appropriate.
- Planting cattails is permitted only as interim vegetation in the sediment forebay to aid in sediment trapping (NOTE: it is accepted that this material will be removed with sediment cleanout prior to assumption).

Stocking:

- Provide caliper vegetation (approx 5 to 6 cm) to aid in solar insolation of permanent pool, particularly for downstream coldwater systems – plant within 3m of permanent pool edge.
- Provide caliper material to screen adjacent private lands and facility infrastructure – ensure that spreading and suckering vegetation (i.e. sumac, ash, willow) are setback approximately 3m from private property, access roads and sediment drying areas.
- Increase density of vegetation along that portion of the facility adjacent to the valley corridor to create a live fence.
- Use whips or bare-root small caliper stock for future canopy cover where larger stock in not appropriate.
- Plant in nodal groupings or natural configuration. The shrub to tree ratio should be approximately 5:1.
- Shrub material should be approximately 03. to 0.6 m in height.
- A calculation of the plant material should be provided on the appropriate landscape plan.
- Plant material should be guaranteed for a minimum of 2 years.

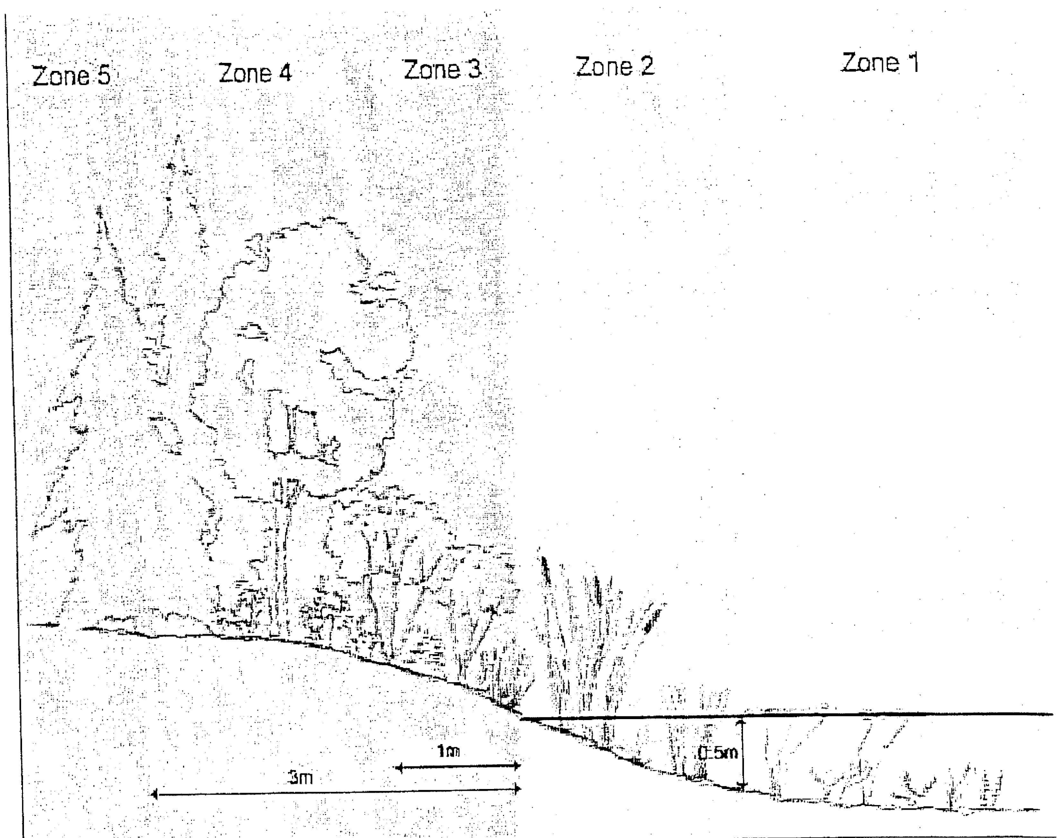
Topsoil Requirements:

- Terrestrial: Provide 0.45 m to 1 m of topsoil above the permanent water level.
- Aquatic: Provide 0.3m of topsoil for the first 1m below the permanent water level.
- Design engineer and site supervisor should review suitability of subsoil material and compaction with landscape architect.

Plant List – Storm Water Management Ponds

* This table is based on the SWM Planning & Design Manual issued by the MOE (2003) and native watershed species listed in the State of the Lake Simcoe Watershed Report (2003). The table of suggested species below is not exhaustive; please refer to appendix E in the MOE manual or the LSEMS report for a more expansive list.

There are five distinct moisture zones found within SWM ponds (see figure below). Plantings that are appropriate for the conditions of each zone should be provided. Please refer to the attached table for acceptable species. Early successional native species of trees, shrubs and herbaceous vegetation that are compatible and complementary to adjacent natural areas should be used. Depth and frequency of inundation, particularly during the growing season, are the primary factors controlling species survival. Water quality may be a secondary consideration.



Moisture Zones within Stormwater Management ponds. (TRCA SWMP planting guidelines, 2007).

Acceptable Floral Species for SWM Pond Planting:

Please note that acceptable native species may vary by Municipality due to Asian Longhorn Beetle, Emerald Ash Borer, etc.

Plant Type	Common Name	Scientific Name	Suitable Moisture Zone	Notes
Tree	Sugar Maple	Acer saccharum ssp. saccharurr	5	
	Red Maple	Acer rubrum	3,4,5	
	Silver Maple	Acer saccharinum	3,4,5	
	Bur Oak	Quercus macrocarpa	4,5	
	Red Oak	Quercus rubra	5	
	White Ash	Fraxinus americana	5	
	Green Ash	Fraxinus pennsylvanica	4,5	
	Black Ash	Fraxinus nigra	3,4,5	
	Black Cherry	Prunus serotina	5	
	Balsam Poplar	Populus balsamifera	4,5	
	Trembling Aspen	Populus tremuloides	5	
	Paper Birch	Betula papyrifera	5	
	Bitternut Hickory	Carya cordiformis	5	Mid to upper slopes
	White Spruce	Picea glauca	4,5	
	White Cedar	Thuja occidentalis	3,4,5	
	Tamarack	Larix laricina	4,5	
	Shining Willow	Salix lucida	3,4	
	Black Willow	Salix nigra	3,4	
	Peach-leaved Willow	Salix amygdaloides	3,4,5	
	White Pine	Pinus strobus	5	

Plant Type	Common Name	Scientific Name	Suitable Moisture Zone	Notes
Tree	Red Osier Dogwood	Cornus stolonifera	3,4,5	
	Gray Dogwood	Cornus foemina	4,5	
	Alternate Leaved Dogwood	Cornus alternifolia	5	
	Chokecherry	Prunus virginiana	5	
	Maple-leaved Viburnum	Viburnum acerifolium	3,4,5	
	Nannyberry	Viburnum lentago	4,5	
	Highbush Cranberry	Viburnum trilobum	3,4	
	Serviceberry	Amelanchier spp.	5	
	Bush Honeysuckle	Diervilla lonicera	4,5	
	Black Chokeberry	Aronia melanocarpa	3,4	
	Common Winterberry	Ilex verticillata	3,4	
	Common Elderberry	Sambucus canadensis	3,4,5	
	Pussy Willow	Salix discolor	3,4	
	Sandbar Willow	Salix exigua	3,4	
	Shining Willow	Salix lucida	3,4	
	Peach-leaved Willow	Salix amygdaloides	3,4	
	Slender Willow	Salix petiolaris	3,4	
	Bebb's Willow	Salix bebbiana	3,4	
	Sage leaved/Hoary Willow	Salix candida	3,4	
	Black Willow	Salix nigra	3,4	
	Staghorn Sumac	Rhus typhina	5	
	Elderberry	Sambucus canadensis	3,4	
	Common Ninebark	Physocarpus opulifolius	3,4	
	Speckled Alder	Alnus incana spp. Ranus	3,4	
	Narrow-leaved meadowsweet	Spirea alba	3,4	

Plant Type	Common Name	Scientific Name	Suitable Moisture Zone	Notes
Aquatic – Submergent	Common Waterweed	Elodea canadensis	1	
	Coontail	Ceratophyllum demersum	1	
	Tape Grass	Vallisneria americana	1	
	Northern Water Milfoil	Myriophyllum sibiricum	1	Not to be confused with Invasive Eurasian Milfoil
	Water Starwort	Callitriche hermaphroditica	1	
	Slender/Small Pondweed	Potamogeton pusillus	1	
Aquatic – Floating	White Water Lily	Nymphea odorata	1	
	Floating Pondweed	Potamogeton natans	1	
	Large-leaved Pondweed	Potamogeton amplifolius	1	
	Yellow Pond Lily	Nuphar variegatum	1	
Aquatic – Robust Emergent	Common Cattail	Typha latifolia	2	
	Bulrush	Scirpus spp.	2	
Aquatic – Broadleaved Emergent	Broadleaved Arrowhead	Sagittaria latifolia	2	
	Common Water Plantain	Alisma plantago-aquatica	2	
Aquatic – Narrowleaved Emergent	Burreed	Sparganium spp.	2	
	Grasses	Leersia spp.	2	
	Sedges	Carex spp.	2	

LSRCA NATIVE SEEDMIX GUIDELINES
- 2008 -

The LSRCA does not have a prescribed seed mix list. However, landowners and consultants are often directed to browse through the variety of native seed mixes offered by the Ontario Seed Company (OSC) and from Pickseed's Eastern restoration catalogue. Please be aware that not all of the mixtures listed in the catalogues contain 100% native species and that LSRCA is not endorsing these companies, merely the lists, as they are valuable starting-points when creating your own seedmix.

http://www.oscseeds.com/NativePlantSeedsCatologue.pdf
http://www.pickseed.com/ECanada/reclamation/doc/EasternReclamation_ts.pdf

General Recommendations:

- Optimal seeding time for all mechanical seeding – April 15 to May 30 and August 15 to September 30. If seeding occurs after September 30, additional erosion and sediment control measures may be required to minimize sediment transport off-site and seeding may be required the following growing season.
- Optimal seeding time for dormant wildflower seed is in the autumn. However, seeding may also occur in late spring, during drier conditions.
- A minimum 150 mm of top soil should be applied to all areas subject to permanent landscaping. ***The top-soil may need to be stabilized with and erosion control process after seeding application has been completed.***

Acceptable Upland Seedmixes:

- OSC 6677 – Tableland Grass Mixture: low maintenance & naturalized areas.
- OSC 6672 – Native Prairie Meadow: large areas, no mow, habitat/cover.
- OSC 6676 / 6678 / 6694 / 6695 – Upland meadow mixes, habitat.
- OSC 7112 – Rural Ont. Roadside Mix: reduce erosion, habitat, rural property.
- OSC 7127 – Woodland Seed: ideal for woodland edge habitats.
- Pickseed Native Slope Mix: poor soil on steep slopes.

Acceptable for Riparian areas and SWM ponds:

- OSC 6679 / 7109 / 7106 / 7116 ("stormwater pond mixture") / 7126
- OSC 7107 / 7111- Seasonally Flooded & Low Maintenance: new basins, wet construction sites.
- OSC 7117 – Shoreline Mixture: new shorelines.
- OSC 7118 – Bank Seed Mix: plant on edges of new ponds, basins, etc.
- Pickseed Detention Basin Grass

Acceptable for Wetland Restoration:

- OSC 7105 – Obligate wetland meadow mix: 99% occur in wetlands normally.
- OSC 7125 – Acidic soil wetland mixture: for difficult growing conditions.
- Pickseed Wet Native Grass: damp soil that do not dry completely, erosion control.

Acceptable for Septic Beds & Lawns:

- OSC 7131 – Septic Bed Mix: shallow rooted.
- OSC 7104 / 7120 (Xericscaping) / 7100 (mini mow).

Unacceptable exotic/invasive seeds are as follows:

Scientific Name	Common Name	Native Alternative
Agrostis gigantea	Red top	
Bromus inermis spp. inermis	Smooth brome	*Bromus pubescens*
Carex spicata	European meadow sedge	
Chrysanthemum leucanthemum	Ox-eye daisy	
Convallaria majalis	Lily-of-the-valley	*Maianthemum canadensis*
Convolvulus arvensis	Field bindweed	
Coronilla varia	Crown vetch	
Dactylis glomerata	Orchard grass	*Danthonia spicata*
Elymus repens	Quack grass	*Elymus hystrix*
Festuca arundinacea	Tall fescue	*Festuca obtuse*
Festuca pratensis	Meadow fescue	
Festuca rubra	Red fescue	
Festuca trachyphylla	Sheep fescue	
Glechoma hederacea	Ground-ivy	*Physostegia virginiana*
Glyceria maxima	Rough manna grass	*Glyceria striata*
Hemerocallis fulva	Orange day-lily	*Erythronium americanum*
Hesperis matronalis	Dame's rocket	*Phlox divaricata*
Iris pseudocorus	Yellow flag	*Iris versicolor*
Iris virginica	Southern blue flag	
Juncus compressus	Compressed rush	
Linum perenne	Perennial flax	
Linum usitatissimum	Common flax	
Lotus corniculatus	Bird's foot trefoil	
Lycopus eropaeus	European Waterhorehound	
Medicago lupulina	Black medick	
Medicago sativa spp. falcata	Alfalfa	
Medicago sativa spp. sativa	Alfalfa	
Melilotus alba	White sweet clover	

Scientific Name	Common Name	Native Alternative
Melilotus officinalis	Yellow sweet clover	
Miscanthus sacchariflorus	Amur silver grass	
Myosotis scorpioides	European forget-me-not	
Phalaris arundinacea	Reed canary grass	*Glyceria striata*
Phleum pratense	Timothy grass	
Phragmites autralis	Great reed	*Typha sp.*
Poa pratensis	Kentucky blue grass	*Poa compressa*
Polygonum convolvulus	Black bindweed	
Seteria faberi	Giant foxtail	
Setaria glauca	Yellow foxtail	*Elymus canadensis*
Setaria italica	Foxtail millet	
Setaria verticillata	Bristly foxtail	
Setaria viridis	Green foxtail	*Elymus canadensis*
Trifolium arvense	Rabbit foot clover	
Trifolium aureum	Hop clover	
Trifolium campestre	Large hop clover	
Trifolium hybridum	Alsike clover	
Trifolium medium	Zig-zag clover	
Trifolium pratense	Red clover	
Trifolium repens	White clover	
Vicia cracca	Cow vetch	
Vicia sativa spp. nigra	Common vetch	

PLANNING and DEVELOPMENT FEES POLICY

Under
Section 21 (m.1) of the *Conservation Authorities Act*

For the

Lake Simcoe Region Conservation Authority
120 Bayview Parkway
NEWMARKET, Ontario
L3Y 4X1
Tel: (905)895-1281; Fax: (905) 853-5881
Web: www.lsrca.on.ca

Dated: June 27, 2008

BASIS

Legislative

The *Conservation Authorities Act* provides the legislative basis to allow conservation authorities in Ontario to charge fees for services approved by the Minister of Natural Resources. Section 21(m.1) of the *Act* allows for the collection of fees for planning and development related activities such as:

- Permitting
- Plan review
- Public and legal inquiries

Policy

The Ministry of Natural Resources (MNR) established the *Policies and Procedures for the Charging of Conservation Authority Fees* in order to fulfill Section 21(m.1) of the *Conservation Authorities Act*. These *Policies and Procedures* further provide the Lake Simcoe Region Conservation Authority (LSRCA) with the policy basis to charge fees for planning and development proposals.

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PLANNING and DEVELOPMENT FEES POLICY

June 27, 2008

PRINCIPLES

As a result of the legislative and policy basis, the LSRCA's Fees Policy is based on the following:

- The user-pay principle
- Adequate consultation and notification
- Opportunity or right to an appeal

RELATIONSHIP TO PLANNING PROGRAM BUDGET

In 2008, the approved LSRCA planning budget is approximately (~) 1.4 million dollars ($). Based on the current funding formula, ~60% of the total planning revenue (~$840,000) will be generated through user-fees. The remaining 40% (~$560,000) will be collected primarily through municipal levy and secondarily via provincial grant. This 60-40 user fee to levy/grant ratio represents the maximum reliance on user-fees in order to safeguard the planning program and its services against economic volatility and subsequent budgetary uncertainty. It is also intended to reflect that significant effort and resources are used for "non-development" related activities and proposals including Official Plans, Secondary Plans, and Comprehensive Zoning By-Laws.

PROCESS and NOTICATION

In May 2008, a Working Group was established with members of BILD (Building Industry and Land Development Association) and planning staff of the LSRCA. The purpose of the Working Group was to review the 2007 Fees Policy in accordance with its Monitoring provisions. This Planning and Development Fees Policy reflects the discussions and consensus achieved at the Working Group meetings. A letter of acceptance from BILD forms part of this Policy. Ultimately, this Policy requires approval by the LSRCA Board of Directors (BOD). Once approved, the Policy is circulated to:

- Regional and local municipalities
- Neighbouring conservation authorities
- Conservation Ontario
- Ministry of Natural Resources
- BILD
- Consultants and general public as requested

IMPLEMENTATION

LSRCA staff shall apply the fees as prescribed on the Schedule of Fees when reviewing planning and development related applications. When registering a plan of subdivision in phases and the maximum fee is triggered for the entire plan, the maximum amount of $14,000 shall be collected based on the number of Lots/Units within each phase (e.g. if Phase 1 = 200 Lots of a total of 1000 Lots, then 20% of $14,000 is due for the first phase). In addition, the fees charged for plans of subdivision will include the estimated number of Lots/Units for any Blocks within the plan. As such, the circulation of any subsequent plan of condominium or residential site plan to the LSRCA will not trigger any further fee requirement. Commercial, industrial, institutional site plans circulated to the LSRCA will trigger a general "no objection" comment and the $500 fee recognizing that storm water management (to current standards) has been provided through the previous plan of subdivision process.

Transition

The Fees Policy comes into effect on the date of Board approval by resolution. The Policy supercedes and replaces all previous Fee Policies.

Appeal

An applicant, proponent, or developer has the right to appeal should he or she be dissatisfied with the prescribed fee. Any appeal shall be heard by the LSRCA Board of Directors through a deputation by the proponent. Any deviation from this Policy requires written approval of the Board of Directors. The appeal will be heard in accordance with the *Statutory Powers Procedure Act* based on the principles of fairness, opportunity, and notification.

MONITORING

This Fees Policy shall be monitored on an annual basis to evaluate its effectiveness and fairness. A Working Group has been established with members of BILD in order to evaluate this Fees Policy. Any changes or amendments to the Policy, as recommended by the Working Group, shall require the approval of the BOD.

SCHEDULE 1 - FEES
To be read in conjunction with text of Policy

June 27, 2008

Applications made under the ***Planning Act***

CATEGORY	FEE
Official Plans	$0 – General Levy
Secondary Plans – Municipally Initiated	$0 – General Levy
Secondary Plans – Developer Initiated	$10,000
Comprehensive Zoning By Laws	$0 – General Levy
Official Plan, Zoning By-Law Amendments	$400
Draft Subdivision Plan Approval – Minimum Fee	$6,000
Final Subdivision Plan Approval – Minimum Fee	$4,000
Application for draft plan of subdivision approval	$120/Lot, Unit
Draft plan approval - Maximum Fee	$21,000
Submission for final plan of subdivision approval	$80/Lot, Unit
final plan approval - Maximum Fee	$14,000
Draft Plan of Subdivision – Red-line Revision	$2,500
Site Plan/Condo. – Residential (multi-unit)	$10,000
Site Plan - Residential (single-unit)	$500
Site Plan – Golf Courses, Aggregate	$15,000
Site Plan – Commercial, Industrial, Institutional	$500
Site Plan – Study Review Required	$2,500
Consent Application	$300
Minor Variance Application	$200
Peer Review (e.g. Geotechnical Study)	Cost Paid by Applicant

Applications made under the ***Conservation Authorities Act*** and ***Environmental Assessment Act***

CATEGORY	FEE
Permit Application – General	$450
Permit Application – Minor (decks, docks, pools)	$150
Permit – Unauthorized works	$1000
Legal/Real Estate Inquiries	$150
Site Clearance Letter	$75
EA undertakings or proposals	$0 – General Levy