Technical and Engineering Guidelines for Stormwater Management Submissions

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December 2014

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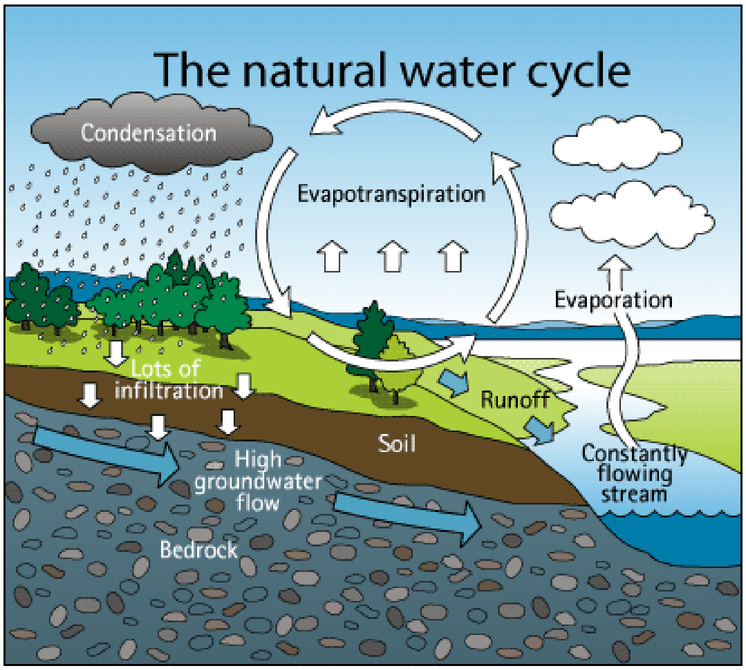
1 INTRODUCTION

1.1 The Need for Effective Stormwater Management

Lake Ontario plays an essential role in the health and well being of residents of Northumberland County. Lake Ontario provides the Town of Cobourg and the Municipality of Port Hope with a safe and abundant source of drinking water, and supports a wide range of recreational opportunities that include swimming, boating, fishing.

Effective management of stormwater is critical to the continued health of our streams, rivers, lakes, fisheries and terrestrial habitats. As can be seen in **Figure 1.1** below, rain can take several paths once it falls on the ground. It can infiltrate into the soil, evaporate, be subject to evapotranspiration, or it can run overland as runoff. In natural settings, vegetation and the lack of hard surfaces ensures that little runoff occurs. In urban areas with hard surfaces and limited vegetation, the majority of the rainwater becomes runoff.



Source: Charles River Watershed Association

Figure 1.1 Water Cycle

The water quality of Lake Ontario is directly dependent on the health of the rivers and creeks that feed into it. Lake Ontario and its contributing watersheds can be severely impacted by human activity, particularly through the release of various pollutants into the natural environment. Human activity affects the quality and quantity of runoff. In urban areas, for example, buildings and paved streets increase the amount of hard surfaces and in turn reduce opportunities for natural infiltration. These hard surfaces decrease water quality by providing increased opportunity for pollutants to accumulate (e.g. oil, grease, and exhaust emissions from vehicles), which are washed off during rainfall events polluting ground and surface waters. As well, hard surfaces generate increased levels of runoff, which causes downstream flooding and erosion.

The increase in surface runoff may cause flooding, thus damaging property and municipal infrastructure. Water-borne pollutants can cause hydrological, water quality, and ecological impacts to natural heritage features. Natural flow patterns are disrupted since rainfall is redirected via storm sewers away from source areas to concentrated outfalls. As a result, urban areas change the natural hydrology cycle by altering the volume, frequency, duration, timing, and distribution of runoff.

1.2 Policy Framework

The Ganaraska Region Conservation Authority (GRCA) is a corporate body established under the *Conservation Authorities Act of Ontario* in October of 1946 to further the conservation, restoration, development and management of renewable natural resources.

The *Conservation Authorities Act* requires that the GRCA prevent, eliminate, or reduce the risk to life and property from flooding and erosion, and encourage the protection and regeneration of natural systems. The GRCA works with municipalities to ensure that the tenets of the Provincial Policy Statement (PPS) are upheld, and limit effects to natural features result from development applications approved through the Planning Act.

1.3 Purpose of the Document

The purpose of this manual is to provide a stormwater management (SWM) planning framework, complete with associated criteria and design guidelines, to be applied at the various stages of the planning process, ranging from Official Plan and Secondary Plan studies through to plans of subdivision and site plans.

Referenced documents include:

- Ministry of the Environment *Stormwater Management Planning and Design Manual* (2003)
- CVC/TRCA *Low Impact Development Stormwater Management Planning and Design Guide*, Version 1.0 (2010)
- Ministry of Transportation *Drainage Management Manual* (1997)
- Golden Horseshoe CA *Erosion and Sediment Control Guideline for Urban Construction* (2006)

The criteria used in this document are mainly based on provincial recommendations and guidelines. In some situations, local standards or requirements may overwrite provincial guidelines. For example, identified erosion sites on a creek may necessitate a lower flow rate than provincial guidelines.

1.4 Stormwater Design Criteria

Stormwater criteria shall be defined at the preliminary stages of a new planning development, and are defined to reflect the scale of studies. For example, at the watershed scale, flood control targets may consist of peak flow rates at the subwatershed outlet, while the focus at the site plan scale is on site release rates.

Design criteria are provided to:

- Prevent increased flooding
- Protect water quality
- Preserve baseflow characteristics
- Limit undesirable geomorphic changes in watercourses
- Maintain groundwater quality

1.5 Ontario Regulation 168/06

Hazardous land (such as unstable slopes, wetlands, floodplain, etc) within the GRCA watershed is generally unsuitable for any type of development. Any consideration of land development is considered on an individual basis and requires unique engineering analysis for these following items:

- The straightening, changing, diverting or interfering in anyway with an existing channel, a river, creek, stream or watercourse
- The construction of any building or structure in or on a wetland, or in any area subject to flooding
- The placing of fill or dumping of fill of any kind in any defined part of the area over which the conservation authority has jurisdiction which, in the opinion of the conservation authority, the control of flooding or pollution or the conservation of land may be affected.

2 STORMWATER MANAGEMENT DESIGN PROCESS

2.1 Project Scale and the Planning Process

All change in land use proposed by a development application must evaluate the hydraulic, hydrologic, geomorphic, and ecological conditions of a subject area. SWM designs shall address quantity, quality, and erosion controls. The scale and scope of land development ranges widely. The level of detail required to address SWM controls reflects the land use application under consideration, as described in the subsequent sections of this document.

Official Plan Amendments, Secondary Plans, or "Block" Plans

These are normally supported by a functional servicing report, a component of which includes a detailed evaluation of the subject area and its catchment(s) to derive a preliminary SWM plan. Preliminary targets and criteria are established.

Zoning By-law Amendments

If the change in proposed land use is significant, a SWM plan shall be created as part of a functional servicing report. Since the scale of project is more defined than at an official plan stage, a more detailed evaluation of site conditions is expected.

Plans of Subdivision

These require detailed infrastructure design. A conceptual SWM plan, usually based on an existing functional servicing report, is usually submitted to get draft plan approval. Prior to construction, a detailed SWM plan is required.

Site Plans

Depending on the size and complexity of the site, either a functional servicing report or detailed SWM plan is required.

Consents (Severances) and Minor Variances

These may require technical analyses and SWM controls, depending on the size and complexity of the site.

Single Lot Residential Development (<0.5 ha)

These usually require an outline brief of the best management practices (BMPs such as roof drain disconnection, rain garden, soakaway pit) to be incorporated for the site.

2.2 Design Steps

Define Existing Conditions

Pre-development conditions must be established. All analyses shall include maps showing existing land use, external drainage areas, topography, relevant environmental features, and existing infrastructure. A soils analysis, outlining the native soil types, infiltration capacity and depth to water table must be included.

Establish SWM and/or Environmental Design Criteria

With the existing conditions established, individual SWM components must be assessed to define the project's SWM design criteria, which may be: quantity control (or flood protection) discussed in **Section 3**, erosion control (**Section 4**), water quality (**Section 5**), stormwater management practices (**Section 6**), storm infrastructure design (**Section 7**), stormwater management facilities design (**section 8**), and erosion and sediment control (**section 9**).

Screen and Select Potential SWM Strategies
It is strongly encouraged that more than one treatment system be used for a project by using a treatment train approach. A combination of source, conveyance, end-of-pipe facilities, and low impact development practices shall be considered to meet the water quantity, quality, and erosion design criteria.

Assess the Effectiveness of the Stormwater Management Plan
With a SWM strategy selected, an analysis of its effectiveness must be carried out. Depending on the size of the project, calculations or computer models shall be used to test the SWM concept. **Table 2.1** below outlines the computer models and manual calculations that have been accepted in the past. Alternative models may be used, but require prior authorization by GRCA staff.

Table 2.1 Calculation Recommendations

Application	Model Recommendations	Additional Guidance
Hydrology (single event) To calculate peak flow rate targets for SWM facilities Storm sewer design Storage Facilities	Visual Otthymo (VO_2) PCSWMM SWMM Rational Method Modified Rational Method	IDF equation or data from municipal engineering standard, if possible Watersheds < 5Ha
Watercourse Hydraulics To determine flood limits To design culverts, bridges	HEC-RAS Manning's, Chezy equations Culvert design sheets	Use GRCA HEC models, if possible

Detailed Design
Section 6 provides report requirements for the design of SWM infrastructure. Additionally, local municipal engineering standards shall be referenced. **Section 7** details the design criteria for major and minor storm infrastructure. **Section 8** outlines the requirements for the design of possible SWM facilities.

Construction
During construction, SWM is largely focused on erosion and sediment control. The *Erosion and Sediment Control Guideline for Urban Construction* (Greater Golden Horseshoe Conservation Authorities, 2006) provides guidance on the approaches and criteria to be applied during construction, as discussed in **Section 9**.

2.3 Practitioner Credentials
The evaluation, planning, and design of SWM systems shall be undertaken and overseen by professionals with education, experience, and certification in Water Resources Engineering and/or Civil Engineering Technology.

2.4 Summary of Stormwater Management Design Criteria

For quantity control, the minimum requirement is that post-development flow is restricted to pre-development peaks, unless identified otherwise in **Table 3.1** and/or **Figure 3.1**. More detailed information can be found in **Section 3**.

For erosion control, the minimum requirement is that the runoff from a 25mm storm is detained for 24 hours, unless identified otherwise in **Table 4.1**. More detailed information can be found in **Section 4**.

For water quality control, outflow from SWM facilities must meet enhanced level requirements (80% removal of total suspended solids), unless identified otherwise in **Table 5.1** and **Figure 5.1**. Most watercourses within the GRCA jurisdiction are cold-water systems. SWM facilities shall therefore incorporate measures to reduce the temperature of water discharging to the receiving watercourses. More detailed information can be found in **Section 5**.

2.5 Fisheries Criteria

Where stormwater management, erosion, or sedimentation control issues related to development proposals may impact fish habitat, review to ensure protection of habitat.

2.6 Erosion and Sediment Control during Construction

Proponents shall adhere to the recommendations outlined in the December 2006 *"Erosion and Sediment Control Guideline for Urban Construction"* written by the Greater Golden Horseshoe Area Conservation Authorities.

2.7 Hydraulic Considerations

The GRCA requires a thorough hydraulic analysis for all developments proposing to alter land use and grades within the Regulatory floodplain. The proponent will be required, where available, to use existing GRCA-approved analyses, maps, and/or computer models as the base model for computations.

The MNR's 2002 *"River and Stream Systems Flooding Hazard Limit Technical Guide"* must be followed at all times when developing the hydraulic model and completing the analysis. The U.S Army Corps of Engineers' HEC-2 or HEC-RAS must be used, unless an alternative is approved by the Authority. Both paper and digital copies of model input/output must be submitted. If hydrologic analyses have been undertaken by the consultant, calculation sheets, model outputs, and digital model files must be appended to the report.

2.8 Channelization

Creek channelization or re-channelization shall be avoided wherever possible. Depending on the watercourse, the Municipality and Authority shall determine conveyance requirements for any proposed channelization.

3 QUANTITY CONTROL

3.1 Quantity Control Objective

In order to protect downstream properties from flooding due to upstream change in land use caused by development, quantity control criteria have been established.

3.2 Flood Damage Centres

Flood damage centers are buildings impacted by flooding. The GRCA has 100-year and Regulatory flood plain mapping for all its urban areas, and a portion of its rural area. Some Special Policy Areas have flood maps for the 2- to 50-year storms.

3.3 Quantity Control Criteria

Quantity control facilities are to be designed in accordance with recommendations set out in the Ministry of Environment's (MOE's) 2003 *"Stormwater Management Planning and Design Manual"*. Additional watershed-specific criteria are summarized in **Table 3.1**, as well as applicable models and reports to be used and referenced for stormwater design of new development. This table shall be used in conjunction with **Figure 3.1**.

Post-development drainage boundaries shall follow the pre-development pattern. In extenuating circumstances, the GRCA may consider a shift in boundaries, but only after a pre-consultation discussion.

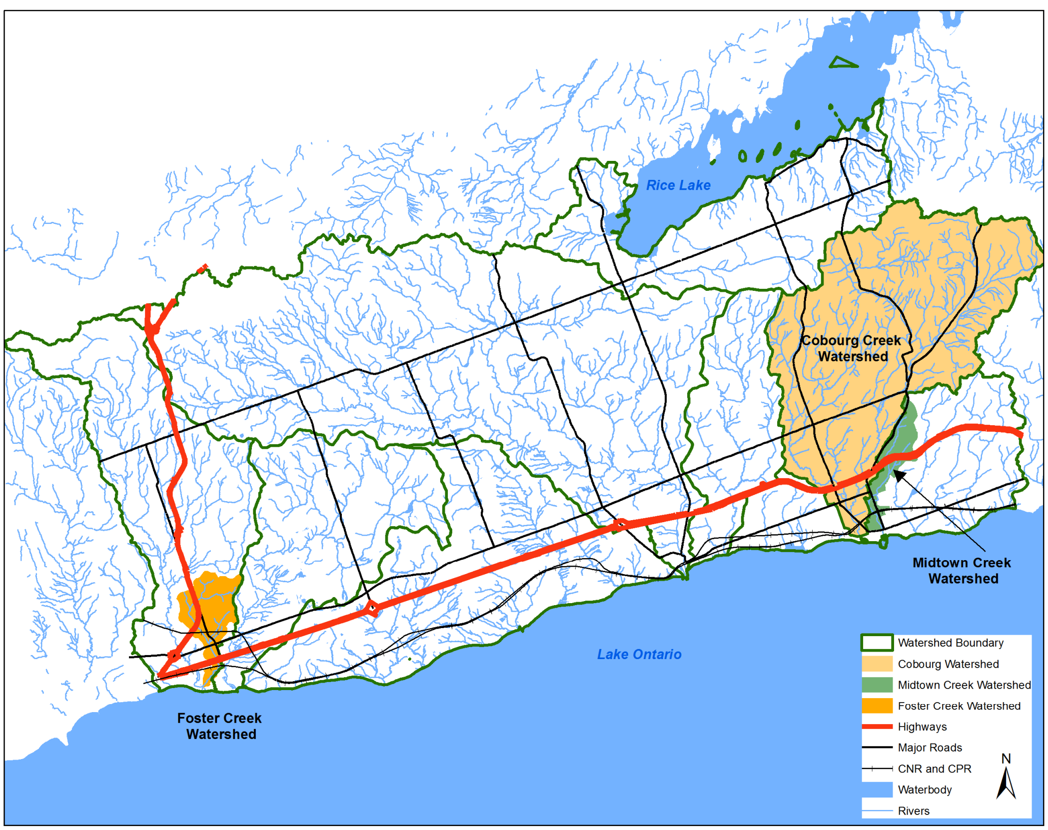


Figure 3.1 Watersheds where post-development flows must be less than pre-development

Table 3.1 Water Quantity Control Requirements

Subwatershed	Flood Control Criteria	References & Notes
Wilmot Creek	Post- to pre-dvlp control for all storms (2-100 year)	1. Draft Wilmot Ck Hydrology Update (2011) 2. Hydrology model: VO_2
Foster Creek	Post-dvlp peak flows only 70% of pre-dvlp peaks	1. Draft Foster Ck Subwatershed Study (2001) 2. Hydrology model: VO_2
Graham Creek	Post- to pre-dvlp control for all storms (2-100 year)	1. Draft Graham Ck Hydrology Update (2012) 2. Hydrology model: VO_2
Little Creek	1. Post- to pre-dvlp control for all storms (2-100 year) 2. in groundwater recharge areas, foundation drain collection system must discharge directly to creek, bypassing SWM ponds	1. Little Creek Master Water Management Plan (1998) 2. Hydrology model: VO_2 model
Ganaraska River	Post- to pre-dvlp control for all storms (2-100 year)	1. Ganaraska River Hydrology Update (2006) 2. Hydrology model: VO_2 model
West Gage Ck	1. sub-basins have unique control requirements 2. 100-yr storm is the flood event	1. West Gage Ck MDP (2007) 2. Hydrology model: VO_2 model
Gage Ck	Post- to pre-dvlp control for all storms (2-100 year)	1. Gage Ck Floodplain Mapping Study (1993) 2. Hydrology model: Ott-HYMO model
Cobourg Creek	1. 2-year post-dvlp flows only 50% of pre-dvlp peaks 2. 5-100yr post- to pre-dvlp within Town of Cobourg, or as dictated by infrastructure limits 3. 5-100yr post-dvlp is either 70% or 100% of pre-dvlp peaks within Hamilton Township limits	1. Cobourg/Midtown Creeks MDP (1992) 2. Cobourg Ck Hydrology Update (2007) 3. Hydrology model: VO_2 model

Table 3.1 Water Quantity Control Requirements (con`t)

Subwatershed	Flood Control Criteria	References & Notes
Midtown Creek	1. 2-year post-dvlp flows only 50% of pre-dvlp peaks 2. 5-100yr only 70% pre-dvlp within Town of Cobourg 3. 5-100yr post-dvlp only 70% of pre-dvlp peaks within Hamilton Township limits	1. Cobourg/Midtown Creeks MDP (1992) 2. Midtown Ck Hydrology Update (2007) 3. Hydrology model: VO_2
Brook Creek	Post- to pre-dvlp control for all storms (2-100 year)	1. Draft Brook Creek MDP (1991) 2. Brook Ck Hydrology Update (2007) 3. Hydrology model: VO_2 model
Massey Creek	Post- to pre-dvlp control for all storms (2-100 year)	1 Brook Ck Hydrology Update (2007) 2. Hydrology model: VO_2 model
North Lake Ontario shoreline	Quantity control not required for small developments draining directly to Lake Ontario **provided the development does not cause adverse downstream flooding**	Lake Ontario Shoreline Management Plan (1992)

SWM ponds offering quantity control cannot be located within the Regulatory or the 1:100 year flood plain, or other natural heritage areas. On-line facilities are not permitted.

Although control of the Regional storm (Hurricane Hazel) is not required in SWM facilities, it will have to be assessed to ensure the facility can safely convey the Regional flow.

4 EROSION

4.1 Erosion Control Objective

Erosion is a natural process. However, changes in land use cause an increase in runoff flows and a change in sediment loading to watercourses. Downstream channels can suffer from channel instability, bank erosion, and channel migration due to upstream change in land use. The main methods used to reduce erosion problem are: reducing the peak flow rate, decreasing the duration of storm flows, minimizing the volume of runoff, and implementing Low-Impact Development (LID) techniques in new construction.

4.2 Erosion Control Criteria

Some Master Drainage Plans (MDP) studies have evaluated methods to control downstream erosion. They are listed in **Table 4-1** below. In the absence of a detailed study, the erosion requirements from the MOE manual will be applied: requiring the 25mm 4-hour Chicago storm to be stored and released over a 24-hour period.

Table 4.1 Erosion Control Criteria

Subwatershed	Flood Control Criteria	References & Notes
Foster Creek	48-hour detention of 25mm storm	1. Draft Foster Ck Subwatershed Study (2001) 2. Hydrology model: VO_2 model
West Gage Ck	Flow restricted to downstream erosion threshold limits	1. West Gage Ck MDP (2007) 2. Hydrology model: VO_2 model

5 QUALITY CONTROL

5.1 Water Quality Control Objective

Downstream channels can experience water quality degradation due to upstream change in land use caused by development. Suspended solids and thermal warming are the key items targeted for control.

5.2 Water Quality Control Criteria

For water quality control, runoff from SWM facilities must meet enhanced level requirements (80% removal of total suspended solids), unless identified in **Figure 5-1** or **Table 5-1**. **Figure 5-1** displays where watershed-specific water quality control is required within the GRCA watershed. Any SWM facility releasing water to a cold-water stream must incorporate a reverse-grade outlet pipe (or a similar device) to draw upon the deeper (colder) water. **Table 5-1** below lists alternative quality control requirements.

Table 5.1 Quality Control Criteria

Subwatershed	Quality Control Criteria	References & Notes
Foster Creek	Normal level (70% removal of suspended solids)	1. Draft Foster Ck Subwatershed Study (2001) 2. Hydrology model: VO_2 model
West Gage Ck	Normal level (70% removal of suspended solids)	1. West Gage Ck MDP (2007) 2. Hydrology model: VO_2 model

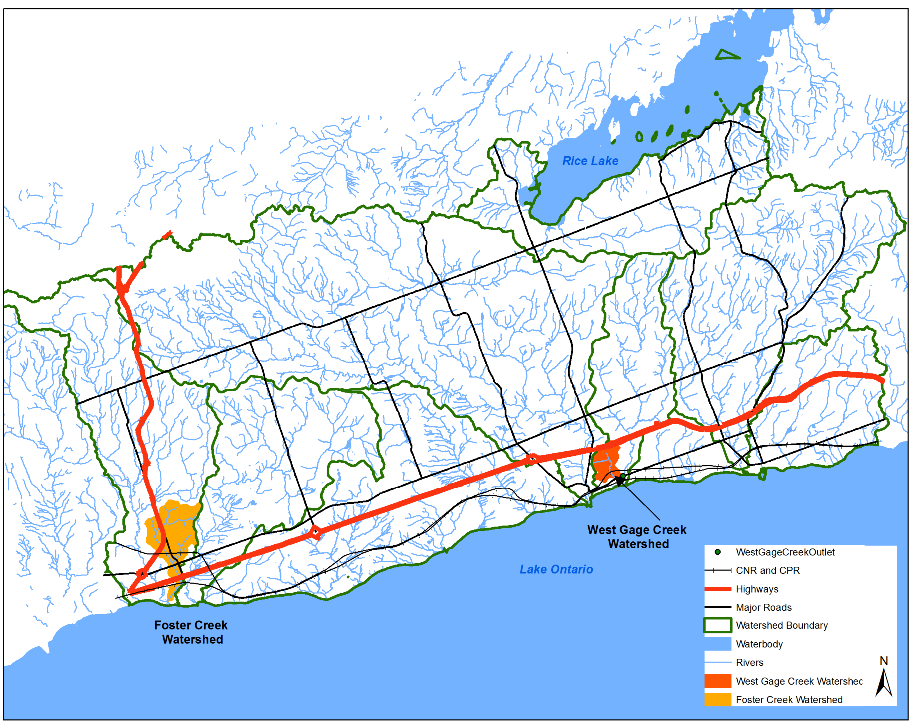


Figure 5.1 Watersheds with Normal Water Quality Targets

Facilities providing quality control only must be located outside the 25-year floodline, and the outlet structure invert elevation must be higher than the 2-year flood elevation. Typically, quality control is not provided within a municipal right-of-way unless it is a recommended LID facility.

Spills can severely impact the quality of the receiving water. It is recommended that spill control provisions (such as reverse-grade pond outlet pipes, under-flowing forebay weirs, oil-grit separators preceding a SWM pond) be included to all SWM facilities servicing commercial/industrial areas, or roadways with a high volume of commercial/industrial traffic.

Some Ontario municipalities are requiring that SWM facilities include temperature controls, and bacterial controls to reduce downstream beach closures. This is currently not required in the GRCA jurisdiction.

6 STORMWATER MANAGEMENT PRACTICES

6.1 Overview

All submissions must meet the requirements of the appropriate subwatershed study, master drainage plan (MDP), or other relevant study listed in **Table 3.1**, if applicable. All submissions shall also refer to the requirements of the following documents:

- March 2003 Ministry of the Environment (MOE) *"Stormwater Management Planning and Design Manual"*
- 1995 Ministry of Transportation (MTO) *"MTO Drainage Management Manual"*
- 2002 Ministry of Natural resources (MNR) *"River and Stream Systems Erosion Hazard Limit Technical Guide"*
- December 2006 Greater Golden Horseshoe Area Conservation Authorities' *"Erosion and Sediment Control Guideline for Urban Construction"*
- August 2010 Credit Valley Conservation and Toronto and Region Conservation *"Low-Impact Development Stormwater Management Planning and Design Guide"*
- Municipal engineering standards

6.2 Stormwater Management Facilities

The specific design of stormwater management facilities will be designed to municipal stormwater management standards. Please refer to those standards for specific engineering requirements.

6.3 Submission/Review Process

All development submissions shall include a report outlining stormwater controls. The level of report detail required is dependent on the type of development and the stage of approval being sought.

The purpose of the report is to:

- Indentify the quality and quantity impacts of the change in stormwater runoff on the watercourses and existing infrastructure due to the proposed development
- Determine if any improvements to municipal infrastructure are required to support the proposed development
- Determine mitigation measures to minimize any negative impacts

6.3.1 Report Requirements for Site Plans

The purpose of a SWM report for this type of development is to show:

- how SWM treatment will be accommodated on-site
- the site is not encroaching into floodplain or other environmentally sensitive areas
- the site has no adverse impact on downstream municipal infrastructure

A design brief or letter report is sufficient for sites less than 5.0Ha.

Surface storage for stormwater quantity control (i.e. parking lot and rooftop storage) shall be considered only if it is demonstrated that no other measures for stormwater quantity control can be reasonably implemented. Above and below-ground stormwater storage can be achieved in parking lots on private sites by strategically placing a restriction in an outlet structure. For infrastructure that will remain under private ownership, orifice plates and catch basin (CB) inlet control devices (ICDs) are discouraged since they can easily be removed. Orifice tubes (short sections of undersized pipes) are recommended instead of orifice plates.

Stormwater can be stored on flat rooftops, with the outflow controlled by specialized roof drains. Runoff from rooftops is considered clean and will not require quality treatment, unless mixed with other runoff in the drainage system.

Copies of all relevant recent soils and/or hydrogeological investigations must be included with the submission.

The following items shall be included in the SWM document:

a) An outline of all relevant background information (planning studies, OP, zoning plan, MDP)

b) Soils information derived from a soils or hydrogeological report written by a qualified engineer

c) A discussion of the municipal engineering standards and design criteria applicable to the site, including screening of SWM approaches

d) Drainage area details
   - All drainage area plans shall include:
     - Source of topographic information (such as municipal GIS, provincial OBMs, local survey), collection date (survey date, LiDAR flight date), and benchmark (if applicable)
     - Property limits
     - watercourse(s), if applicable
     - top of bank location(s), if applicable
     - Regulatory floodline(s), if applicable
     - Regulatory fill lines(s), if applicable
     - catchment areas (tagged with ID #, area size, and C or CN value)
     - natural heritage areas
   - In addition to the items above, the pre-development drainage area plan shall include:
     - existing buildings and infrastructure
     - contours at 0.5m increments, extending to a suitable distance beyond the property limits to support off-site drainage patterns
     - overland flow paths
     - the outlet of any tributary storm sewer network
   - The post-development drainage area plan shall include:
     - proposed buildings and stormwater infrastructure
     - proposed storm sewer system
     - length, size, grade, and direction of flow for each section of storm sewer
     - SWM facility, its inlet(s), and outlet(s), if applicable
     - overland flow route(s)

e) If parking lot storage is being proposed:
   - The design shall ensure that the minimum freeboard is 0.3m (or as dictated by municipal standards) is obtained between the lowest opening of any buildings and the 100-year ponding level.

- The site grading plan shall include an emergency overflow, designed to route runoff safely for events greater than the 100-year storm. Runoff shall be directed to a suitable downstream outlet.
- The site servicing plan shall show details of the orifice tube (or plate) and its outlet. Storm pipe inverts and manhole top of grate elevations shall also be shown.
- The maximum depth of ponded water shall not exceed 0.3m

f) If rooftop lot storage is being proposed, the following are required:
- Copies of building mechanical drawings, stamped by a mechanical engineer, to confirm the manufacturer, model type, and location of roof drains.
- Copies of the roof drain product specifications to confirm release rates and surface ponding.
- Calculations of ponding volume, release rate, and drawdown time. These must be for individual structures as well as for the total for the roof(s).
- An overflow scupper/weir shall be incorporated into the roof design.
- The site servicing drawings shall show the location, size, and type of connection between the roof(s) and the storm pipes.

g) A grading plan supporting the post-development drainage pattern. If any surface water ponding is proposed for the site, the 5-year and 100-year storage extents and elevations shall be shown on the plan

h) A servicing plan showing all above- and below-grade infrastructure. A paper copy of the storm sewer design sheet must be included.

i) The rational method may be used for simple hydrology. The modified rational method can be used for storage calculations, as outlined below.

Table 6.1 Modified Rational Method Calculation

1	2	3	4	5
Time (min)	Intensity, I *for duration shown in column 1* (mm/hr)	Peak Runoff, Q *for intensity shown in column 2* (m^3/s)	Controlled Outflow (m^3/s)	Storage Volume (m^3)
		Q = .00278 * C * A * I		V = [(3)-(4)] * (1) * 60
5				
10				
Etc…				

j) An erosion and sediment control plan

k) All calculations used to derive design variables and/or model input values (i.e. Curve number, runoff coefficients, initial abstraction, time of concentration, overland flow length, manning number, and percent impervious) must be included.

l) Calculations of pre- and post-development runoff, using the appropriate variables as shown in **Appendix C**. All assumptions must be stated, and reference tables/charts/documents used for design variables must be included in technical appendices. Discussion shall include:

- Calculation of permissible release rate and required on-site storage
- Methods of run-off attenuation and on-site storage
- Measures to maintain or improve water quality
- Measures to minimize downstream impacts (i.e. erosion, flooding)
- A table comparing peak pre-development, post-development uncontrolled, and post-development controlled flow rates
- A stage-storage-discharge table, showing individual and total outlet flows.

m) If major/minor separation is incorporated into the design, a hydrology model such as VO_2 shall be used for runoff and storage routing. Design storm distributions and durations shall match the recommendations of the appropriate subwatershed study or MDP. If no such study exists, the SCS type II, Chicago, and AES Southern Ontario 30% distribution shall be applied for 6-hour, 12-hour, and 24-hour durations.

n) Rainfall data may be extracted from the relevant municipal engineering standards. If none are stated, appropriate equations are found in **Appendix B.**

o) Digital copies of all model files must be included on a CD; hardcopy printouts of the model shall be included in the technical appendix. Paper copies of all calculations must be included in technical appendices.

p) A discussion of the quality treatment that will be provided shall be included. All supporting calculations, drawing details, and manufacturer’s specifications shall be included.

q) The report and all engineering plans shall be stamped by a professional engineer.

6.3.2 Preliminary Submission for Subdivision Draft Plan Approval

The purpose of this report is to show at a conceptual level:

- the subdivision road pattern will properly direct major flow
- the lots are not encroaching into floodplain or other environmentally sensitive areas
- the SWM block is large enough to contain the minimum size of facility necessary to provide the required level of treatment
- SWM facilities will be on lands dedicated to the municipality <u>in addition to</u> any lands required to be dedicated for park purposes under the Planning Act.

A SWM report is required. The following items shall be included in the SWM report:

1. <u>Main body of report</u>
   a) An outline of all relevant background information (planning studies, OP, zoning plan, MDP)

   b) Discussion of current and proposed land use

   c) Soils information derived from recent soils and/or hydrogeological studies. If neither is available, soils maps or other reliable data may be used.

   d) An explanation of the municipal engineering standards and design criteria applicable to the site, including screening of SWM approaches

   e) Calculations of pre- and post-development runoff, using a hydrology model such as VO_2. **Appendix C** lists typical values for key input parameters. Discussion shall include:
      - o Calculation of permissible release rate and required on-site storage
      - o Methods of run-off attenuation and on-site storage
      - o Measures to minimize downstream impacts (ie.erosion, flooding)

   f) Design storm distributions and durations shall match the recommendations of the appropriate subwatershed study or MDP. If no such study exists, the SCS type II, Chicago, and AES Southern Ontario 30% distribution shall be applied for 6-hour, 12-, and 24-hour durations. The event which produces the greatest runoff peaks and volumes shall be used for sizing major systems. Hurricane Hazel is the Regional storm.

   g) Rainfall data may be extracted from the relevant municipal engineering standards. If none are stated, appropriate equations are found in **Appendix B.**

   h) A table comparing peak flow rates for pre-development, post-development uncontrolled, and post-development controlled. Also included shall be a discussion of the results, and how the SWM facilities meet municipal and GRCA criteria.

   i) The worst-case or emergency scenario is to be indentified (i.e. plugged drains, blocked control structures). The resulting effect on the SWM facility shall be identified (i.e. Maximum ponding limits, berm stability, emergency overflow route)

2. <u>Appendices</u>
   a) All technical reference tables/charts/documents used as a source for design variables

   b) Printout of hydrology model, including:

- o detailed printout of one scenario
- o summary printout of all other scenarios
- o a schematic of each unique model scenario

c) Digital copies of all model files must be included on a CD

d) Copies of all calculations must be included in technical appendices.

e) Copies of any soils and/or hydrogeological reports.

3. <u>Plans</u>

a) A copy of the draft plan signed by an Ontario Land Surveyor

b) All drainage area plans shall include:
- o Source of topographic information (such as municipal GIS, provincial OBMs, local survey), date of information (survey date, LiDAR flight date), and benchmark (if applicable)
- o Property limits
- o watercourse(s), if applicable
- o top of bank location(s), if applicable
- o Regulatory floodline(s), if applicable
- o Regulatory fill lines(s), if applicable

c) In addition to the items above, the pre-development drainage area plan shall include::
- o contours at 0.5m increments, extending to a suitable distance beyond the property limits to support off-site drainage patterns
- o overland flow paths
- o the outlet of any tributary storm sewer network
- o watercourse(s), swales, ponds
- o catchment areas (tagged with ID #, area size, and C or CN value)

d) Post-development drainage area plan showing:
- o underlying draft plan layout (with lot, block, easement, and road pattern)
- o the major flow route
- o conceptual minor system layout
- o the SWM facility, inlet(s), and outlet(s)

e) A rough grading plan must be provided showing proposed grades at key locations, to support the proposed major flow route.

A professional engineer must stamp and sign the report as well as all engineering drawings.

6.3.3 Detailed Submission for Subdivision

The purpose of this report is to provide detailed calculations, methodology, background criteria, and engineering drawings to support the preliminary concept. Typically the report is an expansion of the report written for the draft plan stage. This is required to get clearance of draft plan conditions.

The following items shall be included in the SWM report:

1. Main body of report
   a) An outline of all relevant background information (planning studies, OP, zoning plan, MDP, draft SWM report and plans)

   b) An explanation of the applicable municipal engineering standards and design criteria used in the design

   c) Calculations of pre- and post-development runoff, using a hydrology model such as VO_2. **Appendix C** lists typical values for key input parameters. Discussion shall include:
      - o Calculation of permissible release rate and required on-site storage
      - o Methods of run-off attenuation and on-site storage
      - o Measures to maintain or improve water quality
      - o Measures to minimize downstream impacts (i.e. erosion, flooding)

   d) Design storm distributions and durations shall match the recommendations of the SWM report created for draft plan approval. If no such study exists, the SCS type II, Chicago, and AES Southern Ontario 30% distribution shall be applied for 6-hour, 12-, and 24-hour durations. The event which produces the greatest runoff peaks and volumes shall be used for sizing major systems. Hurricane Hazel is the Regional storm.

   e) Rainfall data may be extracted from the relevant municipal engineering standards. If none are stated, appropriate equations are found in **Appendix B.**

   f) A table comparing peak flow rates for pre-development, post-development uncontrolled, and post-development controlled. Also included shall be a discussion of the results, and how the SWM facilities meet municipal and GRCA criteria

   g) Stage-storage-discharge table for individual structures and total flows for all outlet structures

   h) Table(s) summarizing pre- and post-development catchment parameters (i.e. ID, area, T_{imp}, X_{imp}, CN*, I_a, T_p)

   i) Discussion of maintenance and operation of SWM facility (i.e. Annual maintenance requirements, frequency of sediment cleanout)

2. Appendices
   a) All technical reference tables/charts/documents used as a source for design variables.

   b) Detailed soils report from a qualified professional engineer discussing:
      - o the viability of using native soils for the SWM facility
      - o soils data
      - o groundwater elevations in the vicinity of the SWM block. A minimum of one borehole shall be located near the centre of the SWM block

- o recommendations for SWM facility bottom lining if native soils are not strong enough to support heavy maintenance equipment
- o recommendations for pond liner and construction methods in cases of high groundwater
- o recommendations for perimeter berm design. Validation must be provided if top width will be less than 3.0m.

c) All calculations used to derive design variables and/or model input values (i.e. Curve number, runoff coefficients, initial abstraction, time of concentration, overland flow length, manning number, and percent impervious) must be included.

d) Drawdown time calculations

e) Major system capacity calculations

f) Erosion protection sizing

g) Calculations for the sizing of major flow inlet(s) and emergency overflow(s). Although SWM facilities are not sized to store the Regulatory event, calculations may be required to show the Regulatory flow can be safely conveyed through the facility via the overland flow inlet(s) and emergency overflow(s).

h) Calculations for the sizing of minor system inlet(s)

i) SWM facility maintenance cleanout calculations

j) Printout of hydrology model, including:
   - o detailed printout of one scenario
   - o summary printout of all other scenarios
   - o a schematic of each unique model scenario

k) Digital copies of all model files must be included on a CD

l) Paper copy of storm sewer design and culvert design sheets

m) Paper copy of the hydraulic gradeline (HGL) sheets

n) A "How-To" SWM Facility Operators Manual to guide municipal Public Works staff to carry out routine maintenance, determine performance measures, calculate costs, and determine major cleanout requirements. Colour photographs shall be included where required for identification of key components. This shall be bound in a separate appendix that can be used as a standalone document.

3. Plans

a) Pre-development drainage area plan showing:
   - o property limits
   - o contours at 0.5m increments, extending to a suitable distance beyond the property limits to support off-site drainage patterns
   - o overland flow paths
   - o the outlet of any tributary storm sewer network
   - o watercourse(s)

- top of bank location(s)
- Regulatory floodline(s)
- Regulatory Conservation fill lines
- environmentally sensitive areas and/or natural heritage areas
- any external tributary area
- catchment areas (tagged with ID #, area size, and C or CN value)

b) Post-development drainage area plan showing:
- lot, block, and easement layout and road pattern
- minor system: pipe network (showing length, size, and grade of pipe); ditch network; and culverts. All pipes and ditches shall show direction of flow
- labeled manholes
- catchment areas (tagged with ID #, area size, and C or CN value)
- property limits
- the major flow route, limited to public property within the road right-of-way or dedicated easements
- the SWM facility, inlet(s), outlet(s), major inflow inlet(s), emergency overflow outlet(s)
- catchment areas (tagged with ID #, area size, and C or CN value)
- separate major and minor drainage area plans are necessary if the major and minor drainage patterns are substantially different

c) Grading plan showing, as minimum:
- proposed and existing grades for all lot corners and boundaries
- finished floor and basement elevations
- detailed lot grading
- for larger blocks, proposed elevation at 15m intervals along frontage, and at reasonable intervals along sides and rear of the block
- extent of proposed overland flow inundation

d) SWM facility plans showing:
- inlet structure detail (pipe size(s), invert elevation(s), pipe grate, MH size, MH top of grate elevation, headwall, erosion protection)
- outlet structure detail (orifice/tube size(s), invert elevation(s), MH size, MH top of grate elevation, headwall, erosion protection, outlet grate)
- minimum of two cross sections through pond (perpendicular to each other) indicating existing ground profile, bottom elevations, top of berm elevations, side slopes, soil/vegetation type, water surface elevations (permanent, 2-, 5-, 10-, 25-, 50-, and 100-year)
- forebay length and width dimensions
- forebay berm cross-section
- major flow path(s) and detail
- cross-section detail of maintenance access
- emergency overflow weir location and cross-section detail
- fence location (if required)
- sign location (if required)
- sediment drying area details and extents
- Landscaping plans for the facility prepared by a qualified landscape architect

    - Erosion and sediment control plans showing the level of detail outlined in section 9

e) Plan and profile drawings, as per municipal requirements. The HGL and proposed basement floor elevations shall also be plotted.

A professional engineer must stamp and sign the report as well as all engineering drawings.

7 STORM INFRASTRUCTURE DESIGN

7.1 Design Flows

The runoff directed to each storm pipe shall be computed on standard storm sewer design sheets according to the Rational formula

Q=0.002778 CIA, where:

A= contributing drainage area in hectares
C= imperviousness, or runoff co-efficient dimensionless
I = rainfall intensity (mm/hr)
Q= volume of runoff in cubic metres per second

7.2 Rainfall Intensity

For normal residential and industrial developments, the minor system shall by sized for the 5-year flow. The rainfall intensity shall be determined from Yarnell's 5-Year Storm Curve

I=2464 / (t + 16), where t is time in minutes

using a 15 minute inlet entry time at the head of the system for residential developments. A longer inlet time may be used if the supporting time of concentration (T_c) calculations are included.

Industrial/commercial and existing heavily developed urban areas shall use the Yarnell 10-Year Storm Curve

I=2819 / (t + 16)

with a 10 minute inlet entry time at the head of the system. A longer inlet time may be used if the supporting time of concentration (T_c) calculations are included.

The equations for all other return period events can be found in **Appendix B**.

7.3 Runoff or Impervious Coefficients

The recommended runoff coefficients to be used in storm sewer design are:

Parks over 4 hectares, cemeteries,	0.20
Parks 4 hectares and under	0.25
Single Family Residential	0.45
Single Family Residential (frontage < 12.2m)	0.60
Semi-detached Residential	0.60
Townhouses, Maisonettes, Row houses	0.75
Apartments	0.75
Schools and Churches	0.75
Industrial (range 0.8-0.9)	0.75
Commercial	0.90
Heavily Developed Areas	0.90
Paved Areas	0.95
Gravel parking Areas	0.95

To account for a decrease in the perviousness during major storms, the recommended factors as identified in MTO's Drainage Design Standards (2008) shall be used. For storms having a return period of more than 10 years, runoff coefficients shall be increased by the following values, up to a maximum coefficient of 0.95.

- 25-year event – add 10%
- 50-year event – add 20%
- 100-year event – add 25%

7.4 Pipe Sizing

Pipe capacity shall be determined on the basis of the pipe flowing full. Alternatively, the tables on the following pages can be used. A sample design sheet can be found in **Appendix D**. The value of the roughness coefficient to be used shall be as follows:

- Concrete Pipe all sizes 0.013
- Concrete Box Culverts 0.013
- Corrugated Metal 13 mm corrugations 0.024
- PVC Pipe 0.013

All minor system flow must be intercepted at each catch basin or catchbasin manhole location. Calculations may be requested to show capture capability.

7.5 Overland Flow

The depths of flooding permitted on streets for the major system are as follows:

(a) there shall be no curb overtopping,
(b) on local roads, the flow may spread to the crown,
(c) on collector roads, the flow spread must leave one lane free of water,
(d) on arterial roads, the flow spread must leave one lane in each direction free of water.

Flow across intersections is discouraged.

The major flow shall not be less than the difference between the 100-year design flow and the 5-year design flow, calculated as follows:

$$Q_{major} = Q_{100year} - Q_{5year}.$$

Table 7.1 Sewer Pipe Capacity

SEWER CAPACITY

Slope (%)	Sewer Diameter (mm)																												Slope (%)
	150		200		250		300		375		450		525		600		675		750		825		900		975		1050		
	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	
0.20											0.128	0.80	0.192	0.89	0.275	0.97	0.376	1.05	0.498	1.13	0.642	1.20	0.810	1.27	1.002	1.34	1.221	1.41	0.20
0.25									0.091	0.80	0.149	0.91	0.224	1.00	0.320	1.10	0.438	1.19	0.581	1.27	0.749	1.36	0.944	1.44	1.169	1.52	1.424	1.59	0.25
0.30							0.055	0.76	0.100	0.88	0.163	0.99	0.246	1.10	0.351	1.20	0.480	1.30	0.636	1.39	0.820	1.49	1.034	1.58	1.281	1.66	1.560	1.75	0.30
0.35							0.060	0.82	0.108	0.95	0.176	1.07	0.265	1.19	0.379	1.30	0.519	1.40	0.687	1.51	0.886	1.61	1.117	1.70	1.383	1.79	1.685	1.89	0.35
0.40					0.039	0.77	0.064	0.87	0.116	1.01	0.188	1.15	0.284	1.27	0.405	1.39	0.555	1.50	0.735	1.61	0.947	1.72	1.194	1.82	1.479	1.92	1.802	2.02	0.40
0.45					0.042	0.82	0.068	0.93	0.123	1.08	0.200	1.22	0.301	1.35	0.430	1.47	0.588	1.59	0.779	1.71	1.005	1.82	1.267	1.93	1.568	2.03	1.911	2.14	0.45
0.50			0.024	0.75	0.044	0.87	0.071	0.98	0.129	1.13	0.210	1.28	0.317	1.42	0.453	1.55	0.620	1.68	0.821	1.80	1.059	1.92	1.335	2.03	1.653	2.15	2.014	2.25	0.50
0.55			0.025	0.78	0.046	0.91	0.075	1.03	0.136	1.19	0.221	1.34	0.333	1.49	0.475	1.63	0.650	1.76	0.861	1.89	1.111	2.01	1.401	2.13	1.734	2.25	2.113	2.36	0.55
0.60			0.027	0.82	0.048	0.95	0.078	1.07	0.142	1.24	0.230	1.40	0.348	1.56	0.496	1.70	0.679	1.84	0.900	1.97	1.160	2.10	1.463	2.23	1.811	2.35	2.207	2.47	0.60
0.65			0.028	0.85	0.050	0.99	0.081	1.11	0.147	1.29	0.240	1.46	0.362	1.62	0.516	1.77	0.707	1.91	0.936	2.05	1.207	2.19	1.523	2.32	1.885	2.45	2.297	2.57	0.65
0.70			0.029	0.88	0.052	1.02	0.084	1.16	0.153	1.34	0.249	1.52	0.375	1.68	0.536	1.84	0.734	1.99	0.972	2.13	1.253	2.27	1.580	2.41	1.956	2.54	2.383	2.67	0.70
0.75	0.014	0.75	0.030	0.91	0.054	1.06	0.087	1.20	0.158	1.39	0.258	1.57	0.389	1.74	0.555	1.90	0.759	2.06	1.006	2.21	1.297	2.35	1.636	2.49	2.025	2.63	2.467	2.76	0.75
0.80	0.014	0.78	0.031	0.94	0.055	1.10	0.090	1.24	0.164	1.43	0.266	1.62	0.401	1.80	0.573	1.96	0.784	2.12	1.039	2.28	1.339	2.43	1.689	2.57	2.091	2.71	2.548	2.85	0.80
0.85	0.015	0.80	0.032	0.97	0.057	1.13	0.093	1.27	0.169	1.48	0.274	1.67	0.414	1.85	0.591	2.02	0.808	2.19	1.071	2.35	1.381	2.50	1.741	2.65	2.155	2.80	2.626	2.94	0.85
0.90	0.015	0.83	0.032	1.00	0.059	1.16	0.096	1.31	0.174	1.52	0.282	1.72	0.426	1.90	0.608	2.08	0.832	2.25	1.102	2.42	1.421	2.57	1.792	2.73	2.218	2.88	2.703	3.02	0.90
0.95	0.015	0.85	0.033	1.03	0.060	1.19	0.098	1.35	0.178	1.56	0.290	1.77	0.437	1.96	0.624	2.14	0.855	2.31	1.132	2.48	1.460	2.65	1.841	2.80	2.279	2.96	2.777	3.11	0.95
1.00	0.016	0.87	0.034	1.06	0.062	1.22	0.101	1.38	0.183	1.60	0.297	1.81	0.449	2.01	0.641	2.19	0.877	2.37	1.161	2.55	1.498	2.71	1.889	2.88	2.338	3.03	2.849	3.19	1.00
1.10	0.017	0.91	0.036	1.11	0.065	1.28	0.106	1.45	0.192	1.68	0.312	1.90	0.471	2.11	0.672	2.30	0.920	2.49	1.218	2.67	1.571	2.85	1.981	3.02	2.452	3.18	2.988	3.34	1.10
1.20	0.017	0.95	0.037	1.16	0.068	1.34	0.111	1.51	0.200	1.76	0.326	1.98	0.491	2.20	0.702	2.40	0.961	2.60	1.272	2.79	1.640	2.97	2.069	3.15	2.561	3.32	3.121	3.49	1.20
1.30	0.018	0.99	0.039	1.20	0.071	1.40	0.115	1.58	0.209	1.83	0.339	2.07	0.512	2.29	0.730	2.50	1.000	2.71	1.324	2.90	1.707	3.09	2.153	3.28	2.666	3.46	3.248	3.63	1.30
1.40	0.019	1.03	0.040	1.25	0.073	1.45	0.119	1.64	0.216	1.90	0.352	2.14	0.531	2.38	0.758	2.60	1.038	2.81	1.374	3.01	1.772	3.21	2.235	3.40	2.766	3.59	3.371	3.77	1.40
1.50	0.019	1.07	0.042	1.29	0.076	1.50	0.124	1.69	0.224	1.96	0.364	2.22	0.549	2.46	0.785	2.69	1.074	2.91	1.422	3.12	1.834	3.32	2.313	3.52	2.863	3.72	3.489	3.90	1.50
1.60	0.020	1.10	0.043	1.33	0.078	1.55	0.128	1.75	0.231	2.03	0.376	2.29	0.568	2.54	0.810	2.78	1.109	3.00	1.469	3.22	1.894	3.43	2.389	3.64	2.957	3.84	3.603	4.03	1.60
1.70	0.021	1.14	0.045	1.38	0.081	1.60	0.132	1.80	0.238	2.09	0.388	2.36	0.585	2.62	0.835	2.86	1.143	3.10	1.514	3.32	1.953	3.54	2.462	3.75	3.048	3.96	3.714	4.16	1.70
1.80	0.021	1.17	0.046	1.42	0.083	1.64	0.135	1.85	0.245	2.15	0.399	2.43	0.602	2.69	0.859	2.94	1.177	3.19	1.558	3.42	2.009	3.64	2.534	3.86	3.137	4.07	3.822	4.28	1.80
1.90	0.022	1.20	0.047	1.45	0.086	1.69	0.139	1.91	0.252	2.21	0.410	2.50	0.618	2.77	0.883	3.03	1.209	3.27	1.601	3.51	2.064	3.74	2.603	3.96	3.223	4.18	3.927	4.39	1.90
2.00	0.022	1.23	0.048	1.49	0.088	1.73	0.143	1.96	0.259	2.27	0.421	2.56	0.634	2.84	0.906	3.10	1.240	3.36	1.642	3.60	2.118	3.84	2.671	4.07	3.306	4.29			2.00
2.50	0.025	1.38	0.054	1.67	0.098	1.94	0.160	2.19	0.289	2.54	0.470	2.86	0.709	3.17	1.013	3.47	1.387	3.75	1.836	4.03	2.368	4.29							2.50
3.00	0.028	1.51	0.059	1.83	0.107	2.12	0.175	2.39	0.317	2.78	0.515	3.14	0.777	3.48	1.109	3.80	1.519	4.11	2.012	4.41									3.00
3.50	0.030	1.63	0.064	1.97	0.116	2.29	0.189	2.59	0.342	3.00	0.556	3.39	0.839	3.76	1.198	4.11	1.641	4.44											3.50
4.00	0.032	1.74	0.068	2.11	0.124	2.45	0.202	2.77	0.366	3.21	0.595	3.62	0.897	4.02	1.281	4.39													4.00
4.50	0.034	1.85	0.073	2.24	0.132	2.60	0.214	2.93	0.388	3.40	0.631	3.84	0.952	4.26															4.50
5.00	0.036	1.95	0.077	2.36	0.139	2.74	0.226	3.09	0.409	3.59	0.665	4.05	1.003	4.49															5.00

Slope (%)	Sewer Diameter (mm)																												Slope (%)
	1200		1350		1500		1650		1800		1950		2100		2250		2400		2550		2700		3000		3600				
	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V			
0.20											6.639	2.15	8.090	2.26	9.724	2.37	11.550	2.47	13.576	2.58	15.812	2.68	20.941	2.87	34.052	3.24			0.20
0.25									5.996	2.28	7.423	2.41	9.044	2.53	10.871	2.65	12.913	2.77	15.179	2.88	17.678	2.99	23.413	3.21	38.071	3.62			0.25
0.30							5.208	2.36	6.568	2.50	8.131	2.64	9.908	2.77	11.909	2.90	14.145	3.03	16.627	3.15	19.365	3.28	25.647	3.51	41.705	3.97			0.30
0.35							5.625	2.55	7.094	2.70	8.782	2.85	10.701	2.99	12.863	3.13	15.279	3.27	17.960	3.41	20.917	3.54	27.702	3.80	45.047	4.29			0.35
0.40					4.664	2.56	6.014	2.72	7.584	2.89	9.389	3.05	11.440	3.20	13.751	3.35	16.334	3.50	19.200	3.64	22.361	3.78	29.615	4.06					0.40
0.45					4.947	2.71	6.379	2.89	8.044	3.06	9.958	3.23	12.134	3.39	14.585	3.55	17.324	3.71	20.364	3.86	23.717	4.01	31.411	4.30					0.45
0.50			3.937	2.66	5.215	2.86	6.724	3.05	8.479	3.23	10.497	3.41	12.791	3.58	15.374	3.75	18.262	3.91	21.466	4.07	25.000	4.23							0.50
0.55			4.129	2.79	5.469	3.00	7.052	3.19	8.893	3.39	11.009	3.57	13.415	3.75	16.125	3.93	19.153	4.10	22.514	4.27	26.221	4.44							0.55
0.60			4.313	2.92	5.712	3.13	7.365	3.34	9.289	3.54	11.499	3.73	14.011	3.92	16.842	4.10	20.005	4.28	23.515	4.46									0.60
0.65			4.489	3.04	5.946	3.26	7.666	3.47	9.668	3.68	11.968	3.88	14.584	4.08	17.529	4.27	20.821	4.46											0.65
0.70			4.659	3.15	6.170	3.38	7.955	3.60	10.033	3.82	12.420	4.03	15.134	4.23	18.191	4.43													0.70
0.75	3.522	3.02	4.822	3.26	6.387	3.50	8.235	3.73	10.385	3.95	12.856	4.17	15.665	4.38															0.75
0.80	3.638	3.12	4.980	3.37	6.596	3.62	8.505	3.85	10.726	4.08	13.278	4.31																	0.80
0.85	3.750	3.21	5.134	3.47	6.799	3.73	8.766	3.97	11.056	4.21	13.686	4.44																	0.85
0.90	3.859	3.31	5.282	3.58	6.996	3.84	9.021	4.09	11.376	4.33																			0.90
0.95	3.964	3.40	5.427	3.67	7.188	3.94	9.268	4.20	11.688	4.45																			0.95
1.00	4.067	3.48	5.568	3.77	7.375	4.04	9.509	4.31																					1.00
1.10	4.266	3.65	5.840	3.95	7.734	4.24																							1.10
1.20	4.456	3.82	6.100	4.13	8.078	4.43																							1.20
1.30	4.637	3.97	6.349	4.30																									1.30
1.40	4.812	4.12	6.588	4.46																									1.40
1.50	4.981	4.27																											1.50
1.60	5.145	4.41																											1.60
1.70																													1.70
1.80																													1.80
1.90																													1.90
2.00																													2.00

7.6 Culvert and Bridge Hydraulic Capacity

Bridges and culverts at watercourse crossings will be designed to the recommendations of the *Canadian Highway Bridge Design Code,* as wells as item WC-1 of MTO's 2008 *Highway Drainage Design Standards*, as follows:

• Driveway	10-year flow
• Local road, span less than 6.0m:	10-year flow
• Local road, span greater than 6.0m:	25-year flow
• collector road, span less than 6.0m:	25-year flow
• collector road, span greater than 6.0m:	50-year flow
• arterial road, span less than 6.0m:	50-year flow
• arterial road, span greater than 6.0m:	100-year flow

Relief flow passage must be incorporated into the design of the roadway in cases where the Regulatory flow exceeds the design flow. Under Regulatory conditions, the maximum depth of flow on the roadway shall not exceed 0.3m, and the product of velocity and depth shall not exceed $0.8m^2/s$.

7.7 Hydraulic Gradeline Calculations

The pipe system will be designed to provide at least 0.3m freeboard between the minimum basement floor elevation and the 25-year hydraulic gradeline (HGL). Spreadsheet calculations shall be provided to show all work. The 25-year HGL and proposed basement floor elevations shall be plotted on all plan/profile drawings .

The rainfall intensity shall be determined from the 25-year equation

$I = 3886 / (t + 18)$ where:

I = rainfall intensity in mm/hr
t = time in minutes

Pipe losses shall be calculated using the friction slope. The change in HGL across a manhole is calculated as shown in **Figure 7.1** below, using the k factors listed in **Table 7.1**. If the upstream HGL is below the pipe obvert, the HGL shall default to the upstream pipe obvert.

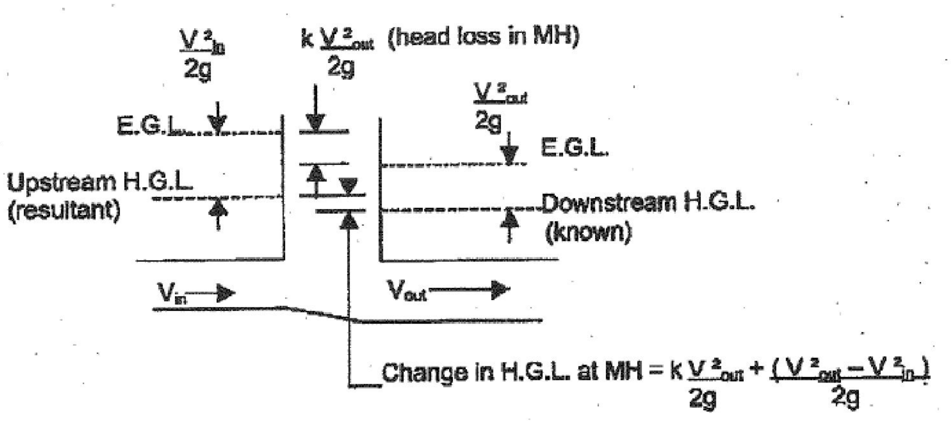


Figure 7.1 MH Losses

Table 7.2 MH Loss Coefficients

Angle of Flow	Loss Coefficient (k)
0° - 25°	0.1
25° - 45°	0.3
45° - 60°	0.5
60° - 90°	0.8

A sample spreadsheet is included in **Appendix D**.

7.8 Outlets

Outlet structures must be designed so that exit velocities minimize potential erosion or damage in the vicinity of the outfall. Where the discharge velocity is high or supercritical, energy-dissipating structures (such as rip rap, headwalls, wingwalls, stilling basins) are required to prevent erosion of the natural channel bed or banks.

Outfalls to natural watercourses shall discharge at or above the bankfull water elevation of the watercourse. Submergence of the outlet during times of high watercourse water levels must be assessed. The outlet invert shall be above the 25-year flood elevation of the receiving channel.

8 STORMWATER MANAGEMENT FACILITIES DESIGN

The aesthetic and landscape design of the SWM facility shall have regard for approved community plans, master drainage plans, subwatershed plans. The guiding principal for this plan shall be that the stormwater management facilities will be a landscape/aesthetic amenity to a community and not simply a fenced treatment facility.

8.1 Dry Pond Requirements

The design of a **dry pond** shall satisfy Table 4.8 of the MOE's *"Stormwater Management Planning and Design Manual"* as well as the criteria listed below:

- maximum water depth of 1.8m
- 0.3m freeboard above the maximum operating water surface elevation
- Side slopes no steeper than 5:1 side slope from the pond bottom to the limit of maximum extended detention
- 1.0% minimum, 5.0% maximum pond bottom slope
- maximum length:width ratio is 4:1

8.2 Wet Pond Requirements

The design of a **wet pond** shall satisfy Table 4.6 of the MOE's *"Stormwater Management Planning and Design Manual"* as well as the criteria listed below:

- permanent pool depth shall be a minimum of 1.0m, and a maximum of 2.0m
- maximum water depth of 4.0m
- 0.3m freeboard above the maximum flood flow level
- Side slopes shall be no steeper than 5:1 at the permanent water's edge (1.5m above and 1.5m below). Below this level, side slope shall be no steeper than 3:1. Above this shelf, side slope shall be no steeper than 7:1
- maximum length:width ratio is 4:1
- Perimeter berm shall have a minimum 3.0m top width, unless substantiated by a qualified soils engineer. The design shall not incorporate the use of retaining walls below the top of berm elevation.

8.3 Wetland Requirements

The design of a **wetland** facility shall satisfy Table 4.7 of the MOE's *"Stormwater Management Planning and Design Manual"* as well as the criteria listed below:

- maximum extended detention depth of 1.0m above permanent pool elevation
- 0.3m freeboard above the maximum operating surface water level
- permanent pool depth shall be a minimum of 0.15m, and a maximum of 0.3m
- maximum side slope between the permanent pool level and pond bottom is 5:1
- side slopes above the permanent pool level shall be no steeper than 5:1, up to the maximum extended detention water level

8.4 SWM Pond Requirements

The design for SWM ponds shall include the following items:

- A gravity by-pass pipe shall be provided to allow the facility to be drained to within 0.5m of pond bottom for emergency/maintenance work (not required for dry ponds)

- The forebay bottom shall be lined with Terrafix Blocks or equivalent

- plantings:
  - slopes 5:1 and steeper ranging from a minimum horizontal distance of 3.0m from the permanent pool level to the property line (not including walkways and trails) shall be planted
  - Trees shall be at a minimum rate of 1 tree (40mm caliper) per $50m^2$
  - Shrub planting density shall vary depending on the degree of slope, as shown in **Figure 8.1** below. In this case 100% density means 1 shrub per $1m^2$, and 25% density means 1 shrub per $4m^2$

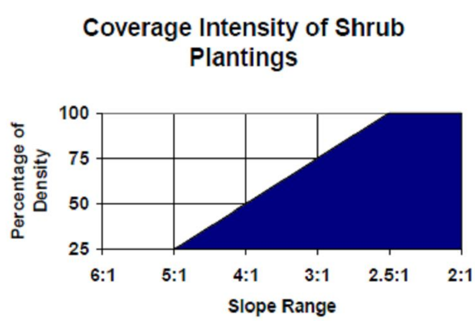


Figure 8.1 Shrub Density Planting

- Perimeter fencing:
  - Fencing is not required if gentle grading is incorporated into the design as per **Figure 8.2**
  - shall be installed in low-visibility and low-use areas (ie. employment lands) in order to control encroachment and debris
  - shall be installed to mark the limits of private and municipal lands
  - shall be minimized elsewhere; benching, terracing, and “unfriendly” planting used to deter access

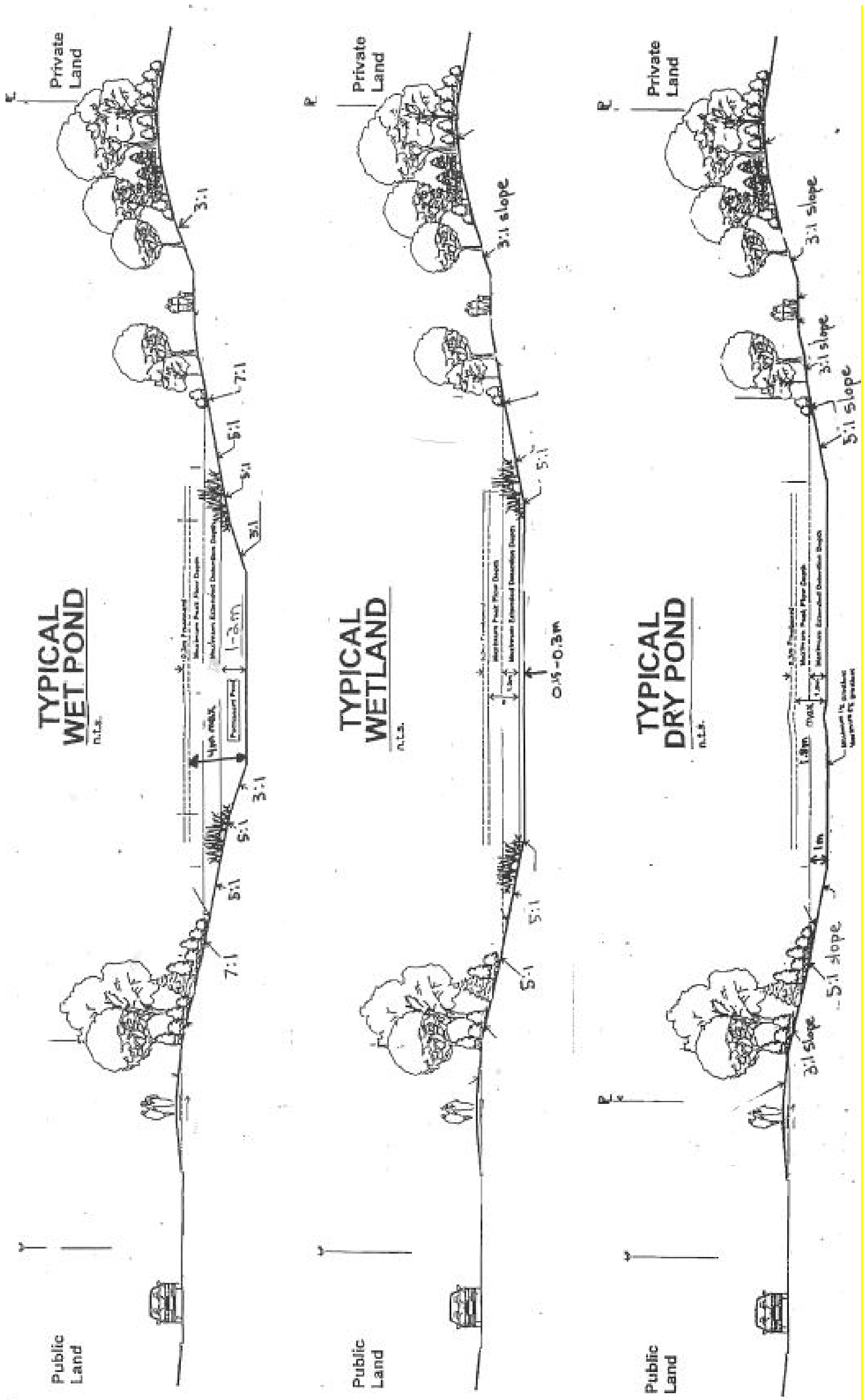


Figure 8.2 SWM Facility Cross-section

- Sign:
  - Shall be installed in easily accessible, visible areas to inform the public of the function, use, and maintenance of the SWM facility/park, as shown in **Figure 8.3**

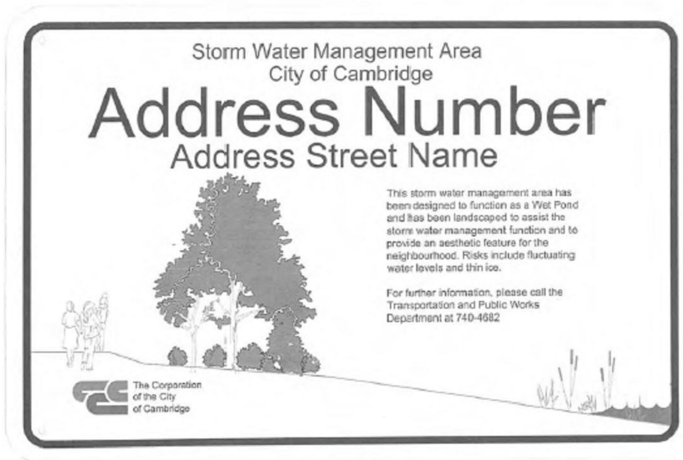


Figure 8.3 Sample SWM Pond sign

- Recreational trail:
  - if a trail is required, it shall be located above the 5-year water surface level in order to prevent frequent flooding
  - minimum width as required by municipal standards
  - to enhance safety and comfort, sightlines shall be preserved for 3.0m either side of the trail
  - all areas of trail shall have barrier-free egress

- Maintenance access:
  - required for the forebay, all inlets, and all outlets
  - minimum 3.0m width
  - maximum 8% longitudinal slope
  - maximum 2% crossfall
  - minimum 10m turning radius
  - consists of 300mm of 50mm crusher run limestone base with suitable surface treatment on an appropriate base as approved by the municipality

- Sediment drying area:
  - located adjacent to forebay
  - 2%-5% crossfall to direct runoff to facility
  - Surface treatment consistent with access road sized for:
    - predicted 10-year sediment volume, piled 1.0m high, or
    - Equivalent to forebay bottom area

- Emergency overflow spillway:
  - sized for either the 100-year or Regulatory event (dependent on facility location)
  - set at 100-year water surface elevation
  - erosion protection consisting of soil reinforcement with natural vegetated surface treatment required from the top to base of spill area

- Major flow inlets:
  - sized to convey 100-year or Regulatory event
  - directed to main cell, not forebay(s)
  - flat-bottomed channel with maximum 3:1 side slopes
  - maximum 0.3m flow depth, and minimum 0.1m freeboard
  - erosion protection required, consisting of soil reinforcement with natural vegetated surface treatment

- Sizing of minor system inlet meeting the following criteria:
  - erosion protection required between pipe invert and bottom of forebay, sized to match headwall width at inlet and extending to 1.5m either side of headwall at forebay bottom
  - Invert is at or above permanent water elevation

- Sizing of forebay berm meeting the following criteria:
  - Set at the permanent water elevation
  - minimum 2.0m top width
  - side slopes shall be no steeper than 3:1
  - incorporate flow-through culverts with minimum 0.3m cover

- Sizing outlet meeting the following criteria:
  - bottom draw pipe is required, located a minimum 1.0m from pond bottom
  - protected from erosion
  - Invert is at or above permanent water elevation
  - Shall incorporate shut-off capability to prevent flow from the facility in the event of a spill
  - Shall not outlet directly to a watercourse or at the top of steep valley slopes. Avoid placing at the outside bend of channel meanders. If possible, place outside meander belt

8.5 Post-construction Monitoring

Developers are required to monitor how the SWM facility operates if the ownership of the facility has not transferred to the municipality within three (3) years of initial construction of the facility. Monitoring is mandatory for the months of May-October, using data logger and pressure transducer. Temporal comparisons shall be made to rain data collected from a nearby rain gauge, whose location shall be approved by the municipality. Results shall be compared with 5-8 significant storms to verify the permanent water elevation, water level fluctuations, outflow, and drawdown time. Data shall be provided to the Director of Public Works monthly.

8.6 Assumption by Municipality

The SWM facility will be assumed by the Municipality as per the subdivision agreement, or once the entire subdivision is complete. The developer is to provide as-built drawings of the SWM pond block (surveyed within 2 months of the time of assumption) showing, as a minimum:

- Key elevations of all inlet and outlet structures:
  - Top of grate elevations
  - Invert elevations
  - Pipe sizes and lengths
  - Orifice sizes
- Adequate bathymetric elevations to confirm clean-out or working bottom elevation
- Perimeter elevations to confirm side slopes
- Elevations of emergency overflow

9 SEDIMENT AND EROSION CONTROL

9.1 Scope

The Sediment and Erosion Control Plan must illustrate how the site will be graded to provide erosion protection during the construction phase. Reference shall be made to the December 2006 manual by the Greater Golden Horseshoe Area Conservation Authorities, *"Erosion and Sediment Control Guidelines for Urban Construction"*.

9.2 Procedure

The base drawing for this Plan is to be the Grading Plan. Superimposed on these drawings, the Engineer is to indicate any temporary and/or permanent control devises and/or ditches and ponds required to keep all materials and surface runoff contained on site.

Quantity calculations, dimensions, and construction materials shall be provided in separate letter brief, or contained within the SWM report.

All permanent sediment and erosion control devices are to be shown on the Plan and Profile Drawing while any temporary construction is to be shown on the Sediment and Erosion Control Plan.

9.3 Implementation

The Sediment and Erosion Control Plan must be submitted with the first submission at the detailed design stage.

9.4 Plan Requirements

The following is required to be shown:

- drawing scale, preferably 1:1000
- geodetic benchmark, or GIS reference
- legend
- north arrow
- key map including site boundary limits, and location of existing buildings
- existing contours at 0.5m intervals to show flow direction. Contours to be extended beyond property limit by 15m-30m
- existing vegetation, showing trees to be retained/protected or removed
- location of any water body, such as wetlands, rivers, streams, or drainage course on or within 30m of the site. Regional floodline and regulated fill line shall also be indicated
- embankments 6:1 or steeper to be shown with slope ratio
- temporary swales, with corresponding gradient (incl. typical swale detail)
- location of all proposed stockpiles, with perimeter fencing
- silt fence locations, with appropriate OPSD detail
- temporary sediment ponds, with outlet and inlet details, with minimum one cross-section
- check dam locations, with appropriate OPSD detail
- sedimentation detail for catch basins and manholes
- mudmat locations, with construction details
- signed professional engineer's stamp

The following notes are required on the drawing:

- All erosion control measures are to be in place before starting construction and remain in place until restoration is complete
- Maintain erosion control measures during construction
- Prevent wind-blown dust

9.5 Construction Requirements

The following apply to land disturbance activities that result in runoff leaving the site:

- Any soil or dirt pile must be stockpiled in such a way that it will not erode and find its way to a watercourse or a roadway. Any stockpiles topsoil shall not be uncovered more than thirty (30) days, after which it shall become covered with mulch or vegetation. A sediment control fence shall be erected around the storage pile during the entire time when it is left uncovered.
- A three (3) meter wide buffer strip of undisturbed land must be provided along the perimeter of the downslope of the site. It must be entirely located upon the site which is to be developed. The buffer zone shall be increased to fifteen (15) meters and thirty (30) meters respectively when the site abuts warmwater or coldwater fisheries.
- A double row of heavy-duty silt fence shall be installed adjacent to any watercourses, separated by a 3m vegetated strip.
- Temporary swales shall be sized to convey a 5-year flow

Definitions

Regulatory Floodplain
Within the GRCA's jurisdiction, the Regulatory Floodplain is the area that would be flooded if the Regulatory Storm event were centered over any one particular watershed. If the Regional Storm or more severe storm has occurred, then the Regulatory Flood is the observed flood level. The 1:100 year flood is the Regulatory flood if it is a greater flood than that produced by the Regional storm.

Watercourse
A watercourse is a channel that carries water from an area to a receiving watercourse or water body. These watercourses may be either perennial or intermittent in nature. Roadside ditches that receive runoff only from an adjacent road and sheet flow from adjacent land are not considered a watercourse.

APPENDICES

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APPENDIX A

Submission Check Lists

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REPORT CHECKLIST

1.0 GENERAL

Site Description

- ☐ Location Plan– nearest roads, watershed & subwatershed
- ☐ Existing Conditions – land use on site & surrounding areas
- ☐ Proposed Conditions
- ☐ Drainage Area – for the site and any external lands
- ☐ Watercourses, Wetlands - present on site, and type (permanent or intermittent)
- ☐ Drainage patterns and ultimate drainage location/outfall
- ☐ Legal Plan, or Draft Plan

Background Information

- ☐ Per Previous Reports and Relevant SWM Requirements
- ☐ Existing Models

2.0 QUALITY CONTROL DISCUSSION AND CALCULATIONS

- ☐ Level of Protection
- ☐ Drainage Area to Facility (Ha)
- ☐ Percentage Impervious – total and directly connected
- ☐ SWM Facility Monitoring and Maintenance Requirements
- ☐ Sediment drying area in SWM block

a) Oil-Grit Separator

- ☐ Approved Manufacturer
- ☐ Model Number
- ☐ Sizing Calculations Included
- ☐ TSS Removal (%)
- ☐ Annual Runoff Treated (%)

b) Extended Detention Wet Ponds

- ☐ Permanent Pool Storage Requirements (m^3/Ha)
- ☐ Permanent Pool Storage Requirements (m^3)
- ☐ Permanent Pool Volume Provided (m^3)
- ☐ Extended Detention Storage Requirements (m^3/Ha)
- ☐ Extended Detention Storage Requirements (m^3)
- ☐ Extended Detention Volume Provided (m^3)
- ☐ 0.3m of free board
- ☐ Outlet Design
- ☐ Permanent Pool Depth (m)
- ☐ Extended Detention Depth (m)
- ☐ Side Slopes above Permanent Pool
- ☐ Side Slopes below Permanent Pool
- ☐ Drawdown time (hrs)
- ☐ Length to Width Ratio
- ☐ Forebay Depth
- ☐ Forebay % of Total Facility Area

- ☐ Emergency Overflow Weir Design
- ☐ Capacity of Overflow Weir
- ☐ Design of Overflow Weir
- ☐ Major Overland Flow Route inlet capacity calculations
- ☐ Planting plan

c) Wetland

- ☐ Permanent Pool Storage Requirements (m^3/ha)
- ☐ Permanent Pool Storage Requirements (m^3)
- ☐ Permanent Pool Volume Provided (m^3)
- ☐ Extended Detention Storage Requirements (m^3/Ha)
- ☐ Extended Detention Storage Requirements (m^3)
- ☐ Extended Detention Volume Provided (m^3)
- ☐ 0.3m of free board
- ☐ Outlet Design
- ☐ Drawdown time (hrs)
- ☐ Permanent Pool Depth (m)
- ☐ Extended Detention Depth (m)
- ☐ Planting Plan
- ☐ Side Slopes above Permanent Pool
- ☐ Side Slopes below Permanent Pool
- ☐ Length to Width Ratio

d) Hybrid Wet Pond / Wetland

- ☐ Permanent Pool Storage Requirements (m^3/ha)
- ☐ Permanent Pool Storage Requirements (m^3)
- ☐ Permanent Pool Volume Provided (m^3)
- ☐ Extended Detention Storage Requirements (m^3/Ha)
- ☐ Extended Detention Storage Requirements (m^3)
- ☐ Extended Detention Volume Provided (m^3)
- ☐ 0.3m of free board
- ☐ Outlet Design
- ☐ Drawdown time (hrs)
- ☐ Permanent Pool Depth (m)
- ☐ Extended Detention Depth (m)
- ☐ Planting Plan
- ☐ Side Slopes above Permanent Pool
- ☐ Side Slopes below Permanent Pool
- ☐ Length to Width Ratio

3.0 QUANTITY CONTROL DISCUSSION AND CALCULATIONS

- ☐ Calculation sheets for all design variable and/or model input parameters
- ☐ Pre Development Peak Flow (m^3/s)
- ☐ Post Development Uncontrolled Peak Flow (m^3/s)
- ☐ Post Development Controlled Peak Flow (m^3/s)

- ☐ SWM Facility Type
- ☐ Stage – Storage – Discharge Table
- ☐ Outlet design
- ☐ Total Storage Required (m^3)
- ☐ Total Storage Provided (m^3)

4.0 HAZARD LAND MANAGEMENT

- ☐ Flood lines shown on plans
- ☐ Valley top of bank, stream erosion, and steep slope allowances assessed *(for confined stream systems only)*
- ☐ Wetlands and required setback limits

5.0 ENGINEERING PLANS

- ☐ Pre Development Drainage Area Plan
- ☐ Post Development Drainage Area Plan
- ☐ Proposed SWM Facility locations
- ☐ Grading Plan
- ☐ Servicing Plan
- ☐ Plan-Profile Drawings
- ☐ Erosion and Sediment Control Plan
- ☐ SWM Facility Plans
  - o Plan view
  - o cross-section
  - o details
  - o grading

6.0 HYDROGEOLOGY

- ☐ Soils , hydrogeology, or geotechnical report
- ☐ Groundwater Elevations
- ☐ Special Construction Considerations

7.0 CONSTRUCTION SEDIMENT CONTROL

- ☐ Sizing of Sediment Basins and details
- ☐ Rock check dam locations and details
- ☐ Silt fence location and details
- ☐ Outlet location
- ☐ Sequencing and Maintenance/Inspection schedule

8.0 HYDROLOGIC ANALYSIS

- ☐ Digital Hydrology Model and associated rainfall input files on a CD
- ☐ Schematic representation of pre and post development hydrologic models
- ☐ Hydrology Summary Output for pre and post development conditions

- ☐ Hydrology Detailed Output for one scenario

9.0 HYDRAULIC ANALYSIS

- ☐ Digital Hydraulics Model on a CD
- ☐ Text describing all of the geometry and flow option included with the model
- ☐ Text describing any changes that have been made to a GRCA-supplied model
- ☐ Drawing showing the location of all sections in relation to the subject property
- ☐ Hydraulics Summary Output Table – Section Number, Flow, Water Surface Elevation

10.0 OTHER

- ☐ Rainfall Data
- ☐ Storm sewer design sheets
- ☐ Hydraulic gradeline analysis spreadsheets
- ☐ Storm sewer design drainage plan, showing areas and runoff coefficients
- ☐ All reports and plans signed and sealed

APPENDIX B

Rainfall Equations

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Clarington Intensity Formulas

IDF Equation	I =a/(b+Td)		Td --- Time in hour I -- Intensity in mm/Hr				Conservative $i = \frac{a}{(td + b)^c}$
Return Period Parameters	2 year	5 year	10 year	25 year	50 year	100 year	100year
a	1778	2464	2819	3886	4750	5588	1770
b	13	16	16	18	24	28	4
							0.82

Rainfall Intensity Formulas (beyond Clarington)

Yarnell Equation

	I =a/(b+Td)		Td --- Time in hour I -- Intensity in mm/Hr			
Return Period Parameters	2 year	5 year	10 year	25 year	50 year	100 year
a	1778	2464	2819	3886	4750	5588
b	13	16	16	18	24	28

BOWMAVILLE MOSTERT IDF BY AES (32years)

IDF Equation

I = a*Td^b
Td --- Time in hour
I -- Intensity in mm/Hr

Return Period Parameters	2year	5 year	10 year	25 year	50 year	100 year
a	19.3	24.6	28	32.4	35.7	38.9
b	-0.63	-0.709	-0.71	-0.711	-0.711	-0.712

	Total Rainfall (mm)					
Minutes	2year	5 year	10 year	25 year	50 year	100 year
5	8.2	10.5	12.1	14	15.5	16.9
10	11.1	14.1	16.1	18.6	20.4	22.3
15	13.3	17	19.5	22.6	24.9	27.2
30	16.9	21.1	24	27.6	30.2	32.9
60	21.2	27	30.8	35.6	39.2	42.8
120	25.4	32.6	37.4	43.5	48	52.5
360	33.7	43.3	49.7	57.8	63.7	69.7
720	39.5	49	55.3	63.3	69.2	75
1440	44	55.8	63.6	73.5	80.8	88.1

	Rainfall Intensity (mm/Hr)					
Minutes	2year	5 year	10 year	25 year	50 year	100 year
5	98.6	126.5	145.0	168.4	185.7	202.9
10	66.6	84.5	96.4	111.4	122.5	133.5
15	53.3	68.2	78.1	90.5	99.8	109.0
30	33.7	42.3	48.0	55.1	60.4	65.7
60	21.2	27.0	30.8	35.6	39.2	42.8
120	12.7	16.3	18.7	21.8	24.0	26.3
360	5.6	7.2	8.3	9.6	10.6	11.6
720	3.3	4.1	4.6	5.3	5.8	6.3
1440	1.8	2.3	2.7	3.1	3.4	3.7

Source: Rainfall Intensity-Duration-Frequency Values for Canadian Locations, Environment Canada, May 2011

APPENDIX C

Hydrological Values
And
Recommended Modeling Parameters

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VO_2 Hydrology Modeling Parameters Selection

COMMAND	PARAMETER	PARAMETER VALUE RECOMMENDATIONS
STANDHYD when catchment area T_{imp}>20%	**AREA**	Digital delineation using software such as GIS or AutoCAD must be used to delineate subcatchment areas.
	X_{imp}	Directly connected imperviousness shall be measured, if possible. Otherwise, use:

Land use	X_{IMP}[1] (Roof Leaders to Road)	X_{IMP}[2] (Roof Leaders to Lawn)
Estate Residential (>3/4 Acre Lot)	**0.14**	**0.09**
2 Acre Lot (180 ft wide)	0.11	0.08
1½Acre Lot (150 ft wide)	0.14	0.09
1 Acre Lot (130 ft wide)	0.17	0.10
Low Density Residential (1/3 to 3/4 Acre Lot)	**0.23**	**0.15**
¾ Acre Lot (110 ft wide)	0.18	0.13
½ Acre Lot (90 ft wide)	0.23	0.15
1/3 Acre Lot (70 ft wide)	0.29	0.18
Medium Density Residential (1/10 to 1/4 Acre Lot)	**0.47**	**0.24**
¼ Acre Lot (60 ft wide)	0.35	0.20
1/8 Acre Lot (50 ft wide)	0.52	0.25
1/10 Acre Lot (40 ft wide)	0.55	0.28
High Density Residential (<1/10 Acre Lot)	**0.65**	**0.35**
Institutional (e.g. school, religious centre)	**0.55**	**0.30**
Industrial	**0.80**	**0.70**
Commercial/ Business	**0.90**	**0.90**
Park	**0.01**	**0.01**

1. Roof leaders connected to impervious area (e.g. driveway) and to storm sewer for X_{imp} calculations.
2. Roof leaders are connected to pervious area (e.g. lawn) for X_{imp} calculations,

Public roads are included in all reported X_{imp} values.

STANDHYD (con't)

T_{imp}

Total imperviousness shall be measured, if possible. Otherwise, T_{imp} based on:

Land use	**T_{imp} (Roof Leaders to Road)**	**Corresponding C**
Estate Residential (>3/4 Acre Lot)	**0.14**	**.3**
2 Acre Lot (180 ft wide)	0.11	.28
1½Acre Lot (150 ft wide)	0.14	.3
1 Acre Lot (130 ft wide)	0.17	.32
Low Density Residential (1/3 to 3/4 Acre Lot)	**0.23**	**.36**
¾ Acre Lot (110 ft wide)	0.18	.32
½ Acre Lot (90 ft wide)	0.23	.36
1/3 Acre Lot (70 ft wide)	0.29	.40
Medium Density Residential (1/10 to ¼ Acre Lot)	**0.47**	**.53**
¼ Acre Lot (60 ft wide)	0.35	.45
1/8 Acre Lot (50 ft wide)	0.52	.56
1/10 Acre Lot (40 ft wide)	0.55	.59
High Density Residential (<1/10 Acre Lot)	**0.65**	**.65 - .6**
Institutional (e.g. school, religious centre)	**0.55**	**.59 - .75**
Industrial	**0.80**	**.75 - .90**
Commercial/ Business	**0.90**	**.84 - .90**
Park	**0.01**	**.21 - .2**

STANDHYD command shall only be used for catchments with a T_{imp}>20%. In case where T_{imp} is <20% and there is a sizeable development area, split the catchment into two using both NASHYD and STANDHYD.

LOSS

VO2 uses Horton's, SCS Modified Curve Number, or Proportional Loss Coefficient Method. The preferred method is SCS Modified Curve Number Method to calculate pervious area losses due to the following reasons:

- Horton is not recommended for storm durations ≥ 12 hours as predicted flows are often erroneous (may under estimate runoff if rainfall intensity is < sol infiltration capacity rate);
- Horton's not recommended if there is significant soil variability;
- Horton's typically used for urban conditions with short duration, high intensity storms (e.g. Chicago distribution) and not much soil variability; and
- SCS Modified CN Method is generally more suitable for subwatershed studies and master drainage plans.

<table>
<tr><td rowspan="8">STANDHYD (con't)</td><td>**CN**</td><td>Same approach as NASHYD. Typically, the pervious component within STANDHYD represents lawn or other grassed area. The pervious area curve number value shall be determined as per Attachment 1. If the assumed pervious area is lawn, the following CN values are recommended:
<table>
<tr><th rowspan="2">Land Use</th><th colspan="7">Hydrologic Soil Group (HSG)</th></tr>
<tr><th>A</th><th>AB</th><th>B</th><th>BC</th><th>C</th><th>CD</th><th>D</th></tr>
<tr><td>Lawn, other open grassed area in good condition (covering > 75% of the area)</td><td>39</td><td>50</td><td>61</td><td>68</td><td>74</td><td>77</td><td>80</td></tr>
<tr><td>Lawn, other open grassed area in fair condition (covering 50-75% of the area)</td><td>49</td><td>59</td><td>69</td><td>74</td><td>79</td><td>82</td><td>84</td></tr>
</table></td></tr>
<tr><td>**I_a**</td><td>
<table>
<tr><th>Land Use</th><th>I_a</th></tr>
<tr><td>Commercial</td><td>2</td></tr>
<tr><td>Residential High Density</td><td>2</td></tr>
<tr><td>Residential Medium/Low Density</td><td>2</td></tr>
<tr><td>Residential Estate</td><td>2</td></tr>
<tr><td>Major Roads</td><td>2</td></tr>
<tr><td>Crop</td><td>7</td></tr>
<tr><td>Pasture</td><td>8</td></tr>
<tr><td>Woodlot</td><td>10</td></tr>
<tr><td>Open Space, Green space</td><td>5</td></tr>
</table></td></tr>
<tr><td>**SLPP**</td><td>Pervious surface slope, preferably measured digitally, other wise assume 2%.</td></tr>
<tr><td>**LGP**</td><td>Length of pervious overland flow typically set to 40 m, unless can be calculated otherwise.</td></tr>
<tr><td>**MNP**</td><td>Manning's pervious "n" value determined by looking at tables, otherwise assume 0.25</td></tr>
<tr><td>**DPSI**</td><td>For roads, driveways and roofs typically use value between 0.8 and 1.5 mm, otherwise assume 2.0 mm</td></tr>
<tr><td>**SLPI**</td><td>Impervious surface slope preferably measured digitally, otherwise assume 1%</td></tr>
<tr><td>**LGI**</td><td>Length of impervious overland flow can be measured if subdivision plans available, however, typically best to use $A= 1.5 (LGI)^2$</td></tr>
<tr><td></td><td>**MNI**</td><td>Manning's impervious "n" value determined using tables if nature of impervious surface is known, otherwise assume 0.013.</td></tr>
</table>

NASHYD	**AREA**	Digital delineation (GIS, AutoCAD) will be used to delineate subcatchment areas.
	CN	CN values are a function of land use and HSG. Use the same table as STANDHYD CN based on the following approach: 1. Area-weighted land use and soils data to be calculated using digital measurements. Soils information must be transformed to hydrologic soil group (HSG) classification using Chart 1.09 MTO Drainage Manual 2. CN values to be calculated on an area-weighted basis using Attachment1. 3. CN to be transformed to CN* using procedure outlined in the VO_2 Reference Manual.
	I_a	Same as STANDHYD (typically set between 1.0 and 5.0 if using CN*)
	N	Number of linear reservoir typically set to 3.0.
	T_p	Time to peak (T_p) is calculated based on time of concentration (T_c). T_p is estimated based on T_p=(N-1)/N*T_c or T_p=0.67Tc The airport method is to be used when C<0.4 and the Bransby-Williams Method is to be used when c>0.4

ATTACHMENT 1
PROPOSED CN AND C-VALUE TABLES

Land Use	CN (AMC II) Values for Hydrologic Soil Group						
	A	AB	B	BC	C	CD	D
Commercial (> 85% impervious)	89	91	92	93	94	95	95
Commercial (75%-85% impervious)	81	85	88	90	91	92	93
Residential (<$^1/_8$ acre lot size)	77	81	85	88	90	91	92
Residential ($^1/_4$ acre lot size)	61	68	75	79	83	85	87
Residential ($^1/_4$ acre lot size)	54	62	70	75	80	83	85
Residential (1 acre lot size)	51	60	68	74	79	82	84
Paved Areas	98	98	98	98	98	98	98
Cultivated, fallow	77	82	86	89	91	93	94
Cultivated, row crops	66	72	77	81	85	87	89
Pasture, good condition	39	50	61	68	74	77	80
Pasture, poor condition	68	74	79	83	86	88	89
Meadow	30	44	58	65	71	75	78
Wood, good cover	25	40	55	63	70	74	77
Wood, poor cover	45	56	66	72	77	80	83

RUNOFF COEFFICIENTS

Topography and Land Use	**SOIL TEXTURE**		
	Open Sandy Loam	**Loam and Silt Loam**	**Tight Clay loam and Clay**
WOODLAND			
Flat (≤ 5% slope)	0.08	0.25	0.35
Rolling (5%-10% slope)	0.12	0.30	0.42
Hilly (10%-30% slope)	0.18	0.35	0.52
PASTURE			
Flat (≤ 5% slope)	0.10	0.28	0.40
Rolling (5%-10% slope)	0.15	0.35	0.45
Hilly (10%-30% slope)	0.22	0.40	0.55
CULTIVATED			
Flat (≤ 5% slope)	0.22	0.35	0.55
Rolling (5%-10% slope)	0.3	0.45	0.60
Hilly (10%-30% slope)	0.4	0.65	0.70
URBAN AREAS	**30% TIMP**	**50% TIMP**	**70% TIMP**
Flat (≤ 5% slope)	0.4	0.55	0.65
Rolling (5%-10% slope)	0.5	0.65	0.8

Adaptation from Determination of Runoff from Agricultural Areas (OMAF Publication 52) and MTO Drainage Manual
Runoff coefficients are intended for 5-10 year storms.
T_{imp} refers to total impervious area.

RUNOFF COEFFICIENTS (continued)

FROM 1995 MTO Drainage Management Manual

Design Chart 2.01: Manning Roughness Coefficient

	Manning Roughness Coefficients
I. Sewers	
A. Concrete pipe storm sewers	0.011 - 0.013
B. Verified clay pipe	0.012 - 0.014
C. Steel pipe (smooth)	0.009 - 0.011
D. Monolithic concrete:	
1. Wood forms, rough	0.015 - 0.017
2. Wood forms, smooth	0.012 - 0.014
3. Steel forms	0.012 - 0.013
E. Cemented rubble masonry walls:	
1. Concrete floor and top	0.017 - 0.022
2. Natural floor	0.019 - 0.025
F. Laminated treated wood	0.015 - 0.017
G. Smooth walled polyethylene pipe	0.011 - 0.013
Corrugated interior polyethylene pipe (tentative)	0.024
H. Corrugated steel pipe or pipe arch	
68 x 13 mm corrugation (riveted, annular)	
Unpaved	0.024
25% paved	0.021
100% paved	0.012
68 x 13 mm helical	
Unpaved: 600 to 1525 mm ϕ range:	0.016 - 0.024
25% paved: 600 to 1525 mm ϕ range:	0.015 - 0.021
100% paved: all sizes	0.012
68 x 25 mm riveted (annular)	
Unpaved	0.027
25% paved	0.023
100% paved	0.012
76 x 25 mm helical	
Unpaved: 900 to 1980 mm dia.:	0.021 - 0.027
25% paved: 900 to 1980 mm dia.:	0.019 - 0.023
100% paved: all sizes	0.012
152 x 51 mm corrugation (annular)	
Unpaved 1550 - 4500 mm dia.or	0.030 - 0.033
1900 to 5050 mm span	0.026
25% paved	
II. Road Gutters	0.012
A. Concrete gutter, trowelled finish	
B. Asphalt pavement:	0.013
1. Smooth texture	0.016
2. Rough texture	
C. Concrete gutter with asphalt pavement:	
1. Smooth	0.013
2. Rough	0.015

	Manning Roughness Coefficients
D. Concrete pavement:	
1. Float finish	0.014
2. Broom finish	0.016
E. Brick	0.016
For gutters with small slope where sediment may accumulate, increase values by 0.002.	
III. Lined Open Channels	
A. Concrete, with surfaces as indicated:	
1. Formed, no finish	0.013 - 0.017
2. Trowel finish	0.012 - 0.014
3. Float finish	0.013 - 0.015
4. Float finish, some gravel on bottom	0.015 - 0.017
5. Gunite, good section	0.016 - 0.019
6. Gunite, wavy section	0.018 - 0.022
B. Concrete bottom float-finished, sides as indicated:	
1. Dressed stone in mortar	0.015 - 0.017
2. Random stone in mortar	0.017 - 0.020
3. Cement rubble masonry	0.020 - 0.030
4. Dry rubble (riprap)	0.020 - 0.030
C. Gravel bottom, sides as indicated:	
1. Formed concrete	0.017 - 0.020
2. Random stone mortar	0.020 - 0.023
3. Dry rubble (riprap)	0.023 - 0.033
D. Asphalt	
1. Smooth	0.013
2. Rough	0.016
E. Wood, planed, clean	0.011 - 0.013
F. 1. Good section	0.017 - 0.020
2. Irregular section	0.022 - 0.027
G. Riprap	0.035 - 0.040
H. Rock cut	0.025 - 0.045
IV. Unlined Open Channels	
A. Earth, uniform section:	
1. Clean, recently completed	0.016 - 0.018
2. Clean, after weathering	0.018 - 0.020
3. With short grass, few weeds	0.022 - 0.027
4. In gravelly, soil, uniform section, clean	0.022 - 0.025
B. Earth, fairly uniform section:	
1. No vegetation	0.022 - 0.025
2. Grass, some weeds	0.030 - 0.035
3. Dense weeds in deep channels	0.030 - 0.035
4. Sides clean, gravel bottom	0.025 - 0.030
5. Sides clean, cobble bottom	0.030 - 0.040

Design Chart 2.01 (Continued)

			Manning Roughness Coefficients
C. Dragline excavated or dredged:			
1. No vegetation			0.028 -0.033
2. Light brush on banks			0.035 -0.050
D. Rock:			
1. Based on design section			0.035
2. Based on actual mean section:			
a. Smooth and uniform			0.035 -0.040
b. Jagged and irregular			0.040 -0.045
E. Channels not maintained, vegetation uncut:			
1. Dense weeds, high as flow depth			0.08 - 0.12
2. Clean bottom, brush on sides			0.05 - 0.08
3. Clean bottom, brush on sides, high stage			0.07 - 0.11
4. Dense brush, high stage			0.10 - 0.14
V. Grassed Channels and Swales[2]			
Depth of Flow:	Up to 0.2 m	0.2 - 0.5 m	
Velocity			
A. Kentucky bluegrass:	0.6 m/s 1.8 m/s	0.6 m/s 1.8 m/s	
1. Mowed to 0.05 m			
2. Length 0.1 to 0.15 m	0.07 - 0.045	0.050 - 0.035	
B. Good stand, any grass:	0.090 - 0.060	0.060 - 0.040	
1. Length 0.30 m			
2. Length 0.60 m	0.180 - 0.090	0.120 - 0.070	
C. Fair stand, any grass:	0.300 - 0.190	0.200 - 0.100	
1. Length 0.30 m			
2. Length 0.60 m	0.140 - 0.080	0.100 - 0.060	
	0.250 - 0.130	0.170 - 0.090	
VI. Natural Watercourses			
A. Minor stream (surface width at flood stage < 30 m).			
1. Fairly regular section:			
a. Some grass and weeds, little or no brush			0.030 -0.035
b. Dense growth of weeds, depth of flow materially greater than weed height			0.035 -0.050
c. Some weeds, light brush on banks			0.035 -0.050
d. Some weeds, heavy brush on banks			0.050-0.070
e. Some weeds, dense willows on banks			0.060-0.080
f. For trees within channel with branches submerged at high stage, add 0.01 to 0.02 to above values.			

	Manning Roughness Coefficients
2. Irregular section with pools, slight channel meander; channels (a) to (e) above, add 0.01 to 0.02.	
3. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stage:	
a. Bottom of gravel, cobbles, and few boulders	0.040 - 0.050
b. Bottom of cobbles with large boulders	0.050 - 0.070
B. Flood plains (adjacent to natural streams):	
1. Pasture, no brush:	
a. Short grass	0.030 - 0.035
b. High grass	0.035 - 0.050
2. Cultivated areas:	
a. No crop	0.030 - 0.040
b. Mature row crops	0.035 - 0.045
c. Mature field crops	0.040 - 0.050
3. Heavy weeds, scattered	0.050 - 0.070
4. Light brush and trees:	
a. Winter	0.050 - 0.060
b. Summer	0.060 - 0.080
5. Medium to dense vegetation:	
a. Winter	0.070 - 0.110
b. Summer	0.010 - 0.160
6. Dense willows, summer, not bent over by current	0.150 - 0.200
7. Cleared land with tree stumps, 250 - 370 per hectare	
a. No sprouts	0.040 - 0.050
b. With heavy growth of sprouts	0.060 - 0.080
8. Heavy stand of timber, a few down trees, little undergrowth:	
a. Flood depth below branches	0.100 - 0.120
b. Flood depth reaches branches (n increases with depth)	0.120 - 0.160
C. Major stream (surface width at flood stage > 30 m): Roughness coefficient is usually less than for minor streams of similar description on account of less effective resistance offered by irregular banks or vegetation on banks. Roughness values may be somewhat reduced. Follow general recommendations if possible. The roughness value for larger streams of mostly regular section, with no boulders or brush, may be in the range.	0.028 - 0.033

APPENDIX D

Storm Sewer Design Sheet

Hydraulic Gradeline

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Sample Hydraulic Gradeline Analysis - 25 year

manning's n = *0.013*

Street	D/S Mh	U/S MH	Peak Flow (m^3/s)	Pipe Diameter (mm)	$\frac{Q^2}{A^2}$	Length (m)	Friction Slope (m/m)	Full Velocity (m/s)	Friction Loss (m)	V_o Outflow Velocity (m/s)	$\frac{V_o^2}{2g}$ (m)	V_i Inflow Velocity (m/s)	$\frac{V_i^2}{2g}$ (m)	k	1 Entrance Loss $\frac{kV_o^2}{2g}$ (m)	2 Loss across MH $\frac{V_o^2}{2g}-\frac{V_i^2}{2g}$ (m)	1 + 2 Total Manhole HGL (m)	D/S Invert Elev. (m)	D/S Obvert Elev. (m)	D/S HGL Elev. (m)	U/S Invert Elev. (m)	U/S Obvert Elev. (m)	U/S HGL Elev. (pipe) (m)	U/S HGL Elev. (MH) (m)	BFE Basement Floor Elev. (m)	U/S T/G Elev. (m)	Remarks
Starting HGL elevation of 86.786 metres corresponding to GHD's spreadsheet																											
Street	107	20	1.117	757	6.155	9.0	0.0096	3.09	0.09	3.09	0.49	3.71	0.70	0.50	0.24	0.00	0.24	86.02	86.78	86.786	86.16	86.91	86.87	87.12		90.20	HGL < T/G
Street	20	21	1.119	681	9.433	12.8	0.0169	3.71	0.22	3.71	0.70	3.71	0.70	0.50	0.35	0.00	0.35	86.23	86.91	87.12	86.55	87.23	87.33	87.68		90.10	HGL < T/G
Street	21	22	1.131	681	9.848	77.6	0.0173	3.71	1.34	3.71	0.70	3.33	0.56	0.10	0.07	0.14	0.21	86.60	87.28	87.68	88.54	89.22	89.02	89.23		91.90	HGL < T/G
Street	22	23	0.945	681	6.726	14.4	0.0120	3.30	0.17	3.30	0.56	3.87	0.76	0.10	0.06	0.00	0.06	88.56	89.24	89.24	88.85	89.53	89.41	89.47		92.30	HGL < T/G
Street	23	24	0.956	681	6.889	84.2	0.0123	3.87	1.04	3.87	0.76	2.84	0.41	0.10	0.08	0.35	0.43	88.69	89.37	89.47	90.97	91.66	90.51	90.94		94.30	HGL < T/G
Street	24	25	0.326	457	3.948	15.1	0.0120	2.84	0.18	2.84	0.41	2.54	0.33	0.10	0.04	0.08	0.12	91.20	91.66	91.66	91.58	92.03	91.84	91.96		94.75	HGL < T/G
Street	25	26	0.331	457	4.082	70.6	0.0124	2.54	0.88	2.54	0.33	1.95	0.19	0.10	0.03	0.14	0.17	91.60	92.05	92.05	93.01	93.47	92.93	93.10		96.30	HGL < T/G
Street	26	27	0.180	381	1.973	15.2	0.0077	1.95	0.12	1.95	0.19	1.59	0.13	0.10	0.02	0.06	0.08	93.08	93.46	93.46	93.31	93.69	93.58	93.66		96.40	HGL < T/G
Street	27	28	0.164	381	2.064	58.1	0.0080	1.59	0.47	1.59	0.13	1.59	0.13	0.10	0.01	0.00	0.01	93.33	93.71	93.71	93.91	94.29	94.18	94.19		97.00	HGL < T/G
Street	28	29	0.134	381	1.375	46.1	0.0053	1.59	0.25	1.59	0.13	1.95	0.19	0.80	0.10	0.00	0.10	93.93	94.31	94.31	94.39	94.77	94.58	94.66		97.50	HGL < T/G

STORM SEWER DESIGN SHEET - 5 YEAR STORM

Project:
Project No.:
Date:

Manning's Coefficient: 0.0130

LOCATION			Length (m)	TIME (MIN)		Rainfall Intensity (mm/hr)	Area (Ha)	C	AC	Cumul AC	Runoff Q (L/s)	Grade (%)	Pipe Diameter (mm)	Capacity (L/s)	Full Flow Velocity (m/s)	% Full	Invert Elevations		U/S T/G	U/S Cover (m)
Street	From	To		To Upper End	In Reach												Upper Inv.	Lower Inv.		
Street	42	41	66.7	15.00	0.74	79.48	0.680	0.344	0.234	0.234	51.7	1.20%	305	109.7	1.50	47.2%	98.70	97.90	101.60	2.60
Street	41	40	79.3	15.74	0.48	77.63	0.400	0.450	0.180	0.414	89.3	4.00%	305	200.4	2.74	44.6%	97.85	94.68	100.90	2.75
Street	40	29	8.5	16.22	0.07	76.47	0.000	0.450	0.000	0.414	88.0	1.51%	381	222.7	1.95	39.5%	94.60	94.48	97.70	2.72