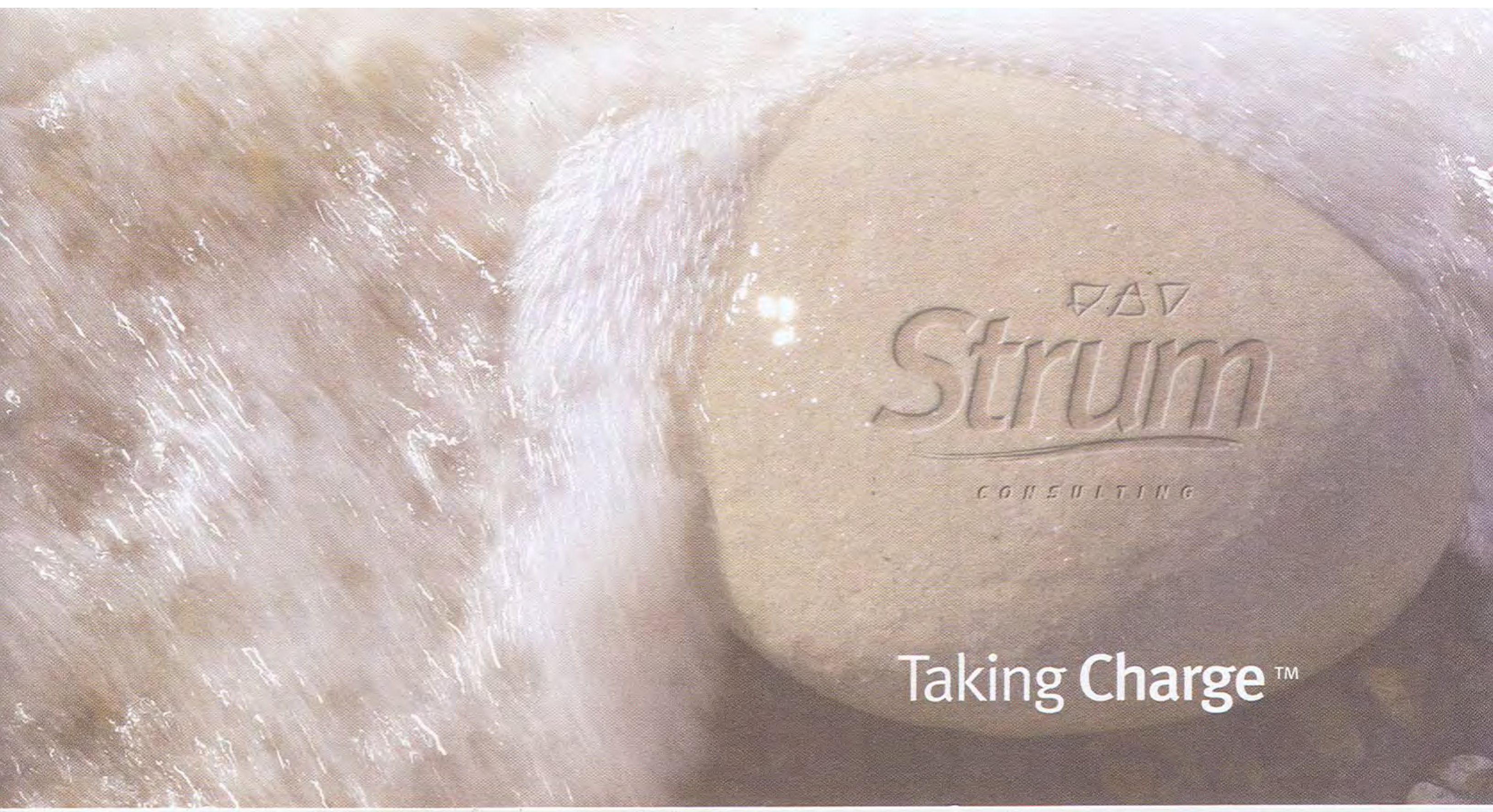
Strum

CONSULTING

PHOSPHORUS LOADING STUDY
Steeple Lake Estates Development

December 5, 2018



December 5, 2018

Mr. Lawrence Tench
LawDia Holdings Limited

Dear Mr. Tench,

Re: Phosphorus Loading Study
Steeple Lake Estates Development

Attached is the Phosphorus Loading Study prepared for the Steeple Lake Estates Development.

This report documents our observations, findings, and recommendations.

We trust this to be satisfactory at this time. Once you have had an opportunity to review this correspondence, please contact us to address any questions you may have.

Thank you,

[redacted]

Chris Boudreau, P.Eng.
Manager, Civil Engineering
cboudreau@strum.com

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APPENDICES

1.0 INTRODUCTION

As part of the development agreement application for the McPherson Road development in Fall River, Nova Scotia (PIDs 40762106, 40770323, 00506196), a stormwater phosphorus loading study was completed by Strum Consulting. The proposed residential development consists of five multi-unit townhouses, for a total of 16 units, which all share a single access driveway and central courtyard parking loop. This development will manage its stormwater through surface conveyance and catchbasins with a discharge outlet directed towards Fletchers Lake. Refer to Servicing Schematic prepared by SDMM on July 19, 2018 in Appendix A for an overview of the proposed site layout and use.

As outlined in the River-Lakes Secondary Planning Strategy section within Halifax's Municipal Planning Strategy for Planning Districts 14/17 (Shubencadie Lakes) the site area is located within the River-Lakes Village Centre designation and requires the satisfaction of Policy RL-22, which states:

> *The River-Lakes Secondary Planning Strategy shall establish a no net increase in phosphorus as the performance standard for all large scale developments […] A study prepared by a qualified person shall be required for any proposed development pursuant to these policies to determine if the proposed development will export any greater amount of phosphorus from the subject land area during or after the construction of the proposed development than the amount of phosphorus determined to be leaving the site prior to the development taking place. If the study reveals that the phosphorus levels predicted to be exported from the proposed development exceed the phosphorus levels currently exported from the site, then the proposed development will not be permitted to take place unless there are reductions in density or other methods that reduce phosphorus export levels to those current before the proposed development. […] Any stormwater management devices designed to treat phosphorus must be located on the privately-owned land included in the proposed development agreement.*

It is expected that through the development of this site we will see the increase of total phosphorus (TP) loadings due to the application of fertilizers, soil erosion, and stormwater surface runoff, which are large contributors to the production of TP. This increase can be mitigated through the use of stormwater treatment best management practices (BMPs).

The purpose of this study was to estimate the TP that is expected to discharge into the site's surrounding water system under pre-development and post-development conditions. Several BMPs were investigated in the post-development scenario in order to satisfy the policy provision of no net increase in TP values during or after construction.

This report presents the findings of the water quality analysis conducted in November 2018.

1.1 Design Criteria

With the introduction of this development in the area of McPherson Road, stormwater management features must be considered in order to adequately maintain TP water quality. This water quality study was completed with a focus on maximizing removal of TP from runoff generated within the developed area and follows the guidelines put forth in the Halifax Regional Municipality Stormwater Management Guidelines published by Dillon Consulting in March 2006.

2.0 SCOPE AND METHODOLOGY

2.1 Scope

The purpose of this water quality study is to analyze the proposed McPherson Road development's pre-development TP loadings, estimate uncontrolled post-development TP loadings, and propose stormwater BMPs to provide a balanced site (i.e. match pre-development TP loading during and after construction). Stormwater peak-flow management design is outside the scope of this report and is to be covered by others.

2.2 Methodology

The methodology undertaken for this analysis consisted of three primary elements listed below. More detailed information on each is contained in Section 3.0.

2.2.1 Historical Data Review

Historical records relating to the site and its surrounding climatic data were reviewed as part of this study. The primary sources of information included aerial photographs, SDMM Servicing Schematic, registered survey plans, and Environment Canada's 1981-2010 Canadian Climate Normals for Halifax Stanfield International Airport, NS (8202250). Strum staff also visited the site during our analysis to gather photographic information to help determine existing land coverage and identify any existing hydraulic and hydrological features.

2.2.2 Hydrological Model

The project site was modeled as a single watershed, solely contained within the property boundaries. It was assumed that areas within the delineated watershed that were not to be altered throughout the development process would be ignored while modeling water quality (i.e. the 20 m wide watercourse buffer). This assumption meant only the developed portion of the site would be considered throughout the analysis. Existing and developed surface characteristics were classified and are discussed further in section 3.1.3.

2.2.3 Water Quality Analysis

Through the use of desktop modeling processes and empirical data presented in the HRM Stormwater Management Guidelines a simulation of TP production for the proposed development was completed in both the pre-development and post-development conditions. Considerations for accurate calculation included:

- Accurately identifying ground surface characteristics
- Assigning TP pollutant washoff values
- Removal rates for a range of different stormwater BMPs

3.0 MODEL CONFIGURATION

The project site consists of an area that has an existing gravel parking lot and forested areas. In the developed Condition, there is a single outlet proposed for the project area that directs water towards Fletchers Lake (refer to Servicing Schematic, Appendix A). A model was created that simulated a full year of precipitation and calculated the anticipated TP, in kilograms, transported from the site through stormwater runoff.

3.1 Hydrology

3.1.1 Rainfall

Average annual precipitation data was collected from Environment Canada's 1981-2010 Canadian Climate Normals for Halifax Stanfield International Airport, NS (8202250). To represent the winter months adequately, both average annual rainfall and average annual snowfall were used as contributors to the production of TP throughout a full year. Table 3.1 below outlines the precipitation values used during the analysis.

Table 3.1: 1981-2010 Canadian Climate Normals, Halifax Stanfield Int'l A

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	83.5	65.0	86.9	98.2	109.8	96.2	95.5	93.5	102.0	124.6	139.1	101.8	1196.1
Snowfall (cm)	58.5	45.4	37.1	15.9	2.0	0.0	0.0	0.0	0.0	0.4	16.6	45.4	221.2
Precipitation (mm)	134.3	105.8	120.1	114.5	111.9	96.2	95.5	93.5	102.0	124.9	154.2	143.3	1396.2

Due to the relatively small catchment area on the site, we do not anticipate significant localized evaporation to occur and therefore evapotranspiration was not considered during the analysis.

3.1.2 Catchment Delineation

Catchment delineation was completed using the SDMM servicing Schematic and AutoCAD Civil3D. Due to the surrounding topography and site layout it was assumed there was no significant anticipated runoff entering the subject site from adjacent properties. As discussed in section 2.2.2, the water quality model catchment consists only of areas that will experience a change in land-use or surface type. This means that areas within the catchment area but outside of the proposed development will not be considered in TP calculations as the surface cover and use will not change throughout the life of the development. Considering the excluded areas, the development area was calculated to be 5,528m^2. Refer to Drawing 1 in Appendix A for the delineated catchment boundary and the area considered as development area.

3.1.3 Land Use and Surface Cover

The following land use scenarios were used during analysis:

- Scenario 1: Pre-development conditions
- Scenario 2: Post-development conditions, no BMPs (uncontrolled)
- Scenario 3: Post-development conditions, with BMPs

As discussed in Section 3.1.2, only the areas within the delineated watershed that will be altered during the development's construction process have been considered in the water quality model.

Pre and post-development land use and corresponding phosphorus loading concentrations were assigned using the information presented in Table 5-5 of the HRM Stormwater Management Guidelines, see Appendix B for portions of the HRM document. Pre-development conditions were estimated using a combination of aerial photography as well as data collected during site visits. Table 3.2 below summarizes the land uses and corresponding phosphorus loading values utilized throughout the modelling process.

Table 3.2: Summary of Pre and Post-Development Land Uses

Development Condition	Land Use	Area (ha)	TP (mg/L)	Notes
Pre-Development	Upland Forest	0.44	0.2	*Existing trees/wet areas*
	Medium-Density Residential	0.11	0.2	*Existing gravel parking area*
Post-Development	Medium-Density Residential	0.55	0.2	*Combination pervious and impervious area*

Refer to Drawing 2 in Appendix A for a breakdown of the post-development land uses included in the water quality model.

3.1.4 Runoff Coefficients

Runoff coefficients were used in determining the annual volume of rainfall that runs off of the site. These runoff coefficients are commonly used in rational stormwater models and are also known as rational C values. The runoff coefficient is essentially a ratio of runoff to rainfall and varies based on land use, soil type, and land slope. Runoff coefficients are a value between 0 and 1 that can be taken directly from published tables or used aggregately as a weighted value to represent an area which incorporates multiple land uses. The closer the value is to 1, the more runoff is expected to occur, so for an area covered in asphalt, which would see large quantities of runoff and little infiltration, a runoff coefficient of 0.7-0.95 would be expected.

Table 3.3 below summarizes the runoff coefficients used for each land use outlined in Section 3.1.3.

Table 3.3: Site Runoff Coefficients

Development Condition	Land Use	Runoff Coefficient
Pre-Development	Upland Forest	0.15
	Medium-Density Residential (Gravel parking area)	0.90
Post-Development	Medium-Density Residential	0.69*

*Weighted runoff coefficient based on multiple land uses

3.2 Water Quality

A water quality model was prepared to estimate the proposed development's annual generation of TP in kilograms.

TP loading is dependant on the land use of a particular area. Land use and corresponding TP concentrations are outlined in Section 3.1.3 and were selected from the HRM Stormwater Management Guidelines. The TP values used (measured in mg/L) are solely the result of stormwater runoff. This means that any pollutants derived directly from groundwater or any other water sources are not considered in the model.

Using the provided TP concentrations, an annual mass of phosphorus in kilograms was calculated using the estimated annual rainfall for the area. The anticipated pre-development annual TP mass was used as the target values during post-development balancing.

3.3 Best Management Practices (BMPs)

BMPs are devices or features included in a stormwater system with the goal of improving water quality. Typically, BMPs are introduced in areas that experience a change in land use and have an increased percentage of impervious area, causing more direct runoff and pollutant transfer to occur. The performance of various BMPs has been monitored in studies across North America and published values for removal efficiency are widely available. Removal efficiency values quantify the BMPs ability to remove pollutants, one of which being TP. BMP removal efficiencies used during analysis were retrieved from the following sources:

- Halifax Regional Municipality Stormwater Management Guidelines prepared by Dillon Consulting in March 2006
- Standard and Guidelines for Municipal Waterworks, Wastewater, and Storm Drainage Systems published by Alberta Environment in March 2013
- New Jersey Stormwater Best Management Practices Manual published in February 2004

Refer to Appendix B, C, and D respectively for portions of the reports stated above.

Table 3.4 below outlines some examples of BMPs and their TP removal efficiencies that are often introduced to a development. The values presented below are have been compiled from the resources listed above.

Table 3.4: BMPs and Related TP Removal Efficiency Ranges

Best Management Practice (BMP)	HRM TP Removal Efficiency (%)	Alberta Environment TP Removal Efficiency (%)	New Jersey Stormwater TP Removal Efficiency (%)
Wet Pond	50	45	50
Grass Swale	40	20	-
Vegetated Filter Strip	-	40	30
Permeable Pavement	80	5	60
Constructed Stormwater Wetland	50	25	50
Sand Filter	60	50	50
Infiltration Trench	70	60	-

The BMPs listed above can be incorporated into the design topography of most developments but some need special consideration for placement due to size requirements (i.e. a wet pond may require a minimum plan area for effective removal).

BMPs can act as stand-alone features that work to remove a defined percentage of waterborne pollutants but they can also be arranged in-line in a series configuration, known as a train, to increase the overall removal efficiency.

Equation 3-1 below is used to determine the removal efficiency of BMPs in series:

BMPs in Series

$$R = A + B - \frac{AB}{100}$$ **Equation 3-1**

Where,

R = Total aggregate removal rate
A = Removal rate of the upstream BMP (%)
B = Removal rate of the downstream BMP (%)

3.4 Construction Period

During construction of this development, it will be important to monitor how and where material stockpiles are stored. If topsoil and grubbings are stored on-site during construction, there is potential that increased phosphorus concentrations could be generated in surface water that contacts those materials.

To mitigate this potential concern, topsoil and grubbings piles on the site shall be removed from the site prior to rainfall events, or will be covered with tarps to limit exposure to precipitation and surface water. Additionally, other erosion and sedimentation controls (e.g. sediment fence) shall be installed and maintained on the site during construction, which will limit the transport and loss of sediment from topsoil or grubbings that may contain elevated phosphorus concentrations.

Other than topsoil and grubbings, the main sources of increased phosphorus loading are through the introduction of fertilizers, biosolids, or other concentrated organics, and industrial wastes. As these main sources of phosphorus will not be present during the construction phase, it is not expected that there will be a net increase of phosphorus through the construction phase of the development. Since no increase in phosphorus is anticipated during the construction phase, it was not included in site modeling.

4.0 MODEL RESULTS

The water quality model was initially run in the pre-development scenario to determine the base-line values. Then, a model was created that ran uncontrolled and did not include any pollutant loading attenuation features (BMPs). This provided an understanding of how the expected pollutant loading would be affected by a developed site. Table 4.1 summarizes the pre and post-development (uncontrolled) TP values.

Table 4.1: TP loadings for Pre and Post-Development (Uncontrolled)

Development Scenario	Annual TP Loading (kg)
Pre-Development	0.47
Post-Development (Uncontrolled)	1.06

Based on the values stated above it was determined that stormwater BMPs are required in order to achieve a balanced site for TP. Comparing the pre-development and the uncontrolled post-development values shows the sites require the implementation of measures with a 56% removal efficiency of TP in order to achieve Halifax's River-Lakes Secondary Planning Strategy requirement of no net increase in phosphorus during or after construction. To satisfy these removal efficiencies, several BMPs were investigated to help produce a post-development site that would meet this requirement.

Several iterations of the water quality model were run in the controlled post-development condition to find the best pollutant loading attenuation methods. Table 4.2 below summarizes the BMPs investigated to create a balanced post-development site. The TP removal values presented below are based on an average of the values found in Table 3.4.

Table 4.2: BMP TP Removal Efficiencies

BMP	TP Removal Efficiency (%)
Wet Pond	47
Grass Swale	30
Vegetated Filter Strip	35
Permeable Pavement	48
Constructed Stormwater Wetland	42
Sand Filter	53
Infiltration Trench	65

Section RL-22 of Halifax's Municipal Planning Strategy for Planning Districts 14/17 states that "*Any stormwater management devices designed to treat phosphorus must be located on the privately-owned land included in the proposed development agreement"*, therefore all BMPs must be contained within the project's property boundary. The five proposed townhouse buildings are located within the same property with very little distance to the 20 m watercourse buffer. This means that any BMPs specified will have to be situated within the 20 m watercourse buffer. Because of the space constraints of the site it was determined that BMPs such as wet ponds and stormwater wetlands were not feasible. An efficient combination of BMPs to achieve the necessary minimum 55% TP removal rate was determined to be a treatment train of grass swale and infiltration trench, totalling 80 m in length.

Best practice for BMP design suggests that for grass swales to achieve the optimal published TP removal efficiency (30%) the swale shall be 60 m long. Therefore, it was assumed that every 60 m of grass swale would produce a TP removal efficiency of 30% and the remainder of the available ditching would be used as an infiltration trench (i.e. 80 m of available ditch yields one 60 m grass swale and one 20 m of infiltration trench). Equation 3-1 was applied to calculate the aggregate removal efficiency of 75.5% as they will act as BMPs in series. Refer to Drawing 3 in Appendix A for preliminary BMP layout and typical detailing.

4.1 Model Outputs

Pre and post-development pollutant loadings with and without the use of BMPs are summarized for the proposed site in Table 4.3, with detailed calculations and model results presented in Appendix E.

Table 4.3: Post-Development Pollutant Loading Summary

Development Scenario	BMPs Used	TP Removal Efficiency (%)	Annual TP Loading (kg)
Pre-Development	N/A	N/A	0.47
Post-Development	Uncontrolled	0.0	1.06
Post-Development (treatment train)	Grass Swale & Infiltration Trench	75.5	0.26

4.2 Maintenance

In order to provide BMPs that maximize their TP removal potential it is important that regular maintenance be completed. For natural BMPs such as grass swales and infiltration trenches, making sure they are free of debris and excess sediment will help to have them operate at their full potential.

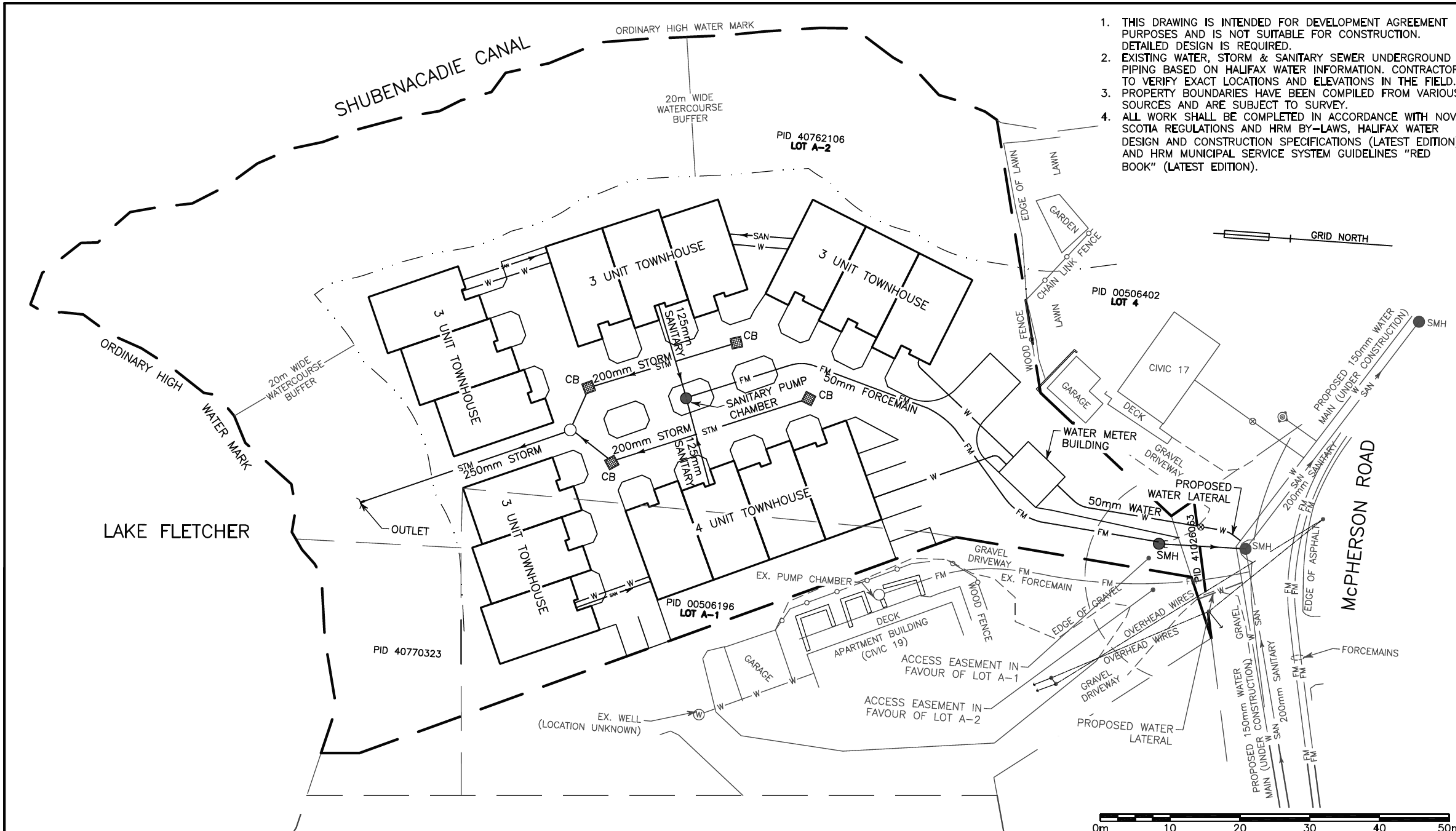
Ultimately, maintenance schedules are the responsibility of the owner but it is imperative that regular maintenance be performed to ensure peak operational efficiency of any BMP implemented.

5.0 CONCLUSIONS AND RECOMMENDATIONS

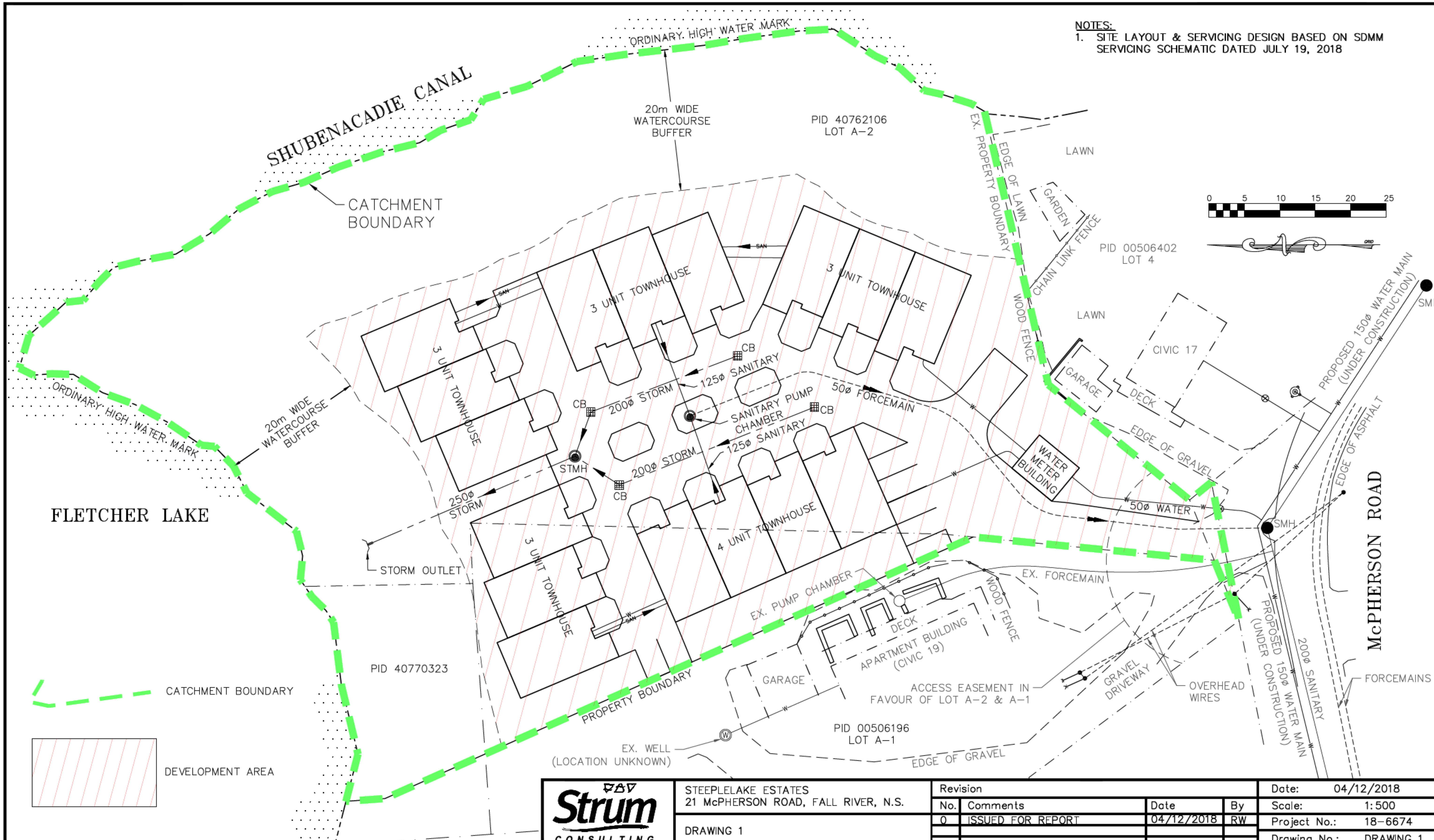
Based on the data collected above, it is recommended that BMPs be introduced into the final site design to treat site runoff and pollutants in order to achieve a balanced water quality site. Using a treatment train consisting of a grass swale and infiltration trench, a removal efficiency of 75.5% can be achieved, reducing the post-development TP loadings to a value less than that experienced in the pre-development scenario. Refer to Drawing 3 in Appendix A for typical preliminary BMP layout. Final layout of BMPs to be determined by others during detailed site design.

APPENDIX A
DRAWINGS

1. THIS DRAWING IS INTENDED FOR DEVELOPMENT AGREEMENT PURPOSES AND IS NOT SUITABLE FOR CONSTRUCTION. DETAILED DESIGN IS REQUIRED.
2. EXISTING WATER, STORM & SANITARY SEWER UNDERGROUND PIPING BASED ON HALIFAX WATER INFORMATION. CONTRACTOR TO VERIFY EXACT LOCATIONS AND ELEVATIONS IN THE FIELD.
3. PROPERTY BOUNDARIES HAVE BEEN COMPILED FROM VARIOUS SOURCES AND ARE SUBJECT TO SURVEY.
4. ALL WORK SHALL BE COMPLETED IN ACCORDANCE WITH NOVA SCOTIA REGULATIONS AND HRM BY-LAWS, HALIFAX WATER DESIGN AND CONSTRUCTION SPECIFICATIONS (LATEST EDITION) AND HRM MUNICIPAL SERVICE SYSTEM GUIDELINES "RED BOOK" (LATEST EDITION).



SDMM Servant, Dunbrack, McKenzie & MacDonald Ltd.	36 OLAND CRESCENT BAYERS LAKE BUSINESS PARK HALIFAX, NOVA SCOTIA OFFICE: (902) 455-1537 FAX: (902) 455-8479 WEB: www.sdmm.ca	TITLE: SERVICING SCHEMATIC LOCATION: STEEPLELAKE ESTATES 21 McPHERSON ROAD, FALL RIVER, NOVA SCOTIA	NOTES: 1. PLAN IS METRIC.	Date: JULY 19, 2018 Scale: 1:500 Prepared by: A. PULSIFER	Project No.: 33291 Sheet Size: 11"X17"



Strum CONSULTING	STEEPLELAKE ESTATES 21 McPHERSON ROAD, FALL RIVER, N.S. DRAWING 1			

Revision			
No.	Comments	Date	By
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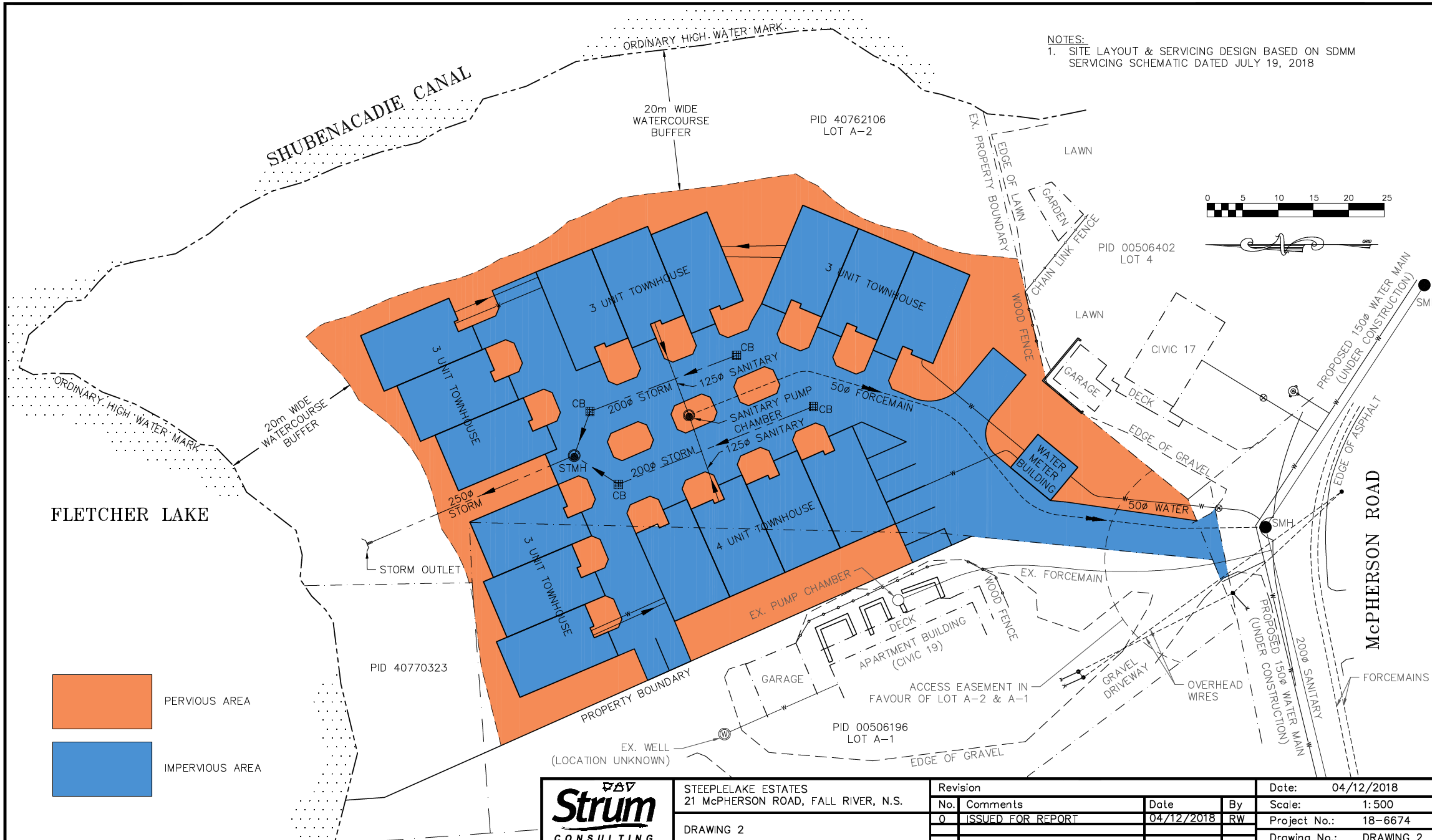
Date:	04/12/2018
Scale:	1:500
Project No.:	18-6674
Drawing No.:	DRAWING 1


NOTES:
1. SITE LAYOUT & SERVICING DESIGN BASED ON SDMM SERVICING SCHEMATIC DATED JULY 19, 2018
SHUBENACADIE CANAL
ORDINARY HIGH WATER MARK
20m WIDE WATERCOURSE BUFFER
PID 40762106 LOT A–2
EX. PROPERTY BOUNDARY
EDGE OF LAWN
LAWN
GARDEN
CHAIN LINK FENCE
PID 00506402 LOT 4
WOOD FENCE
CIVIC 17
GARAGE
DECK
EDGE OF GRAVEL
PROPOSED 150ø WATER MAIN (UNDER CONSTRUCTION)
SMH
EDGE OF ASPHALT
McPHERSON ROAD
3 UNIT TOWNHOUSE
4 UNIT TOWNHOUSE
CB
125ø SANITARY
200ø STORM
SANITARY PUMP CHAMBER
50ø FORCEMAIN
STMH
250ø STORM
WATER METER BUILDING
50ø WATER
FLETCHER LAKE
STORM OUTLET
EX. PUMP CHAMBER
EX. FORCEMAIN
APARTMENT BUILDING (CIVIC 19)
ACCESS EASEMENT IN FAVOUR OF LOT A–2 & A–1
GRAVEL DRIVEWAY
OVERHEAD WIRES
200ø SANITARY
FORCEMAINS
PID 40770323
PROPERTY BOUNDARY
EX. WELL (LOCATION UNKNOWN)
PID 00506196 LOT A–1
PERVIOUS AREA
IMPERVIOUS AREA
0 5 10 15 20 25
Strum CONSULTING
STEEPLELAKE ESTATES
21 McPHERSON ROAD, FALL RIVER, N.S.
DRAWING 2
Revision
No. Comments Date By
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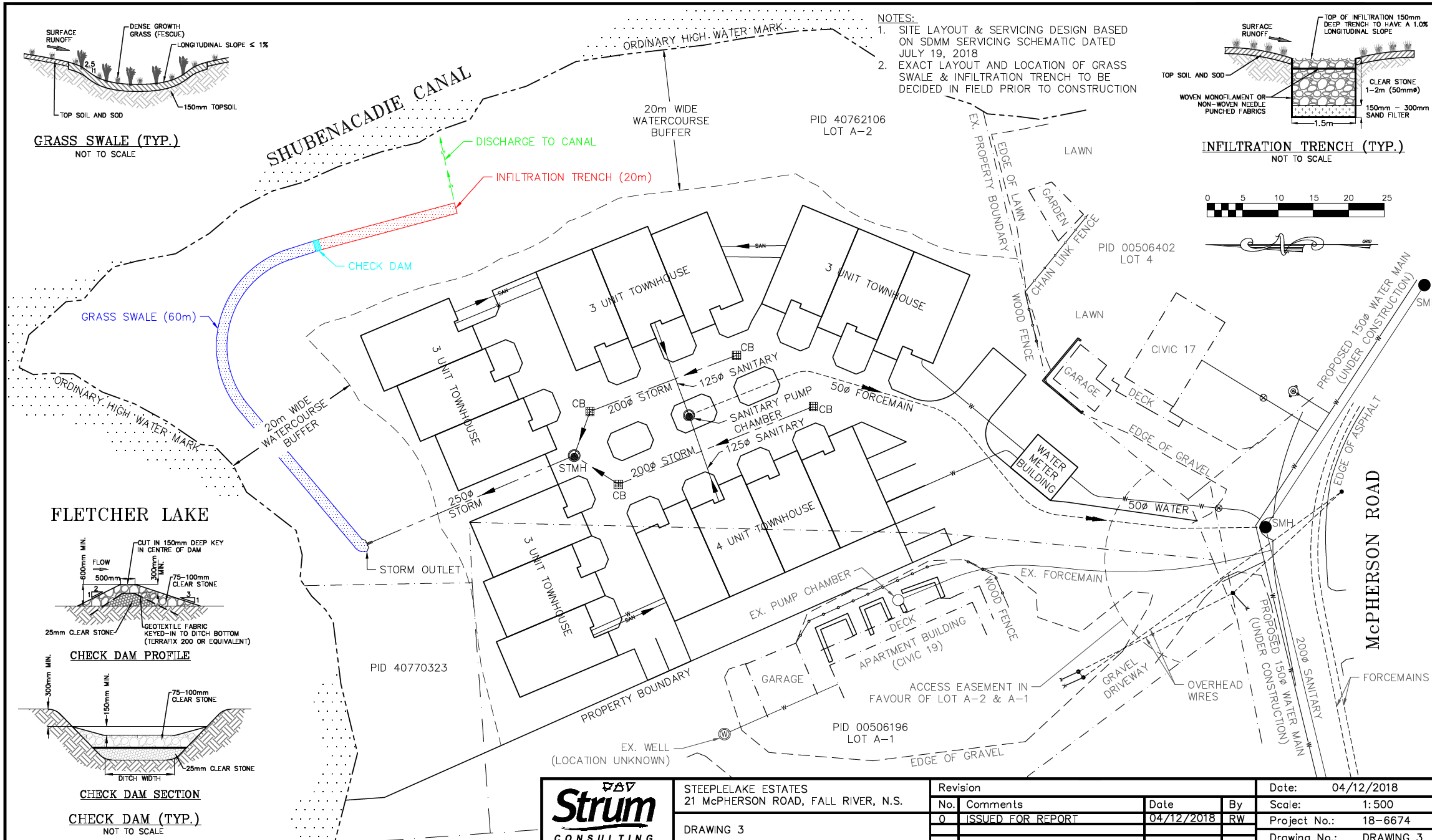
Date: 04/12/2018
Scale: 1:500
Project No.: 18–6674
Drawing No.: DRAWING 2



Strum CONSULTING

STEEPLELAKE ESTATES
21 McPHERSON ROAD, FALL RIVER, N.S.

DRAWING 3

Revision			
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Date:	04/12/2018
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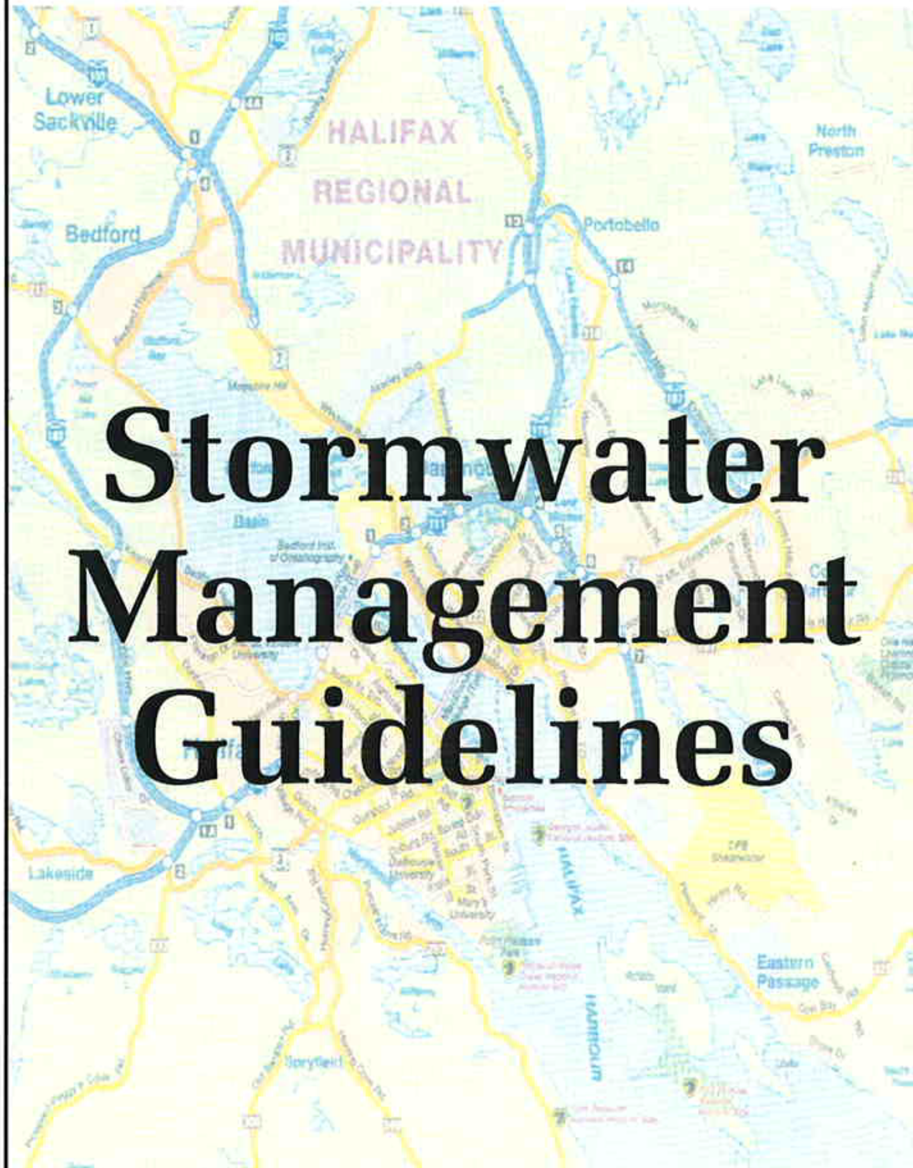
Project No.:	18-6674
Drawing No.:	DRAWING 3

APPENDIX B
PORTIONS OF HALIFAX REGIONAL MUNICIPALITY STORMWATER MANAGEMENT GUIDELINES – MARCH 2006

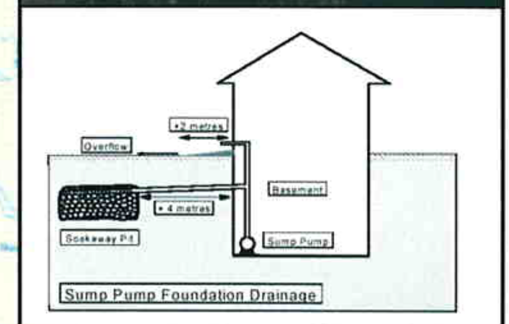
HALIFAX
REGIONAL MUNICIPALITY

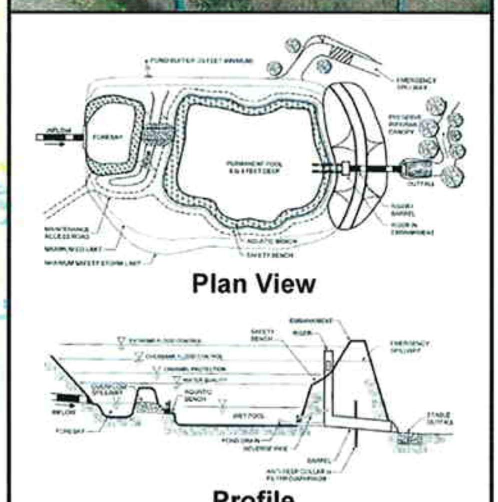


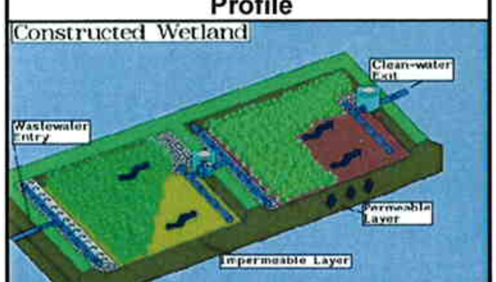
Stormwater Management Guidelines

March 2006

DILLON
CONSULTING







Stormwater Management Guidelines

March 2006

Halifax Regional Municipality

05-4680-0400

Submitted by:

Dillon Consulting Limited

Executive Summary

The purpose of the Stormwater Management Guidelines is to describe a set of criteria for the design of stormwater management practices to protect the environment of the Halifax Regional Municipality from adverse impacts of urban storm water runoff. The Guidelines describe Best Management Practices (BMPs), techniques and methods of managing stormwater drainage for adequate control and pollutant reduction by using the most effective and practical means that are economically acceptable to the community.

The ultimate selection of recommended stormwater BMPs is dependent on the tributary-specific and in some instances, the reach-specific characteristics, sensitivities and functionalities present within the watershed. Ideally, all BMP design criteria should be based on recommendations developed as part of a comprehensive watershed or subwatershed plan prepared for the subject location's basin. These plans are produced through the study of the environmental and land use features of a watershed. The purpose of the plan is to identify those areas that should be protected and preserved as part of the land use planning process, to evaluate the impact of future land use changes and to develop criteria to mitigate potential cumulative impacts in the watershed.

In the absence of watershed/subwatershed study recommendations, the Guidelines provide general design criteria that should be used in HRM for quantity, quality, erosion, and base flow control. The use of this unified approach should result in a design of stormwater management practices that would meet the flood, water quality, erosion control and groundwater recharge criteria adopted until the completion of the watershed and subwatershed studies.

The overall objectives of introducing BMPs are to minimize the adverse effects on and off the development site. An important part of the selection of BMPs is to preserve the sensitive, natural features and to develop a new stormwater system that can reproduce, as closely as possible, the natural conditions of the undeveloped state. This approach stresses the importance of preserving natural storage, infiltration and pollutant filtering functions where feasible, thus reducing the lifecycle cost for stormwater management and minimizing the need for costly capital improvements to the existing system.

There is no single BMP that suits every development, and a single BMP cannot satisfy all stormwater control objectives. Therefore, cost-effective combinations of BMPs may be required that will achieve the objectives.

These Guidelines are intended to be a tool to be used by HRM to guide developers and their designers toward the selection and design of appropriate stormwater management facilities. It will also be used by HRM staff for the review and design of facilities. It is intended that it will be used in combination with the Regional Plan and other planning and design tools already in place to achieve HRM's long-term goals and objectives.

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Acronyms

BMP	Best Management Practice
HRM	Halifax Regional Municipality
MGA	Municipal Government Act
MSS	Municipal Services System
NP	Not practical
NSEL	Nova Scotia Environment and Labour
OP	Operating Procedure
SWM	Stormwater Management
SUDS	Sustainable Urban Drainage Systems
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
US	United States
USEPA	United States Environmental Protection Agency

Ideally, watershed or subwatershed studies should evaluate requirements for post-development water quantity controls based on the potential cumulative impacts of development and potential flood hazards. Where such studies do not exist, requirements for water quantity control should be based on potential downstream flooding hazard. Generally, the criteria are to control post-development peak flows for the 2, 5, 25, 50 and 100–year storms to pre-development levels. If a proposed development is located in the lower reaches of a watershed or subwatershed discharging to coastal waters or large lakes with no downstream developments, quantity control may not be required.

For sizing wet ponds and constructed wetlands, a 24-hour duration event should be selected, as shorter rainfall durations may under-estimate design runoff volumes and associated storage volume requirements. Hydrographs for the individual return period events should be generated by hydrologic models using the Shearwater gauge Intensity-Duration-Frequency data. A more detailed discussion on design storms is presented in ***Appendix E.***

5.3 Design Criteria for Water Quality Control

Maintenance of healthy aquatic ecosystems requires that pre-development water quality be maintained and enhanced where feasible. The goal is to restore, protect and enhance water quality and associated aquatic resources and water supplies of the receiving watercourse. This goal mandates the prevention of contamination of streams and lakes from urban runoff containing nutrients, pathogenic organisms, organic substances, heavy metals and toxic substances.

Similar to the quantity criteria, water quality criteria should be based on the premise that where feasible the post-development water quality should be similar to the pre-development water quality.

The selection of water quality criteria is influenced to a great extent by the receiving system environment. Protection of receiving waters from impacts of sediments generated by urban development construction and post construction periods have been recommended by most provincial and municipal agencies across the North American continent. In Canada the Federal Government prepared guidelines on the potential impacts of sediment on aquatic organisms and their habitat.

In controlling the pollutant efficiency of a BMP, it is recommended that Total Suspended Solids (TSS) be adopted as a primary indicator. As a rule of thumb, when rural land use becomes urbanized, the resulting runoff volume could double. At the same time the TSS loads from urban land uses are twice as high as from rural land uses. Therefore, the combined effect could be a fourfold increase in the TSS loads caused by urbanization. To match the pre-urbanized TSS loading, the selected BMP should reduce the post-development load by approximately 75%. Wet ponds and constructed wetlands are capable of removing 80% of TSS or higher.

The design criteria selection should start by assessing the state of the environment in the downstream receiving water bodies. There are two alternative indicators of the downstream water quality that could be considered in the selection of design criteria: 1) fish habitat, and/or 2) the nutrient concentration in the receiving system.

For the first alternative indicator, consideration should be given to the selection of design criteria based on the potential effects of urban runoff on the aquatic habitats of the receiving system streams and lakes. A simple classification is presented in ***Table 5-1*** to describe the downstream habitat:

Table 5-1
Classification of Downstream Habitat

Category	Fishery	Type of species	Suggested TSS control
I	Cold water fishery	Salmonids, lobster fishery, aquaculture	80%
II	Warm water fishery	Perch, minnows, suckers and urbanized lakes	70%
III	No existing or prospect of future habitat	Habitat in ditches, intermittent streams, stream with blockage	60%

The TSS indicator could also be used to assess receiving system impacts of the health on existing or potential future fish habitat. Impacts on this health can be measured by the relative changes in in-stream fish population or by the severity of impacts due to sediment concentration and duration of exposure.

The following table compares the suspended solids concentration guidelines prepared by the European Inland Fisheries Advisory Commission and the Government of Canada, in the Yukon Placer Authorization 1993, document, based on suspended solids increases.

Table 5-2
Risk to Fish Habitat by Increase in TSS

European Commission		Canada	
TSS – mg/L	**Risk Level**	**TSS – mg/L**	**Risk Level**
<25	Not harmful	<25	Very low risk
25-80	Somewhat diminished yield	25-100	Low risk
80-400	Unlikely to support fisheries	100-200	Moderate risk
>400	Only poor fisheries	200-400	High risk

Researchers on fish and exposure to increases in sediment concentration identified that most species of fish can withstand higher exposure of elevated levels of TSS, but impairment will occur when sediment exposure increases beyond threshold values which are a function of both the sediment concentration and its duration. According to Ward (1992) sediment concentration in the receiving stream below 25 mg/L would result in few ill effects regardless of the duration. For typical runoff events lasting less than 4 hours, moderate impacts would occur at about 200 mg/L. For duration of more than 10 hours, a concentration of 1,000 mg/L could result in major impacts.

Where body contact recreation, aesthetic or other uses require the control of nutrients entering the receiving system, it is recommended that Total Phosphorus (TP) removal be adopted as an alternative or as an additional primary design criterion. The following general relationship exists between TSS and TP removal rates:

TSS %	TP %
80	50
70	45
60	35

Based on estimated 50% higher TP concentration and 100% increase in runoff caused by urbanization, there could be an associated 150% increase in the TP loads. To match the pre-urbanized TP loads, the selected BMP should reduce the post-development load by approximately 67%. Wet ponds and constructed wetlands TP removal capability is limited to approximately 45% to 50%. Therefore, where the TP design criteria requires a reduction in excess of that range, additional BMPs would be required to meet the desired level of control. There is extensive background information available on the water quality of local lakes and rivers in the HRM area (http://lakes.chebucto.org), assembled by the Soil and Water Conservation Society of Metro Halifax.

Just as comprehensive watershed studies may include flood control requirements based on cumulative effects of multiple developments, nutrient loading and trophic status modelling may be required to determine TP removal requirements. These studies may even identify linkages between nutrient levels and fish habitat as excessive algae and plant growth can result in the depletion of dissolved oxygen as plant material decomposes.

The water quality criterion for sizing stormwater management facilities has two components: 1) for sizing storage facilities a volume criterion; and 2) for flow-through BMPs a peak flow criterion is recommended. Water quality control BMPs use primarily sedimentation processes to remove pollutants, through settling and/or filtering. Particulate pollutants such as sediment and metals are relatively easy to remove, while soluble pollutants such as nitrates and phosphates are more difficult to remove. A volume generated by a relatively low rainfall and runoff design event generally defines the detention volume requirement for water quality control with a storage facility. Design criteria for BMPs that permit runoff to a flow-through filtration or settling system are related to flow rates and velocities.

When managing runoff for water quality impacts, the control of more frequent and smaller rainfall events are selected. This approach is based on the fact that the percentage of annual precipitation for very large events is relatively small, and the construction cost of storage facilities based on extreme rainfall events would be prohibitive. This approach can still provide partial benefit for larger storms as the BMP can continue to control pollutants from the first portion of the larger storm's runoff.

The water quality volume criteria for sizing BMPs for the HRM area was determined from an analytical model as described in ***Appendix F***. Long-term local rainfall data was analyzed to determine storage requirements for different impervious conditions and TSS removal efficiencies. The total storage volume in a wet pond or in a constructed wetland consisting of a permanent pool and an extended detention should generally be equivalent to the runoff volume generated by 90% of the long-term rainfall events observed in HRM. (For rainfall information see ***Appendix E***)

An example of the relationship between permanent pool storage and TSS removal efficiency as described in ***Appendix F*** is reproduced on ***Figure 5-1***. Increasing the active storage over 40 m^3/ha would only marginally increase the TSS removal.

The peak flow water quality criterion is based on a statistical analysis of local precipitation data. It is recommended that a 25 mm winter rain event should be used to estimate the peak flow generated by the proposed land use.

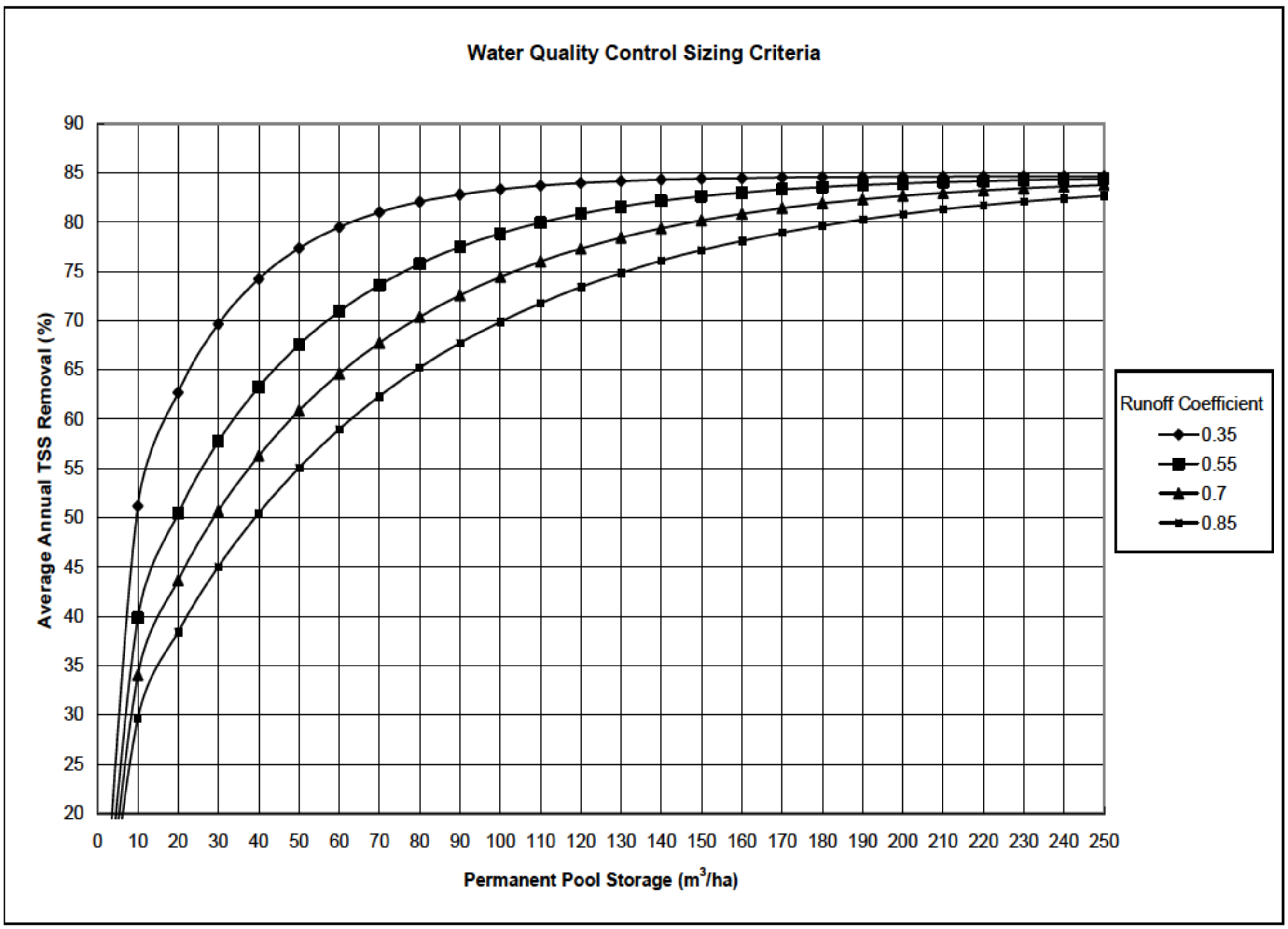

Figure 5-1 **Example of Sizing Permanent Pool Storage for Water Quality Control**

5.4 Design Criteria for Erosion Control

The preferred approach for addressing erosion concerns is at the watershed/subwatershed planning level. During watershed/subwatershed planning, pre and post-development exceedance erosive index values are computed for a watercourse to determine the need for and the magnitude of erosion control measures.

To select the erosion criterion when no such information is available, it is recommended to undertake an analysis of downstream channel conditions to assess the potential effects of post-development flows, water levels, and velocities on erosion. Such an analysis of erosion potential should extend downstream to a point where the runoff from the upstream drainage area controlled by the pond represents only 10% of the total drainage area.

In the absence of information on downstream channel conditions, a 25 mm winter storm is recommended for the erosion control design event. This storm should be based on a 6 hour Chicago distribution event and should be routed through a storage facility assuming a gradual release rate with a drawdown time of 24-48 hours. For sensitive streams, the longer drawdown time should be used. The required storage is then compared to the extended quality control storage, and the greater of the two is used for design.

For BMPs other than wetpond/wetland, the analysis of downstream channel conditions should determine the need for flow control or erosion protection requirements based on velocities and erosive forces generated by a 25 mm winter rain.

5.5 Recharge and Base Flow Maintenance

The need for providing groundwater recharge at a particular site will depend on the use of local aquifers. Where there is a potential risk of adversely affecting groundwater supply (quantity or quality) in the area, or the risk of reduction in base flow, the recharge from a proposed development should attempt to match the pre-development recharge. The pre- and post-development recharge can be estimated by a simple computation of the hydrologic cycle components.

The local average annual precipitation and evaporation components of the hydrological cycle in the HRM area are:

Precipitation	1421 mm
Evapotranspiration	552 mm
Surplus	869 mm (made up of recharge/base flow and surface runoff)

The recharge and base flow components of the surplus can be estimated by an infiltration factor determined by summing the following factors for topography, soils and cover (Ontario Ministry of the Environment, Stormwater Management Planning and Design Manual (2003)):

Topography	**Factor**
Flat Land, average slope <0.6 m/km	0.3
Rolling Land, average slope 2.8 m to 3.8 m/km	0.2
Hilly Land, average slope 28 m to 47 m/km	0.1
Soils	
Tight impervious clay	0.1
Medium combinations of clay and loam	0.2
Open sandy loam	0.3
Cover	
Cultivated Land	0.1
Woodland	0.2

The range of infiltration factor to be applied is 0.3 to 0.8, therefore the minimum recharge and base flow component of the hydrological cycle could be 260 mm (= 0.3 x 869 mm). For post-development conditions when an area is paved and becomes impermeable, the infiltration/base flow and evapotranspiration components are removed from the hydrologic cycle.

Infiltration through BMPs can provide groundwater recharge by diverting runoff from small and moderate storms into an infiltration facility. An additional benefit is achieved by providing opportunities for a number of physical, chemical and biological processes that remove pollutants from the recharge water. A general guideline for recharge and base flow maintenance is to capture where feasible the first 5 mm of rainfall.

A summary of the recommended design criteria for BMPs is listed in ***Table 5-3.***

Table 5-3
Summary of Design Criteria

Control	Criteria	Comments
Flood and water quantity control	Control peak discharges from the 2, 5, 25, 50 and 100-year storms to pre-development rates	• Downstream system analysis may reveal that flood control criterion may not be required. • Should consider the cumulative effects of development and controls.
Water quality	Volume control for storage facilities, or control of peak flow from a 25 mm winter rainfall	• Compute storage from design graphs, or generate hydrographs for the single event design storm
Stream channel erosion	Control of peak flows	• 24 hour-48 hour extended detention of post-development 25 mm winter storm event. • Should consider the cumulative effects of development and controls.

Control	Criteria	Comments
Baseflow	Infiltrating the first 5 mm rainfall	• Where feasible, the pre-development hydrologic cycle components should be maintained.

5.6 Municipal Infrastructure Criteria

A set of storm drainage guidelines was released by HRM in 2005 as part of the Municipal Services Systems Design Guidelines. This municipal document describes the guidelines to be used in the design of municipal storm sewer pipes, ditches and other appurtenances. In particular, the document deals with the design of the major-minor drainage components of urban drainage systems, such as sewers, catch basins, and foundations drains. The stormwater sections of the Guideline document, reproduced in ***Appendix G,*** contains information on:

- Design parameters for the Minor Drainage system;
- Storm sewer system design: pipes, catchbasins, street drainage, ditches, culverts;
- Minor drainage system connections, roof leaders, foundation drains; and
- Erosion and sediment control.

Table 5-4 summarizes the various guidelines listed in the Municipal document. It also details design requirements in addition to those outlined in the Municipal Services System Guidelines.

Table 5-4
Summary of Existing HRM Storm Drainage Design Guidelines

System Component	Guideline	Additional Requirements
Minor System		
Design flow	• Larger of the winter or annual flow. • Where time of concentration >6 hours use winter precipitation and ice/snowmelt. • Where significant portion of area is underdeveloped use annual and winter data. • Piped systems and driveway culverts: minor storm. • Combined capacity of major and minor systems: major storm. • Watercourses, culverts, roadside ditches, in absence of minor system: major system. • Road culverts: 1:10 year storm.	• As recommended in watershed or subwatershed plans. • In absence of such plans the sewer sizing should be based on 1 in 5 year storm without surcharge.
Downstream effects	• Have capacity to convey discharge from fully developed watershed.	
Rainfall data	• Historical data IDF curves for nearby station. • Synthetic storms, Chicago distribution of 2 and 24 hours, r=0.5, discretization 5	• Storm discretization be selected considering basin size. Five minutes is less than the minimum Tc for

System Component	Guideline	Additional Requirements
	minutes and 1 hour for the two storms. • Historical storms used for verification of storage pond performance.	most rational method design – it can lead to very high peaks in small basins.
Runoff computation	• Model must be calibrated and verified. • Rational method for preliminary design for <20 ha, but not for storage.	
Hydraulic design of sewer pipe	• Manning formula, based on published roughness coefficients. • Minimum pipe size is 300 mm diameter. • No decrease in size in the downstream direction, except at intakes.	
Catch basins	• Located in the gutter line, should minimize ice accumulation and ponding. Double catch basins may be required at locations to prevent by-pass of storm flows. • Spacing not to exceed 120 m. • Interception capacity be compatible with the storm drainage capacity. • Where potential for contamination inverted siphons or separators may be required.	• For more details see Appendix G.
Catch basin leads	• Minimum size 200 mm. • Minimum cover 1 m at construction and 1.2 m at completion of construction. • Minimum slope 1%. • Incorporate flexible joint. • Generally, catch basin connection to another catch basin is not permitted.	• For more details see Appendix G
Storm sewer leads	• Connected from the building foundation should be PVC DR35, 150 mm diameter or less.	
Foundation drains	• Normally drained by gravity to storm sewers and located above the hydraulic grade of major storms, or above the major storm flood if connected to a watercourse.	• No connection permitted to sanitary sewers. Basement floor >1m above 100 year hydraulic grade line.
Roof drains	• May be connected to the storm sewer system if capacity available. • Discharge to a dry well normally not permitted. • Under the Lot Grading bylaw, roof drains are not permitted to be connected to the storm sewer except at discretion of HRM.	• Infiltration of roof runoff to be encouraged subject to soil conditions. Roof leaders should discharge to splash pads 4 m away from building.
Institutional, commercial and industrial connections	• Limit flow to 40% of uncontrolled fully developed flow.	
Major System		
Street and overland flow routes	• Minor storms, depth of flow in gutters <50 mm. • Major storms, depth of flows <50 mm at	• For major system use 100 year return storm event.

System Component	Guideline	Additional Requirements
	crown. • No overtopping of curbs and gutter enter driveways, except where a major system is provided. • Open ditches should not be overtopped and enter driveways.	
Ditches and open channels	• Minimum grade 1%. • For rural roads ditch capacity based on major storm. • Depth at bank full conditions <1.2 m, side slopes not steeper than 2H:1V. • Wetted perimeter stabilized above 4% grade. • Maximum velocity at unlined.	
Culverts	• Grade, obverts of outfalls <150 mm above minor storm level, above normal ice level, allowance for accumulation of debris at the outfall. Minimum grade 1%. • Hydraulic capacity to determined by inlet and outlet control computation. • Headwater depth <2 x diameter of pipe. No inundation of buildings. • Grates if structure >30 m long. • Inlet and outlet structure if piped diameter >375 mm extended >600 mm beyond toe of slope. • Minimum diameter for driveway culvert diameter 450 mm, or not smaller than upstream culvert. • Minimum diameter for roads 525 mm. • Culvert materials: reinforced concrete CSA 257.2 and STM C-76 or high-density polyethylene pipe CSA B182.6. ASTM F-667, and have a minimum stiffness of 320 kPa. • Watercourses with drainage area > 40 ha to be maintained as open.	Culvert design capacities: • Urban arterial road, 50-100 year return frequency. • Rural arterial road, 25 – 50 year return frequency. • Local road, 10-25 year return frequency.

5.7 Pollutant Loads

The goal in selecting the best BMP for a site is to minimize the adverse effects of the proposed development on the environment. The aim is to match predevelopment conditions in the receiving system. A list of pollutant loads generated by different land uses based on CH2M Hill is presented in ***Table 5-5*** to assist the designer in estimating pre and post development pollutant

Table 5-5
Mean Pollutant Concentration Generated by Different Land Uses

Land Use	Primary Indicators		Secondary Indicators					Metals						
	TSS (mg/L)	TP (mg/L)	BOD (mg/L)	COD (mg/L)	TKN (mg/L)	TDS (mg/L)	TN (mg/L)	Cd (ug/L)	Cr (ug/L)	Cu (ug/L)	Pb (ug/L)	Ni (ugL)	Zn (ug/L)
Forested wetland	19.0	0.2	4.1	29.4	0.6	52.0	1.1	0.5	2.8	5.3	3.0	4.7	22.9
Cropland and Pasture	19.2	0.2	4.2	29.7	0.6	52.0	1.1	0.5	2.9	5.4	3.1	4.7	23.5
Upland forest	19.7	0.2	4.3	30.4	0.7	52.0	1.1	0.5	2.9	5.6	3.2	4.7	24.8
Urban open	20.0	0.2	4.4	30.7	0.7	52.0	1.1	0.5	2.9	5.7	3.2	4.7	25.4
Communication and utilities	20.7	0.2	4.6	31.7	0.7	52.0	1.2	0.5	3.0	6.0	3.4	4.8	27.5
Low-density Residential	22.1	0.2	5.0	33.4	0.8	52.0	1.2	0.5	3.1	6.5	3.8	4.8	31.2
Medium-density residential	30.5	0.2	7.5	43.5	1.1	52.0	1.7	0.6	3.8	9.7	6.1	5.0	59.4
Institutional	41.9	0.3	11.3	56.7	1.5	52.0	2.4	0.6	4.5	14.7	9.9	5.3	112.9
High-density residential	47.7	0.3	13.3	63.1	1.7	52.0	2.7	0.7	4.9	17.3	12.0	5.4	145.9
Multifamily residential	47.7	0.3	13.3	63.1	1.7	52.0	2.7	0.7	4.9	17.3	12.0	5.4	145.9
Commercial	54.2		15.7	70.1	2.0		3.1	0.7	5.3	20.4	14.5	5.5	188.7
Highways	57.8		17.0	74.0	2.1	1.3	3.3	0.7	5.5	22.1	16.0	5.5	214.6
Industrial	57.8		17.0	74.0	2.1	1.3	3.3	0.7	5.5	22.1	16.0	5.5	214.6

loads for selected parameters. The data represents event mean concentrations monitored across North America. Generally, in the design of stormwater management facilities, only one or two key indicators, such as TSS and TP are considered. Runoff from impervious surfaces has a high potential for introducing pollutants to surface waters. Suspended solids, dissolved nutrients and oil/grease cause the most common water quality concerns. The existing and future pollutant loads could be estimated to provide an indication to the desired level of control. This early estimate will assist in the selection of the most appropriate alternative BMPs.

The portion of the HRM Waste Water Discharge by-law related to stormwater is presented in ***Appendix H***. This by-law describes limits for chemicals discharged to the municipal storm sewer system.

5.8 Exemptions From Runoff Control

Stormwater control would not normally be required for:

- Single lot development of one family dwelling should apply, as a minimum, basic source control measures, such as reduced lot grades and disconnection of roof leaders. Additional stormwater management measures may also be needed subject to local conditions;
- Addition to existing commercial buildings, provided the total impervious area is not increased, and the existing stormwater management facilities are adequate and are not altered; and
- Runoff from a development if it will be controlled by an external regional stormwater facility.

It is recommended that recognition should be given to any non-structural facility when selecting and sizing BMPs for a particular site. For example, appropriate reduction in the design volume or peak flow should be permitted for conservation of natural areas, disconnection of roof runoff if diverted to an infiltration facility, or use of vegetated swales with an infiltration function which will reduce the effective drainage area contributing to the BMP.

APPENDIX C
PORTIONS OF STANDARD AND GUIDELINES FOR MUNICIPAL WATERWORKS, WASTEWATER, AND STORM DRAINAGE SYSTEMS
PUBLISHED BY ALBERTA ENVIRONMENT IN MARCH 2013

Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems

Part 5
Stormwater Management Guidelines
of a Total of 5 Parts

March 2013

Alberta Government

ISBN: 978-1-4601-0298-5 (Printed Edition)
ISBN: 978-1-4601-0299-2 (On-Line Edition)
Website: http://environment.gov.ab.ca/info/library/8559.pdf

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Part 5 STORMWATER MANAGEMENT GUIDELINES
March 2013

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Additional Parts published separately are:

Part 1 Standards for Municipal Waterworks
Part 2 Guidelines for Municipal Waterworks
Part 3 Wastewater Systems Standards for Performance and Design
Part 4 Wastewater System Guidelines for Design, Operating and Monitoring

FOREWORD TO PART 5 STORMWATER MANAGEMENT GUIDELINES (2013)

Alberta Environment and Sustainable Resource Development (AESRD) has the regulatory mandate, in accordance with the Environmental Protection and Enhancement Act and Regulations, for the Drinking Water, Wastewater and Storm Drainage serving large public systems in Alberta. AESRD considers the establishment of standards and guidelines for municipal waterworks, wastewater and storm drainage facilities an integral part of our regulatory program directed at ensuring public health and environmental protection. AESRD's objective is to develop comprehensive and scientifically defensible standards and guidelines that are effective, reliable, achievable and economically affordable.

Since publication of the last revision of the Standards and Guidelines, Alberta Environment and Sustainable Resource Development has embarked on a process of "decoupling" the various components of the January 2006 document into functionally-associated sections to aid those using the document. This process started with the publication of the January 2006 version of the Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems in the Alberta Gazette. A program of separating the component parts of this document is under way and new parts will eventually replace the corresponding sections in the January 2006 Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems. Until the process of "decoupling" is completed with new "Parts" the existing sections of the 2006 Standards and Guidelines document will remain in operation. This Part (Part 5) details system components that are guidance to best practices in providing well designed and managed Storm Drainage System.

Engineering consultants and / or the system owners / utilities are responsible for the detailed project design and satisfactory construction and operation of the Storm Drainage systems.

In accordance with the Wastewater and Storm Drainage Regulation (119/1993) storm drainage will be designed so that it meets, as a minimum, the applicable standards set out in the Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems, published by AESRD, as amended or replaced from time to time, or, any other standards and design requirements specified by the Regional Director.

AESRD last revised its Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems in January 2006.

This present part is intended to provide general guidance on for storm drainage management. Good engineering and best management practices are included in this Part. These are not mandatory requirements but they establish the minimum expectation when the system owner / utility applies for registration.

The only change from the January 2006 version of the Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems is the numbering of Section 6 – Stormwater Management Guidelines. This document, Part 5 – Stormwater Management Guidelines is now numbered 5.0 through 5.3.6.4.

DEFINITIONS / ABBREVIATIONS

AO	-	Aesthetic Objectives
AESRD	-	Alberta Environment and Sustainable Resource Development
AWWA	-	American Water Works Association
BDOC	-	Biodegradable Dissolved Organic Carbon
BNR	-	Biological Nutrient Removal
BPJ	-	Best Professional Judgement
BPR	-	Biological Phosphorus Removal
BPT	-	Best Practicable Technology
CBOD	-	Carbonaceous Biochemical Oxygen Demand at 5 days and 20 °C
CFID	-	Continuous feed and intermittent discharge
DAF	-	Dissolved Air Flotation
DBP	-	Disinfection By-product
DCS	-	Distributed Control System
DO	-	Dissolved Oxygen
DOC	-	Dissolved Organic Carbon
DWSP	-	Drinking Water Safety Plan
EPEA	-	Environmental Protection and Enhancement Act
F/M	-	Food to Microorganism ratio
G	-	Velocity Gradient
GCDWQ	-	Guidelines for Canadian Drinking Water Quality
GWUDI	-	Groundwater under the direct influence of surface water
HPC	-	Heterotrophic Plate Count
HRT	-	Hydraulic Retention Time
IFID	-	Intermittent feed and intermittent discharge
MAC	-	Maximum Acceptable Concentration
MLSS	-	Mixed Liquor Suspended Solids
NH_3-N	-	Ammonia nitrogen
NSF	-	National Sanitation Foundation
NTU	-	Nephelometric Turbidity Unit
ORP	-	Oxidation Reduction Potential
OU	-	Odour Unit
PLC	-	Programmable Logic Controllers
QA/QC	-	Quality Assurance/Quality Control
RBC	-	Rotating Biological Contactor
SAR	-	Sodium Adsorption Ratio
SBR	-	Sequencing Batch Reactor
SRT	-	Sludge Retention Time
TBOD	-	Total Biochemical Oxygen Demand at 5 days and 20 °C
TOC	-	Total Organic Carbon
TP	-	Total Phosphorus
TSS	-	Total Suspended Solids
TTHM	-	Total Trihalomethanes
UC	-	Uniformity Coefficient
USEPA	-	United States Environmental Protection Agency
UV	-	Ultraviolet
WHO	-	World Health Organization

Average daily design flow (water and wastewater) - The product of the following:

- design population of the facility, and
- the greatest annual average per capita daily flow which is estimated to occur during the design life of the facility.

Co-op - An organization formed by the individual lot owners served by a waterworks system, wastewater system or storm drainage system.

Granular filter media:

1. Effective Size (D_{10}) - Size of opening that will just pass 10% of representative sample of the granular filter media.
2. Uniformity Coefficient - A ratio of the size opening that will just pass 60% of the sample divided by the opening that will just pass 10% of the sample.

Groundwater - All water under the surface of the ground.

Maximum daily design flow (water) - Maximum three consecutive day average of past-recorded flows, times the design population of the facility. If past records are not available, then 1.8 to 2.0 times the average daily design flow.

Maximum hourly design flow (water) - 2.0 to 5.0 times the maximum daily design flow depending on the design population.

Maximum monthly average daily design flow (wastewater) - The product of the following:

1. design population of the facility, and
2. the greatest monthly average per capita daily flow which is estimated to occur during the design life of the facility.

Owners - Owners of the waterworks or wastewater systems as defined in the regulations.

Peak demand design flow (water) - the maximum daily design flow plus the fire flow.

Peak wastewater design flow (wastewater) - The sum of the peak dry weather flow rates as generated by population and land use, and the rate of all extraneous flow allowances, as determined for the design contributing area (see Section 4.1.1).

Potable water – As defined in the EPEA. Other domestic purposes in the EPEA definition include water used for personal hygiene, e.g. bathing, showering, washing, etc.

Sodium adsorption ratio - A ratio of available sodium, calcium and magnesium in the soil solution which can be used to indicate whether or not the accumulation of sodium in the soil exchange complex will lead to a degradation of soil structure.

$$SAR = \frac{Na}{\left[\frac{Ca}{2} + \frac{Mg}{2}\right]^{1/2}}$$

Note : All concentrations expressed in milliequivalents per litre

Surface water - Water in a watercourse.

Watercourse - As defined in the EPEA.

TABLE 5.3 PHYSICAL BMP CONSTRAINTS					
BMP	Criteria				
	Topography	Soils	Bedrock	Groundwater	Area
On-Lot BMP					
Flat lot grading	<5%	none	none	none	none
Soak-away pit	none	loam (min. infiltration rate ≥15 mm/h)	>1 m below bottom	>1 m below bottom	<0.5 ha
Rear yard infiltration	<2%	loam (min. infiltration rate ≥15 mm/h)	>1 m below bottom	>1 m below bottom	<0.5 ha
Conveyance BMP					
Grassed swales	<5%	none	none	none	none
Perforated pipes	none	loam (min. infiltration rate ≥15 mm/h)	>1 m below bottom	>1 m below bottom	none
Pervious catch basins	none	loam (min. infiltration rate ≥15 mm/h)	>1 m below bottom	>1 m below bottom	none
End-of-Pipe BMP					
Wet pond	none	none	none	none	>5 ha
Dry pond	none	none	none	none	>5 ha
Wetland	none	none	none	none	>5 ha
Infiltration basin	none	loam (min. infiltration rate ≥15 mm/h)	>1 m below bottom	>1 m below bottom	<5 ha
Infiltration trench	none	loam (min. infiltration rate ≥15 mm/h)	>1 m below bottom	>1 m below bottom	<2 ha
Filter strips	<10%	none	none	>0.5 m below bottom	<2 ha
Sand filters	none	none	none	>0.5 m below bottom	<5 ha
Oil / grit separators	none	none	none	none	<1 ha

5.3.6.3 Final Screening

In the initial screening phase the options for BMPs were limited by particular disadvantages and site constraints. The list of BMP options that are still considered feasible are further screened by the application of specific objectives that must be met as part of the development including:

- water quality
- flooding
- erosion
- recharge.

The performance of BMPs in regard to the objectives for stormwater management are shown in Table 5.4.

TABLE 5.4
POTENTIAL BMP OPPORTUNITIES

Stormwater BMP	Water Quality	Flooding	Erosion	Recharge
Lot Level BMPs				
Lot grading	♦	♦	♦	•
Roof leader ponding	♦	♦	♦	•
Roof leader soak-away pits	♦	♦	♦	•
Conveyance BMPs				
Pervious pipes	•*	♦	♦	•
Pervious catch basins	•*	♦	♦	•
Grassed swales	•	♦	•	♦
End-of-Pipe BMPs				
Wet pond	•	•	•	❍
Dry pond	♦	❍	•	❍
Dry pond with forebay	•	•	•	❍
Wetland	•	•	•	❍
Sand filter	•	♦	♦	❍
Infiltration trench	♦*	♦	♦	•
Infiltration basin	♦*	♦	♦	•
Vegetated filter strip	•	❍	♦	♦
Buffer strip	♦	❍	♦	♦
Special purpose BMP				
Oil / grit separator	♦	❍	❍	❍

• Highly effective (primary control)
♦ Limited effectiveness (secondary control)
❍ Not effective
* May have adverse effects
From MOEE, 1994

5.3.6.4 Water Quality Control and Enhancement Opportunities

In many areas of development, stormwater management practices must meet stringent water quality objectives to protect sensitive receiving waters. Water quality objectives can be defined for a stormwater management system and then appropriate BMPs can be selected from the pre-screened list that will meet the water quality objectives.

The reported effectiveness of a number of BMPs to remove pollutants are shown in Table 5.5.

TABLE 5.5
EFFECTIVENESS OF BEST MANAGEMENT PRACTICES FOR CONTROL OF RUNOFF FROM NEWLY DEVELOPED AREAS

Management Practice		Removal Efficiency (%)						Factors	References
		TSS	TP	TN	COD	Pb	Zn		
Infiltration Basin	Average:	75	65	80	65	65	65	Soil percolation rates Basin surface area Storage volume	NVPDC, 1979; EPA, 1977; Schueler, 1967; Griffin et al, 1980; EPA, 1963; Woodword-Clyde, 1966
	Reported Range:								
	SCS Soil Group A	60-100	60-100	60-100	60-100	60-100	60-100		
	SCS Soil Group B	50-80	50-80	50-80	50-80	50-80	50-80		
	No. of Values Considered:	7	7	7	4	4	4		
Infiltration Trench	Average:	75	60	55	65	65	65	Soil Percolation rates Trench surface area Storage volume	NVPDC, 1979; EPA, 1977; Schueler, 1967; Griffin et al, 1980; EPA, 1963; Woodword-Clyde, 1966; Kuo et al 1968; Lugbill, 1990
	Reported Range:	45-100	40-100	(110)-100	45-100	45-100	45-100		
	Probable Range:								
	SCS Soil Group A	60-100	60-100	60-100	60-100	60-100	60-100		
	SCS Soil Group B	50-90	50-90	50-90	50-90	50-90	50-90		
	No. of Values Considered:	9	9	9	4	4	4		

TABLE 5.5 continued
EFFECTIVENESS OF BEST MANAGEMENT PRACTICES FOR CONTROL OF RUNOFF FROM NEWLY DEVELOPED AREAS

Management Practice		Removal Efficiency (%)						Factors	References
		TSS	TP	TN	COD	Pb	Zn		
Vegetated Filter Strip	Average:	65	40	40	40	45	60	Runoff volume Slope Soil infiltration rates Vegetative cover Buffer length	IEP, 1991 Casman, 1990 Glick et al, 1991 VADC, 1987 Minnesota PCA, 1989 Scheuler, 1967 Hartigan et al 1969
	Reported Range:	20-80	0-95	0-70	0-60	20-90	30-90		
	Probable Range:	40-90	30-80	20-60	-	30-80	20-50		
	No. of Values Considered:	7	4	3	2	3	3		
Grass Swale	Average:	60	20	10	25	70	60	Runoff volume Slope Soil infiltration rates Vegetative cover Swale length Swale geometry	Yousel et al, 1965 Dupuls, 1985 Washington State, 1968 Schuerer, 1967 British Columbia Res. Corp, 1991 EPA, 1983 Whelen et al, 1988 PIN, 1966 Caeman, 1990
	Reported Range:	0-100	0-100	0-40	25	3-100	50-80		
	Probable Range:	20-40	20-40	10-30	-	10-20	10-20		
	No. of Values Considered	10	8	4	1	10	7		

TABLE 5.5 continued
EFFECTIVENESS OF BEST MANAGEMENT PRACTICES FOR CONTROL OF RUNOFF FROM NEWLY DEVELOPED AREAS

Management Practice		Removal Efficiency (%)						Factors	References
		TSS	TP	TN	COD	Pb	Zn		
Porous Pavement	Average:	35	5	20	5	15	5	Maintenance Sedimentation storage volume	Pitt, 1965 Field, 1985 Schueler, 1967
	Reported Range:	0-95	5-10	5-55	5-10	10-25	5-10		
	Probable Range:	10-25	5-10	5-10	5-10	10-25	5-10		
	No. of Values Considered:	3	1	2	1	2	1		
Concrete Grid Pavement	Average:	90	90	90	90	90	90	Percolation rates	Day, 1961 Smith et al, 1961 Schueler, 1967
	Reported Range:	65-100	65-100	65-100	65-100	65-100	65-100		
	Probable Range:	60-90	60-90	60-90	60-90	60-90	60-90		
	No. of Values Considered:	2	2	2	2	2	2		
Sand Filter / Filtration Basin	Average:	80	50	35	55	60	65	Treatment volume Filtration media	City of Austin, 1986 Environmental and Conservation Service Department, 1990
	Reported Range:	60-95	0-90	20-40	45-70	30-90	50-80		
	Probable Range:	60-90	0-80	20-40	40-70	40-80	40-80		
	No. of Values Considered:	10	6	7	3	5	5		

TABLE 5.5 continued
EFFECTIVENESS OF BEST MANAGEMENT PRACTICES FOR CONTROL OF RUNOFF FROM NEWLY DEVELOPED AREAS

Management Practice		Removal Efficiency (%)						Factors	References
		TSS	TP	TN	COD	Pb	Zn		
Water Quality Inlet	Average:	35	5	20	5	15	5	Maintenance Sedimentation storage volume	Pitt, 1965 Field, 1965 Schueler, 1967
	Reported Values:	0-95	5-10	5-55	5-10	10-25	5-10		
	Probable Values:	10-25	5-10	5-10	5-10	10-25	5-10		
	No. of Values Considered:	3	1	2	1	2	1		
Water Quality Inlet with Sand Filter	Average:	80	NA	35	55	80	65	Sedimentation storage volume Depth of media	Shaver, 1991
	Reported Range:	75-85	NA	30-45	45-70	70-90	50-80		
	Probable Range:	70-90	–	30-40	40-70	70-90	50-80		
	No. of Values Considered:	1	0	1	1	1	1		
Oil / Grit Separator	Average:	15	5	5	5	15	5	Sedimentation storage volume Outlet configurations	Pitt, 1965 Schueler, 1967
	Reported Range:	0-25	5-10	5-10	5-10	10-25	5-10		
	Probable Range:	10-25	5-10	5-10	5-10	10-25	5-10		
	No. of Values Considered:	2	1	1	1	1	1		

TABLE 5.5 continued
EFFECTIVENESS OF BEST MANAGEMENT PRACTICES FOR CONTROL OF RUNOFF FROM NEWLY DEVELOPED AREAS

Management Practice		Removal Efficiency (%)						Factors	References
		TSS	TP	TN	COD	Pb	Zn		
Extended-Detention Dry Pond	Average:	45	25	30	20	50	20	Storage volume Detention time Pond shape	MWCOG, 1983 City of Austin, 1990 Schueler and Heinrich, 1965 Pope and Hess, 1989 OWML, 1967 Wollnold and Stack, 1990
	Reported Range:	5-90	10-55	20-60	0-40	25-65	(-40)-65		
	Probable Range:	70-90	10-60	20-60	30-40	20-60	40-60		
	No. of Values Considered:	6	6	4	5	4	5		
Wet Pond	Average:	60	45	35	40	75	80	Pond volume Pond shape	Wotzka and Oberta, 1966 Yousel et al, 1968 Cullum, 1985 Driscoll, 1983 Driscoll, 1986 MWCOG, 1963 OWML, 1963 Yu and Benemouflok, 1986 Hother, 1989 Martin, 1966 Dowman et al, 1969 OWML, 1962 City of Austin, 1990
	Reported Range:	(-30)-91	10-85	5-85	5-90	10-85	10-95		
	Probable Range:	50-90	20-90	10-90	10-90	10-95	20-95		
	No. of Values Considered:	18	18	9	7	13	13		

TABLE 5.5 continued
EFFECTIVENESS OF BEST MANAGEMENT PRACTICES FOR CONTROL OF RUNOFF FROM NEWLY DEVELOPED AREAS

Management Practice		Removal Efficiency (%)						Factors	References
		TSS	TP	TN	COD	Pb	Zn		
Extended-Detention Wet Pond	Average:	80	65	55	NA	40	20	Pond volume Pond shape Detention time	Ontario Ministry of the Environment, 1991 cited in Schueler et al 1992
	Reported Range:	50-100	50-60	55	NA	40	20		
	Probable Range:	50-95	50-90	10-90	10-90	10-95	20-95		
	No. of Values Considered:	3	3	1	0	1	1		
Constructed Stormwater Wetlands	Average:	65	25	20	50	65	35	Storage volume Detention time Pool shape Wetlands biota Seasonal variation	Harper et al, 1966 Brown, 1985 Wotzka and Oberta, 1966 Hickock et al, 1977 Burten, 1967 Martin, 1966 Morris et al, 1961 Sherberger and Davis, 1962 ABAG, 1979 Oberts et al, 1969 Rushton and Dye, 1990 Hay and Barrett, 1991 Martin and Smool, 1986 Ralnelt et al, 1990 cited in Woodward and Clyde, 1991
	Reported Range:	(-20)-100	(-120)-100	(-15)-40	20-80	30-95	(-30)-60		
	Probable Range:	50-90	(-5)-80	0-40	-	30-95	-		
	No. of Values Considered:	23	24	6	2	10	8		

NA - Not available

[a] Design criteria: storage volume equals 80% avg. runoff volume, which completely drains in 72 hours; maximum depth = 6 ft.; minimum depth = 2 ft.

[b] Design criteria: storage volume equals 90% avg. runoff volume, which completely drains in 72 hours; maximum depth = 5 ft.; minimum depth = 3 ft.; storage volume = 40% excavated trench volume

[c] Design criteria: flow depth < 0.3 ft.; travel time > 5 min.

[d] Design criteria: Low slope and adequate length

[e] Design criteria: minimum extended detention time 12 hours

[f] Design criteria: minimum area of wetland equal 1% of drainage area

[g] No information was available on the effectiveness of removing oil and grease

[h] Also reported as 90% TSS removed

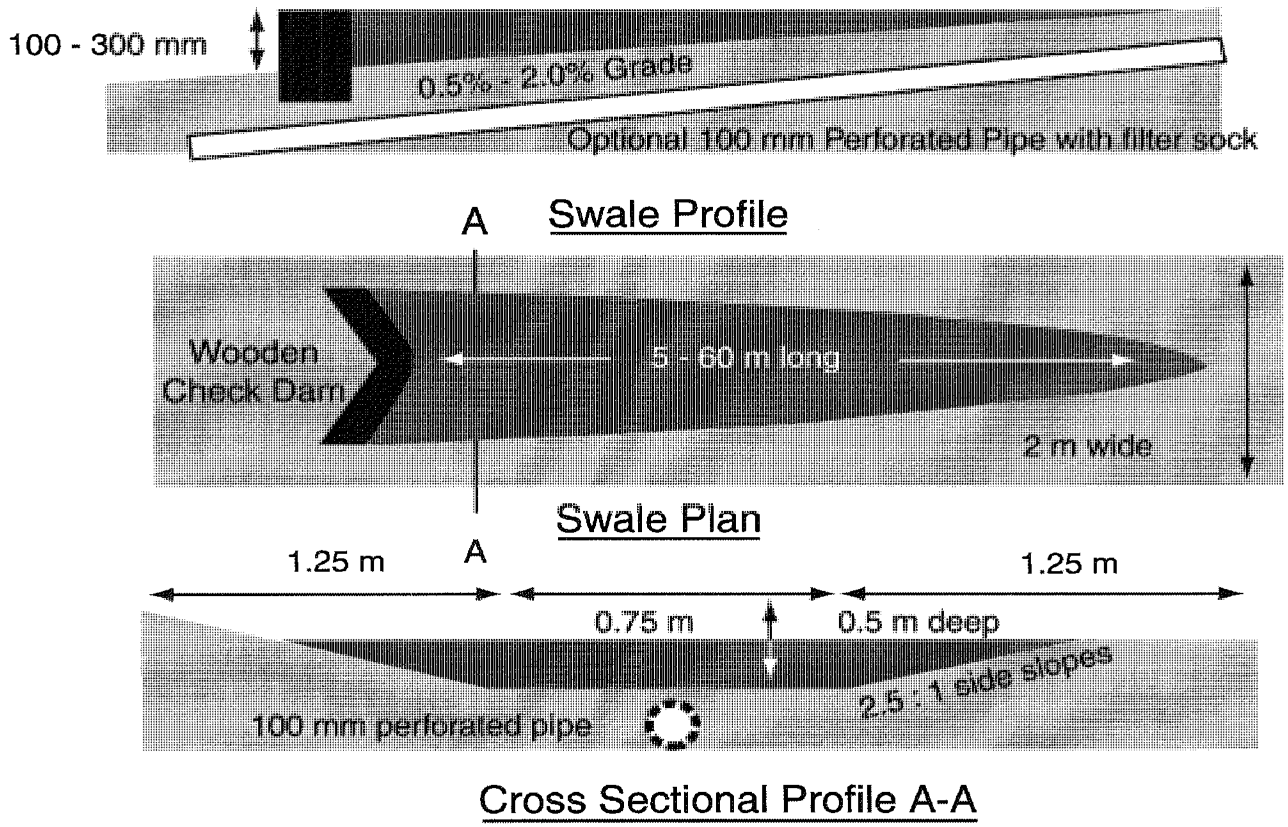


Figure 5.8
Grass Swale Design

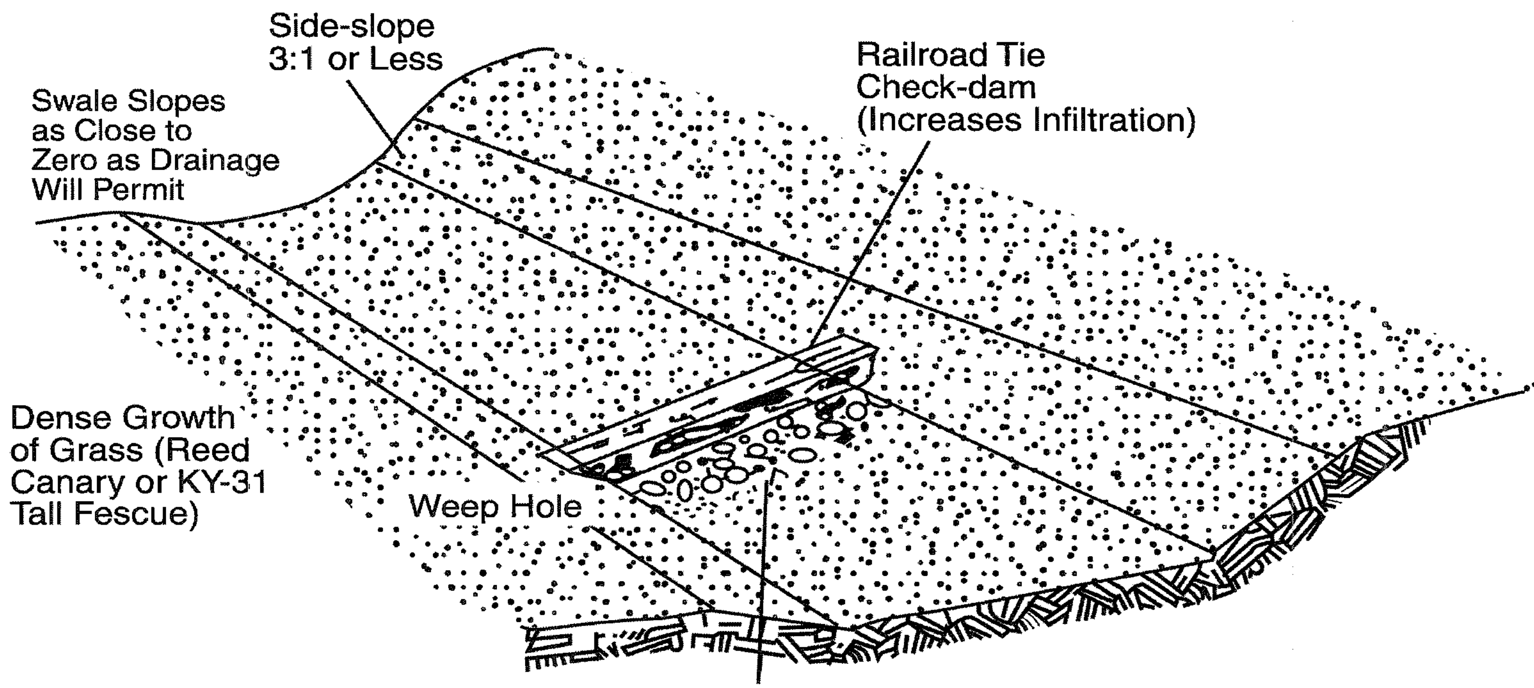


Figure 5.9
Grass Swale with Check Dam

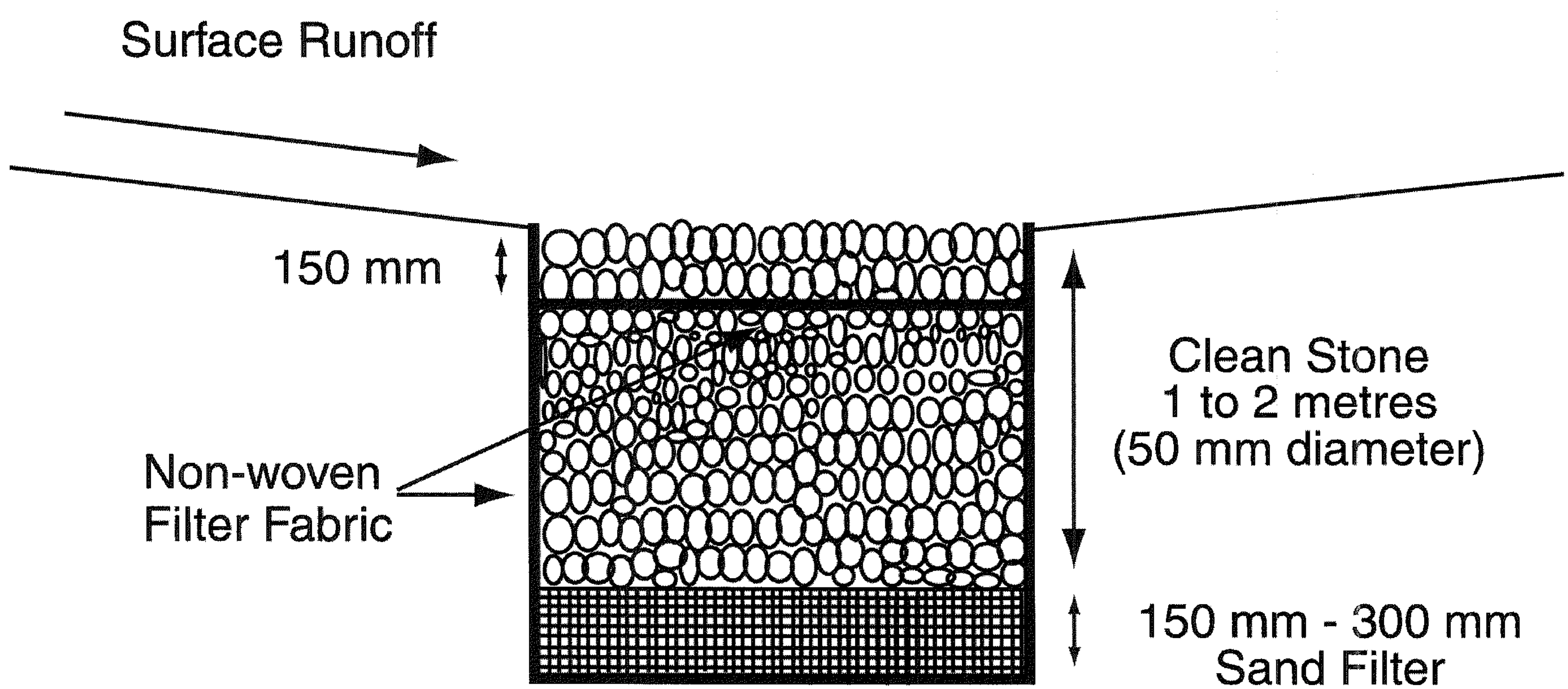


Figure 5.13
Surface Infiltration Trench

APPENDIX D
NEW JERSEY STORMWATER BEST MANAGEMENT PRACTICES MANUAL
PUBLISHED IN FEBRUARY 2004

C H A P T E R 4

Stormwater Pollutant Removal Criteria

This chapter presents the criteria and methodologies necessary to determine the pollutant removal rates of stormwater management measures used individually and in series to meet the stormwater quality requirements of the Stormwater Management Rules at N.J.A.C. 7:8. According to these Rules, a "major development" project that creates at least 0.25 acres of new or additional impervious surface must include stormwater management measures that reduce the average annual total suspended solids (TSS) load in the development site's post-construction runoff by 80 percent. This 80 percent requirement has been based, in part, upon Section 6217(g) of the 1990 Coastal Zone Management Act Reauthorization Amendments as enforced by the U.S. Environmental Protection Agency. In addition, these stormwater management measures must reduce the average annual nutrient load in the post-construction runoff by the maximum extent feasible. This requirement has been included in the Stormwater Management Rules because nutrients, consisting primarily of various forms of nitrogen and phosphorous, are recognized as a major class of stormwater pollutants from land development.

The stormwater management measures used to reduce the average annual TSS and nutrient loads can be structural and/or nonstructural in nature. To achieve the reduction requirements, they must be designed to treat the runoff from the stormwater quality design storm, a 1.25-inch/2-hour variable rate rainfall event. Details of the stormwater quality design storm are presented in *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. Details of nonstructural and structural stormwater management measures, also known as Best Management Practices (BMPs), are presented respectively in *Chapter 2: Low Impact Development Techniques* and *Chapter 9: Structural Stormwater Management Measures.*

TSS Removal Rates for Individual BMPs

As noted above, the Stormwater Management Rules require an 80 percent TSS reduction in the post-construction runoff from a land development site that increases impervious surface by 0.25 acres or more. This reduction is to be achieved by conveying the site's runoff through one or more onsite BMPs that have the ability to remove a portion of the TSS load. To demonstrate compliance with this requirement, the NJDEP has adopted official TSS removal rates for each of the BMPs described in detail in Chapter 9. These BMPs and their adopted TSS removal rates are presented below in Table 4-1. Different removal rates and BMPs may be utilized if supporting information is provided and accepted by the applicable review agencies.

It is important to note that the TSS removal rates shown in Table 4-1 have been based upon several sources of BMP research and monitoring data as well as consultation with numerous stormwater management experts. As demonstrated by that research, actual TSS removals at specific BMPs during specific storm events will depend upon a number of site factors and can be highly variable. As such, the TSS removal rates presented in Table 4-1 are considered representative values that are based upon a recognition of this variability and the state's need to develop and implement a statewide stormwater management program. Furthermore, the TSS removal rates are also considered to accurately represent the relative TSS removal efficiencies of the various BMPs listed in the table.

Table 4-1: TSS Removal Rates for BMPs

Best Management Practice (BMP)	Adopted TSS Removal Rate (%)
Bioretention System	90
Constructed Stormwater Wetland	90
Dry Well	Volume Reduction Only[1]
Extended Detention Basin	40 to 60[2]
Infiltration Structure	80
Manufactured Treatment Device	See N.J.A.C. 7:8-5.7(d)[3]
Pervious Paving System	Volume Reduction Or 80[4]
Sand Filter	80
Vegetative Filter	60-80
Wet Pond	50-90[5]

[1] See text below.
[2] Final rate based upon detention time. See Chapter 9.
[3] To be determined through testing on a case-by-case basis. See text below.
[4] If system includes a runoff storage bed that functions as an infiltration basin. See Chapter 9.
[5] Final rate based upon pool volume and detention time. See Chapter 9.

As shown in Table 4-1, a dry well and certain types of pervious paving do not have an adopted TSS removal rate. This is due to the fact that, as described in Chapter 9, a dry well is intended to infiltrate runoff only from a roof and other impervious area with minimal TSS loading. A pervious paving system without a runoff storage bed can reduce the runoff volume from standard paving, but is not used to treat runoff from other impervious areas. As such, these systems are not considered to be effective in reducing the overall TSS load from a development site. However, in recognition of their infiltration ability, both BMPs can be used to reduce the volume of development site runoff and, consequently, the size and cost of other onsite BMPs. Use of these "volume reduction" BMPs are illustrated in Example 4-2 below and described in detail in Chapter 5.

In addition, Table 4-1 also indicates that the adopted TSS removal rates for manufactured treatment devices must be determined on a case-by-case basis. Manufactured treatment devices are proprietary water quality devices that use a variety of stormwater treatment techniques. They have and continue to be developed by a variety of companies. As such, the actual TSS removal rate for a specific device will depend on a number of factors, and a single representative TSS removal rate cannot be developed. Instead, the NJDEP's Division of Science, Research & Technology (DSRT) is responsible for certifying final pollutant removal rates for all manufactured treatment devices. This certification process is described in detail in Chapter 9.

Finally, as noted in Table 4-1, the adopted TSS removal rates for extended detention basins and wet ponds will vary depending on such specific features as detention time and permanent pool volume. Details for each BMP are also provided in Chapter 9.

TSS Removal Rates for BMPs in Series

The TSS removal rates specified in Table 4-1 for certain BMPs range as low as 40 percent, which indicates that these BMPs will not be able to meet the 80 percent TSS reduction requirement by themselves. As such, it will be necessary at times to use a series of BMPs in a treatment train to achieve the required 80 percent TSS removal rate. In such cases, the total removal rate of the BMP treatment train is based on the removal rate of the second BMP applied to the fraction of the TSS load remaining after the runoff has passed through the first BMP (Massachusetts DEP, 1997).

A simplified equation for the total TSS removal rate (R) for two BMPs in series is:

$$R = A + B - [(A \times B) / 100] \qquad \text{(Equation 4-1)}$$

Where:

R = Total TSS Removal Rate

A = TSS Removal Rate of the First or Upstream BMP

B = TSS Removal Rate of the Second or Downstream BMP

The use of this equation is demonstrated in Example 4-1 below.

Example 4-1: Total TSS Removal Rate for BMPs in Series

A stormwater management system consists of both a vegetative filter and an extended detention basin to collect and treat runoff from a small commercial parking lot. Runoff from the parking lot will sheet flow off the parking lot through the filter strip, which will have a turf grass surface cover, before being discharged to the extended detention basin. The extended detention basin will have a detention time of 18 hours.

From Table 4-1 and Chapter 9, the adopted TSS removal rates for these individual BMPs are:

Turf Grass Vegetative Filter = 60%

Extended Detention Basin with 18-Hour Detention Time = 50%

From Equation 4-1,

$$R = A + B - [(A \times B) / 100]$$

$$R = 60 + 50 - [(60 \times 50) /100] = 110 - 30 = 80\% \text{ Total TSS Removal Rate}$$

It should be noted that the total TSS removal rate of the stormwater management system described in Example 4-1 above can also be computed by the following technique:

Initial TSS Load Upstream of Vegetated Filter Strip = 1.0

TSS Load Removed by Vegetated Filter Strip = 1.0 X 60% Removal Rate = 0.6

Remaining TSS Load Downstream of Vegetated Filter Strip = 1.0 – 0.6 = 0.4

TSS Load Removed by Extended Detention Basin = 0.4 X 50% Removal Rate = 0.2

Final TSS Load Downstream of Extended Detention Basin = 0.4 – 0.2 = 0.2

Total TSS Removal Rate = 1.0 – 0.2 = 0.8 or 80%

This technique can also be used in place of Equation 4-1 when there are more than two BMPs in series.

Guidelines for Arranging BMPs in Series

As described in Example 4-1, it may be necessary or desirable to use a series of BMPs in a treatment train to provide adequate TSS removal. In selecting the order or arrangement of the individual BMPs, the following general guidelines should be followed:

1. Arrange the BMPs from upstream to downstream in ascending order of TSS removal rate. In this arrangement, the BMP with the lowest TSS removal rate would be located at the upstream end of the treatment train. Downstream BMPs should have progressively higher TSS removal rates.
2. Arrange the BMPs from upstream to downstream in ascending order of nutrient removal rate. Similar to 1 above, the BMP with the lowest nutrient removal rate would be located at the upstream end of the treatment train in this arrangement. Downstream BMPs should have progressively higher nutrient removal rates.
3. Arrange the BMPs from upstream to downstream by their relative ease of sediment and debris removal. In this arrangement, the BMP from which it is easiest to remove collected sediment and debris would be located at the upstream end of the treatment train. In downstream BMPs, it should be progressively more difficult to remove sediment and debris.

In applying these guidelines, it is recommended that they generally be applied in the order presented above. As such, a series of BMPs would be preliminarily arranged in accordance with their relative TSS removal rates (Guideline 1). This preliminary arrangement would then be refined by the BMPs' relative nutrient removal rate (Guideline 2) and then their ease of sediment and debris removal (Guideline 3). Two or more iterations may be necessary to select the optimum arrangement, which should also include consideration for site conditions and the abilities and equipment of the party responsible for the BMPs' maintenance.

Finally, it should be noted that, unless otherwise approved by the applicable reviewing agencies or specifically indicated in the certification of a specific manufactured treatment device, all manufactured treatment devices that achieve TSS removal primarily through swirling and/or baffles should be placed at the upstream end of a treatment train.

Sites with Multiple Discharge Points and Subareas

In general, if runoff is discharged from a site at multiple points, the 80 percent TSS removal requirement will have to be applied at each discharge point. However, the application of this requirement will depend upon the exact amount of physical and hydraulic separation between the various discharge points. If the runoff from two or more discharge points combine into a single waterway or conveyance system before leaving the site, these separate discharge points can be considered as a single one for purposes of computing TSS removal.

In addition, where there are multiple onsite subareas to a single discharge point, the removal rates for the subareas can be combined through a weighted averaging technique. It should be noted that the averaging of TSS removal rates is applicable only where the anticipated pollutant loadings from each of the subareas are similar. As such, the TSS removal rate for an onsite BMP receiving runoff from a commercial parking lot cannot be averaged with a second onsite BMP serving a lawn or landscaped area.

Example 4-2 below provides further explanations of the procedures described above for computing TSS removal rates at sites with both multiple discharge points and subareas.

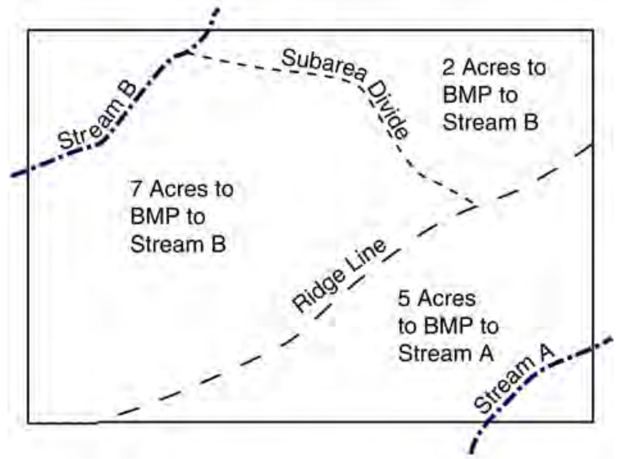
Example 4-2: TSS Removal Rates at Sites with Multiple Discharge Points and Subareas

A 15-acre site has a ridge running through it from northeast to southwest. Five acres of the site drain in a southeasterly direction to Stream A, while the remaining 10 acres drain in a northwesterly direction to Stream B. Since Stream A and B do not join on the site, each portion of the site will have to be evaluated separately for compliance with the 80 percent TSS removal requirement.

Southeast Drainage to Stream A

The site runoff to Stream A will first be routed through a bioretention system.

The bioretention system TSS removal rate is 90 percent. This exceeds the 80 percent removal requirements and meets the TSS removal requirement for the southeast drainage area.



Northwest Drainage to Stream B

One acre of rooftop runoff from the stormwater quality design storm will be directed to dry wells, thereby reducing the drainage area to be served by other BMPs by 1 acre. The remaining 9 acres to Stream B are divided into two subareas of 2 and 7 acres, respectively. A vegetative filter will treat the runoff from one of the subareas, while a constructed stormwater wetland will treat the runoff from other. The anticipated pollutant loadings from each subarea are similar.

The TSS removal rate for a vegetative filter with meadow is 70 percent, which is not sufficient by itself to meet the 80 percent TSS removal requirement. However, the constructed stormwater wetland TSS removal rate is 90 percent, which exceeds the 80 percent TSS removal requirement. By averaging of removal rates, the use of these two BMPs may be sufficient to meet the 80 percent removal requirement for this portion of the site.

Two alternatives to address the TSS load in the runoff from the northwest portion of the site to Stream B are presented below.

OPTION A: The meadow vegetative filter will be used to treat the runoff from the 7 acre subarea, while the constructed stormwater wetland will be used in the 2 acre subarea.

Apply the various TSS removal rates to the areas to be treated by each BMP and determine the average TSS removal rate for the entire northwest portion of the site.

7 Acres X 70% TSS Removal for Vegetative Filter= 4.9

2 Acres X 90% TSS Removal for Wetland = 1.8

Total Acreage-Removal Rate = 4.9 + 1.8 = 6.7

6.7 Total Acreage-Removal Rate / 9 Acres = 0.74 or 74% Average TSS Removal Rate

Therefore, for Option A, the northwest portion of the site does not meet the 80 percent TSS removal requirement.

OPTION B: The vegetative filter will be used to treat the runoff from the 2 acre subarea, while the constructed stormwater wetland will be used in the 7 acre subarea.

Once again, apply the various TSS removal rates to the areas to be treated by each BMP and determine the average TSS removal rate for the entire northwest portion of the site.

2 Acres X 70% TSS Removal for Vegetative Filter = 1.4

7 Acres X 90% TSS Removal for Wetland = 6.3

Total Acreage-Removal Rate = 1.4 + 6.3 = 7.7

7.7 Total Acreage-Removal Rate / 9 Acres = 0.86 or 86% Average TSS Removal Rate

Therefore, for Option B, the northwest portion of the site does meet the 80 percent TSS removal requirement.

Nutrients

In addition to TSS removal, the Stormwater Management Rules also require the reduction of post-construction nutrients to the maximum extent feasible. In general, to demonstrate compliance with this requirement, a two step approach should be used. First, the input of nutrients to the drainage area should be limited as much as feasible. Second, when selecting a stormwater management measure to address the TSS removal requirement, the measure with the best nutrient removal rate that also best meets the site's constraints should be chosen. Details of each step in this approach are provided below.

Reducing Nutrient Input

A significant amount of nutrients are in stormwater runoff due to fertilization of lawns. As described in Chapter 2, lawns should be minimized in favor of other vegetated cover. Existing site areas with desirable vegetation communities should be left in a natural state and forested areas and meadows should be considered as alternatives to the standard lawn. Ground covers provide aesthetically pleasing, innovative landscapes that are adaptable to the local environment. These types of land cover reduce lawn area and the consequent need for fertilization. A landscape design that minimizes the use of lawn can be beneficial in preventing pesticides, as well as nutrients from fertilizers, from stormwater runoff.

Soil testing determines the soil nutrient level as well as pH. Using the test results to determine the appropriate application of lime and fertilizer required for lawn areas will increase efficient uptake and decrease associated costs of lawn maintenance as well as minimize nutrient input. Low or no phosphorous fertilizers may be adequate to maintain the health of the landscape after the vegetation has fully established. Soil test kits are available at most lawn and garden care centers as well as through the Rutgers Cooperative Extension county offices. Fertilization specifications must be included in the maintenance manual.

Pet waste is another source of nutrients in stormwater runoff. To prevent or minimize pet waste problems, residents must be required to pick up after their animal and dispose of the material in the toilet or garbage. Homeowner associations must include this condition in homeowner's agreements. Signage should be located strategically throughout the development to reinforce this criterion. Education is critical to successful pet waste management.

Nutrient Removal Rates

Site conditions and the need to reduce post-construction TSS by 80 percent are primary factors in the selection of appropriate BMPs for a development site. However, removal of nutrients such as phosphorous and the various forms of nitrogen must also be considered in this selection process. The chosen BMP must meet the TSS criteria, but must also maximize nutrient removal for the site. To assist with the selection of BMPs for nutrients, information regarding estimated nutrient removal rates is provided in Table 4-2.

Table 4.2 – Typical Phosphorous and Nitrogen Removal Rates for BMPs

Best Management Practice (BMP)	Total Phosphorous Removal Rate (%)	Total Nitrogen Removal Rate (%)
Bioretention Basin	60	30
Constructed Stormwater Wetland	50	30
Extended Detention Basin	20	20
Infiltration Basin	60	50
Manufactured Treatment Devices	See N.J.A.C. 7:8-5.7(d)	See N.J.A.C. 7:8-5.7(d)
Pervious Paving[2]	60	50
Sand Filter	50	35
Vegetative Filter	30	30
Wet Pond	50	30

The nutrient removal rates presented in Table 4-2 should be considered typical values based upon data from a range of research studies. Due to the multiple forms and complex behavior of nutrients in stormwater runoff and the similarly complex processes by which nutrient loading is altered by BMPs, actual removal rates for specific BMPs and development sites may vary.

The nutrient removal data in Table 4-2 is intended to assist designers in the selection of appropriate BMPs to meet both the 80 percent TSS and maximum feasible nutrient removal requirements in the NJDEP Stormwater Management Rules. During this selection process, primary consideration should be given to achieving the Rules' 80 percent TSS removal requirement with one or more BMPs that are compatible with and responsive to site conditions and constraints, maintenance needs, and safety concerns. The selection process should then be further refined to achieve the Rules' maximum feasible nutrient requirement utilizing the structural BMP data in Figure 4.2 and, as necessary, other appropriate resources. In doing so, it should be remembered that many nonstructural BMPs can also help achieve the nutrient removal requirement, and must be considered prior to the use of structural BMPs.

The nutrient removal data in Table 4-2 can also be used to optimize existing BMP retrofits.

Additional Considerations

From the information presented in this chapter, it should be evident that BMPs are intended to reduce the pollutants in stormwater runoff. However, sometimes an unintended consequence of stormwater management facilities is their attractiveness to waterfowl, such as Canada geese. Canada geese are attracted to lawn areas adjacent to water bodies. As such, wet ponds and other stormwater management structures can appeal to these waterfowl, whose resulting fecal input can result in an increase in nutrient loading to systems that are intended to reduce such pollutants. As a result, adjustments to a BMP's design and/or maintenance plan may be necessary to discourage waterfowl from contributing pollutants to the stormwater measure. Additional guidance on Canada geese is available in Management of Canada Geese in Suburban Areas: A Guide to the Basics, available at http://www.state.nj.us/dep/watershedmgt/DOCS/BMP_DOCS/Goosedraft.pdf.

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APPENDIX E
DETAILED MODEL RESULTS

18-6674 - McPherson's Road Development - Water Quality Model (Pre-Development) 04/12/2018

Pre-Development Conditions									
Land Use	**Area m^2**	**Area-ha**	**Avg Annual Precipitation (m)**	**Runoff C**	**Total Runoff (m^3)**	**TSS - mg/L**	**TSS - kg**	**TP-mg/L**	**TP-kg**
Upland Forest	4,393	0.44	1.40	0.15	920.00	19.7	18.12	0.2	0.18
Medium-Density Residential	1,135	0.11	1.40	0.9	1425 89	30.5	43.49	0.2	0.29
Total	**5,528**	**0.55**			**2345.89**		**61.61**		**0.47**

Post-Development Conditions With No BMPs									
Land Use	**Area m^2**	**Area-ha**	**Avg Annual Precipitation (m)**	**Runoff C**	**Total Runoff (m^3)**	**TSS - mg/L**	**TSS - kg**	**TP-mg/L**	**TP-kg**
Medium-Density Residential	5,528	0.55	1.40	0.69	5324 53	30.5	162.40	0.2	1.06
Total	**5,528**	**0.55**			**5324.53**		**162.40**		**1.06**

Effect of urbanization with no control

	Existing Land Use	**Future Land Use**	**Net Change**
Annual TP Loading (kg)	0.47	1.06	Increase

Pre-development Runoff Coefficients

Land Type	% Land	Runoff C
Impervious	100.0%	0.9
Pervious	0.0%	0.3
Weighted Residential Runoff C	**0.9**	

Post-development Runoff Coefficients

Land Type	% Land	Runoff C
Residential Impervious	65%	0.9
Residential Pervious	35%	0.3
Weighted Residential Runoff C	**0.69**	

18-6674 - McPherson's Road Development - Water Quality Model (Natural BMPs) 04/12/2018

Block A - Post-Development Conditions									
Land Use	**Area m^2**	**Area-ha**	**Avg Annual Precipitation (m)**	**Runoff C**	**Total Runoff (m^3)**	**TSS - mg/L**	**TSS - kg**	**TP-mg/L**	**TP-kg**
Medium-Density Residential	5,528	0 55	1.40	0.69	5324 53	30 5	162.40	0.2	1.06
Total	**5,528**	**0.55**			**5324.53**		**162.40**		**1.06**

Land Use	TP - mg/L	TP - kg None	TP - kg Grass Swale	TP - kg Infiltration Trench
Medium-Density Residential	0.2	1 06	0.75	0.26
Total	**0.20**	**1.06**	**0.75**	**0.26**

Length of Ditch Provided (m)	80
Length of Grass Swale (m)	60
Length of Infiltration Trench (m)	20
Multiples of 60m swales	1.00
Grass Swale Weighted TP Removal Efficiency	30.0%
Infiltration Trench TP Removal Efficiency	65.0%
Total Train TP Removal Efficiency	75 50%

	Total Area	**Total TP**
Pre-Development	5,528	0.47
Post-Development	5,528	0 26
Net Change	**N/A**	**Decrease**