Strum
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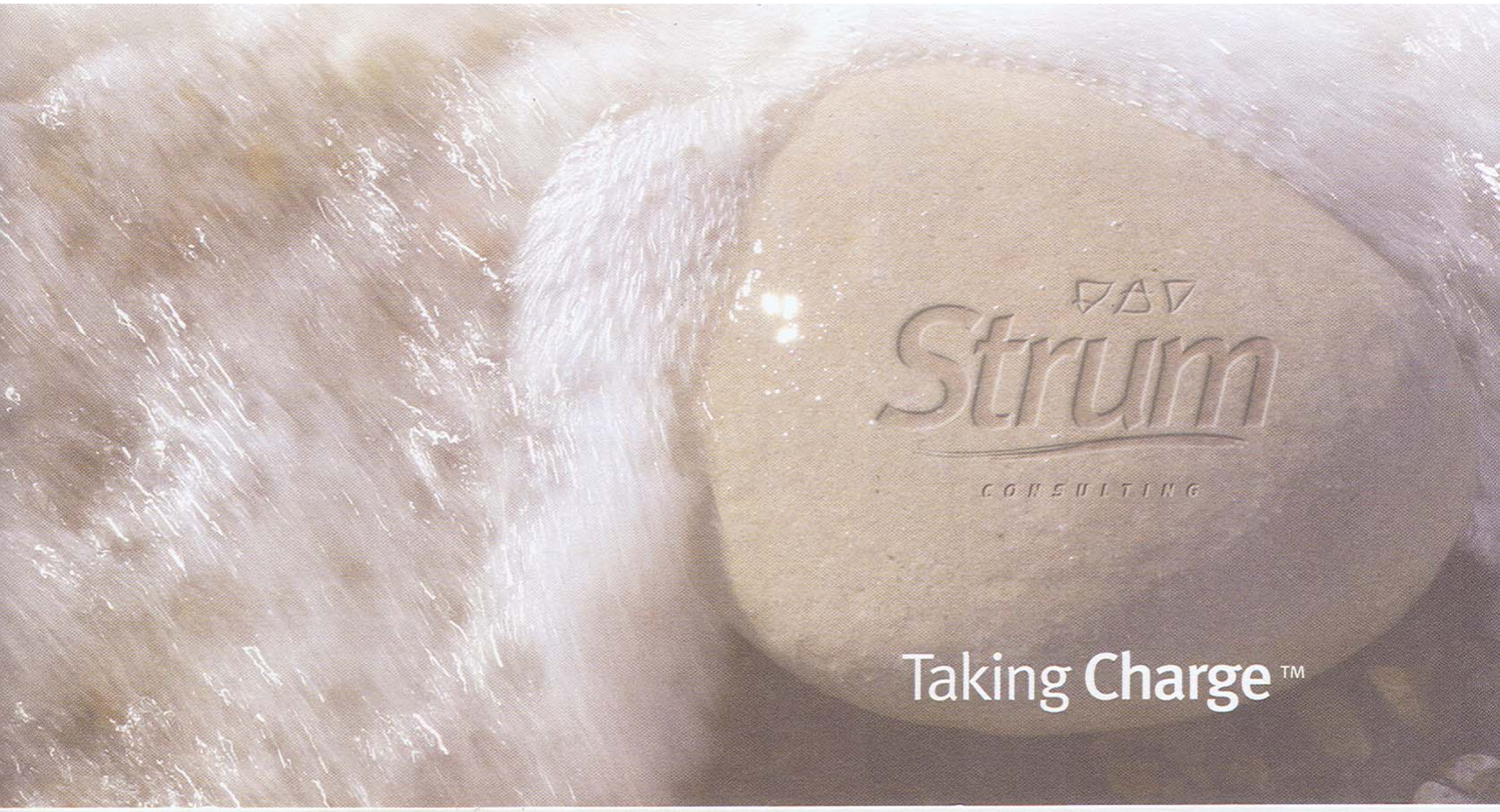
PHOSPHORUS NET LOADING ASSESSMENT
Charleswood Subdivision

January 22, 2020



Strum
CONSULTING

January 22, 2020

Mr. Scott MacCallum
Clayton Developments Limited
255 Lacewood Drive
Suite 100C
Halifax, NS B3M 4G2

Dear Mr. MacCallum,

Re: Phosphorus Net Loading Assessment
Charleswood Subdivision

Attached is the Phosphorus Net Loading Assessment report prepared for the Charleswood Subdivision.

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,

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1.0 INTRODUCTION

The proposed Charleswood Subdivision is located on vacant land between the existing Charleswood Subdivision and Capilano Estates in Windsor Junction, Nova Scotia with access via extensions of existing public streets Cumberland Way and Charleswood Drive, both off of Windgate Drive. The existing lands consist of two parcels (PID's 40699837 and 41470295) owned by Pine Ridge Mews Ltd, a subsidiary of Shaw Group, surrounding the extension of Cumberland Way and two parcels (PID's 40092009 and 00510560) owned by Miller Developments Ltd. surrounding the extension of Charleswood Drive. The project lands are within the River-Lakes Secondary Planning Strategy boundary of Halifax Regional Municipality's Municipal Planning Strategy for Planning Districts 14 and 17 (Shubenacadie Lakes), which requires a Phosphorus Net Loading Assessment (PNLA) to be submitted along with the Development Agreement application (Case 18715) in accordance with policy RL-22 of the River-Lakes Secondary Planning Strategy defined below:

> *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.*

This document is intended to satisfy the requirements of RL-22 listed above and confirm that the post-development scenario will not export any greater amount of phosphorus from the subject land than the pre-development scenario.

1.1 Design Criteria

With the extension of the existing subdivision, the land use will shift from existing forested and deforested areas to developed low and medium density residential with open ditch road construction and municipal water lines, while large portions of land will remain undisturbed. This change in land use will require specific stormwater management features to adequately maintain pre-development Total Phosphorous (TP) levels. In addition to stormwater management features, special consideration will be required when designing the on-site sewage disposal systems (OSSDSs) such that the percentage of TP released through these systems is minimized. While not a direct requirement of the PNLA or RL-22, Total Suspended Solids (TSS) has also been reviewed during the stormwater portion of this study. This water quality study was completed with a focus on low impact development (LID) best management practices (BMPs) designed to balance pre and post development TP and TSS, as well as utilizing advanced OSSDS technology to reduce the load of TP from OSSDSs. Pre-post balancing was completed per the guidelines put forth within Halifax's Municipal Planning Strategy for Planning Districts 14/17 (Shubenacadie Lakes) and the Halifax Regional Municipality Stormwater Management Guidelines published by Dillon Consulting in March 2006.

1.2 Scope

The purpose of this water quality study is to analyze the proposed Charleswood Subdivision extension's pre-development TP and TSS loadings, estimate uncontrolled post-development TP and TSS loadings, and propose stormwater BMPs and OSSDS design features to provide a balanced site (i.e. pre/post TP and TSS export balancing). Stormwater peak-flow management design has been completed concurrently by Strum Consulting. Results of this peak-flow management design are provided in detail on the pre and post-development drainage condition Stormwater Management Plans (SWMP), refer to Drawings D01 and D02 provided in Appendix A.

Please note that while the SWMP analysis includes all tributary watersheds, the areas analyzed for TP and TSS loading have been limited to the areas that will be altered through construction. Refer to Drawing P01 and P02 in Appendix B for a visual representation of the phasing boundaries and the areas determined to be altered during construction. Stormwater and OSSDSs TP models have been completed independently, with results presented in Section 5.0.

2.0 EXISTING CONDITIONS

2.1 Land Use and Topography

The existing properties are fully treed with black spruce and a few mixed hardwoods with some deforestation and initial re-growth (54.4ha total) as a result of clearing operations that previously took place. The areas of re-growth are now in the rejuvenation stage with young growth found throughout these areas. For this reason, a combination of forest and recently cleared forest was used in analyzing existing condition (pre-development) state. The existing land uses for the project area and their respective areas are summarized in Table 2.1 below.

Table 2.1: Existing Land Use Summary of Areas

Existing Land Use	Area (ha)
Forest	±34.4
Initial Forest Re-growth	±20.0

The natural terrain generally rises from south to north with slopes ranging between 1 and 15%. The site consists of flat to rolling ground moraine and streamlined drift features separated by wetlands, drainage channels, and a single watercourse at the northeast end of the site with an assigned 20 m development buffer. The wetlands are mainly treed fens/bogs with one large open water wetland that drains under Windgate Drive and into Second Lake. Characterization of sensitive natural features including wetlands, watercourses, and vegetation within the limits of the project site has been completed by Englobe and has been used throughout the development design. There is no evidence of existing OSSDSs within the limits of the project.

The surrounding lands in the area are largely suburban rural development, with homes having on-site sewage and either well or municipal water (including the existing portion of Charleswood Drive). The existing portion of Charleswood Drive also has open ditches without any stormwater management control or water quality treatment features. The closest lakes (Second and Third Lake) are almost completely surrounded by un-serviced development and appear to have existing OSSDSs within approximately 50-70 m of the edge of water. These existing OSSDSs in such close proximity to the surrounding lake systems have been negatively impacting the lakes nutrient levels. In a 1993 study by Vaughan Engineering Associates Limited titled Shubenacadie Lakes Planning/Pollution Control Study it is noted that the Shubenacadie Headwater lakes of Charles, William, Thomas, Fletcher's, and Grand (located downstream of Second and Third Lakes) are already under significant development related stress, which has contributed to existing excess phosphorus loading.

2.2 Hydrology

Precipitation for this area is best represented by data published by Halifax Water in Section 5.2.2 of the 2018 Design Specifications & Supplementary Standard Specification. Table 2.2 below outlines the rainfall depths and return periods as specified by the PNLA Guideline.

Table 2.2: Halifax Water Rainfall Depth Based on Return Period

	Return Period (years)				
	2	5	10	25	100
Rainfall (mm)	83	107	125	146	176

The existing drainage catchments on these properties are generally bounded to the north by Ashlea Drive and Taylor Drive and to the south by Windsor Junction Road and Windgate Drive. However, existing properties on Shirley Court, Ethan Drive, Elise Victoria Drive, and Peter Thomas Drive all contribute stormwater onto these properties from the north. Similarly, existing properties on Cumberland Way, Carriage Road, Chartwell Road, and Charleswood Drive all contribute stormwater onto these properties from the south.

Within the study area properties; wetlands, drainage channels, and a single watercourse make up five distinct natural drainage corridors leading into Second and Third Lakes in three different locations with elevated land areas in between that drain surface water to the adjacent drainage corridors. Stormwater drainage on the southwest portion of the property surrounding the Cumberland Way extension generally converges into a single channel running in the southwest direction that drains into a large open water marsh and then into Second Lake. On the northeast portion of the property surrounding the Charleswood Drive extension, the majority of stormwater flows through a treed fen wetland and under Windgate Drive into Second Lake. It was identified that beaver activity is present in the existing storage area at the upstream side of the embankment and has caused water to back up and pond prior to passing under Windgate Drive. The remainder of the property drains towards the watercourse at the northeast end of the site which crosses under Windsor Junction Road and into Third Lake.

2.3 Geology and Groundwater

A geotechnical investigation was completed by Stantec Consulting Ltd. (Stantec) in September 2018 on the lands surrounding the Cumberland Way extension which included test pits, laboratory testing, and a report containing a summary of the findings. The subsurface conditions encountered generally consisted of a relatively thin rootmat and topsoil layer underlain by silty sand with gravel and silt/clay till with no bedrock or groundwater encountered in any test pits dug to a depth of 3.5 m below existing ground. Using the Nova Scotia Groundwater Atlas and reviewing well logs from surrounding properties it is approximated that bedrock is situated at an average depth of 35 m below surface and groundwater is 21 m below surface. The low groundwater table and permeable soils will help to encourage infiltration, groundwater recharge, and be more conducive to the LID approach and associated use of stormwater BMPs.

Results of two grain sieve analyses performed on the sandy till, showed 9 to 11% gravel sizes, 29 to 30% sand sizes, and 60% silt and clay sizes. Natural moisture contents of 40 samples ranged from 11 to 21% with an average of 14% overall. The till coefficient of permeability was also analyzed and determined to be 5×10^{-8} cm/s for clay tills and 5×10^{-6} cm/s for silt tills. Published Nova Scotia surficial geology data indicates stony till plain and drumlins as well as silty till plain and drumlins for the project site, which generally agrees with the data collected by Stantec. Additionally, a review of the geological map of Nova Scotia indicates the bedrock in the area, albeit deep, is Halifax Formation of the Meguma Group. The soil parameters outlined above, coefficients of permeability, as well as runoff coefficients (discussed in Section 4.2.2) have been used in the stormwater management design for optimal results and to encourage infiltration of low intensity, high frequency storms that generally constitute over 90% of the anticipated annual rainfall.

2.4 Utilities

To our knowledge, no existing utilities were found within the study area but the area is surrounded by overhead power and communications, public watermains, open ditches within roadways for stormwater conveyance, and OSSDSs. Portions of Cumberland Way and Carriage Road and all of Chartwell Road are not serviced with municipal water and therefore use wells for potable domestic water.

3.0 PROPOSED DEVELOPMENT

Planning and design of this development has considered the sites existing conditions including; natural topography, surface cover, watercourses and wetlands, and natural vegetation. An integrated stormwater management quality and quantity design approach has been utilized when proposing stormwater management infrastructure. This approach includes the selection of features that work to concurrently address stormwater quantity and quality. BMPs will be incorporated such that the maximum amount of natural vegetation is retained and protected. A LID approach has been used to closely mimic the existing features and mitigate the introduction of nutrients and sediment into the surrounding watershed.

The proposed development consists of two separate areas, one surrounding the proposed 500 m long extension of public roadway Cumberland Way and one surrounding the proposed 455m long extension of public roadway Charleswood Drive. The extension of Cumberland Way includes four clusters of 4-unit townhome dwellings totaling 84 units to be privately owned and rented by Pine Ridge Mews and a 315 m long private cul-de-sac with 25 single family dwellings to be owned and rented by Pine Ridge Mews or sold as bare land condominium units. The extension of Charleswood Drive includes approximately 1.2 km of private roadway with 66 single family dwellings to be contained within two separate bare land condominiums (refer to Appendix B for proposed development layout). Both Cumberland Way and Charleswood Drive extensions will have municipal water, open ditch construction for stormwater conveyance, as well as OSSDSs. The dwellings proposed in this development will be considered rentals or condominiums and do not have individual parcels for each dwelling and in most cases several dwellings will share a private water service and single OSSDS with biological wastewater treatment unit.

The public road extensions are proposed to have open ditches on either side of the roadway acting as enhanced grass swale BMPs. Enhanced grass swales differ from a standard grass swale in that they are designed to be wide and shallow with relatively flat longitudinal grades. These characteristics, along with the implementation of check dams and planting selection, encourage water to pond and attenuate peak runoff and nutrient transfer by slowing the water down and encouraging infiltration. The roads will have engineered grass shoulders rather than the standard HRM rural road cross section for improved stormwater quality, conveyance, and aesthetics (refer to detail #5 on Drawing P03 and P04 in Appendix B for cross section). The inclusion of the above stated improvements to the road cross section helps to produce a roadway that more closely resembles the natural pre-development conditions and in turn creates a LID road design. The proposed LID road section will be publicly owned, and will not only assist in removing target nutrients and solids, such as TP and TSS, but will also encourage groundwater recharge and infiltration during high frequency, low depth storms. The roadside ditches will convey stormwater from the public road extensions and prevent public stormwater from entering private lands. Municipal water is provided within the roadway extensions along with overhead power and communications to service the private lots. Stormwater will be managed on these lots with grassed filter strips, shallow detention areas, and enhanced grass swales leading to dispersion areas all arranged in-line. When the BMPs are arranged in-line in a series configuration (one after another) it is known as a treatment train. Treatment trains work to increase the overall removal efficiency of the BMPs by continually removing nutrients as they pass through each in-line BMP. More information on the treatment train approach is provided in Section 4.3.1. After the stormwater has travelled through all of the BMPs it will discharge to wetlands, drainage channels, or watercourses to ensure the post-development stormwater flows are balanced with the pre-development flows in both peak flow rates and TP/TSS loadings. Special consideration has been given to the design of the OSSDSs to mitigate the amount of TP that is discharged to the surrounding water systems. These OSSDS design parameters are further discussed in Section 4.4.

The development is regulated by the classic open space policies which enable homes to be clustered to a maximum gross density of one single unit dwelling per acre or up to two units per acre for townhome development and also requires 60% of the entire parcel to be open space. The proposed development satisfies these criteria with 84 townhome units over 17 hectares and 92 single family units over 37.4 hectares with 20.2 hectares of disturbed net-developable area over the total 54.4 hectares and 62.9% open space.

During construction, it is important that the limit of project disturbance, including wetland and watercourse buffers, be respected to avoid any excessive impact to the existing vegetation that may cause unnecessary erosion and sediment control issues. Additionally, the existing trees identified as to be retained should be respected and retained to aid in soil stabilization to provide a more natural aesthetic to the development. This project will be completed in phases, which will encourage a greater level of attention to be paid to each phase's erosion and sediment control measures (detailed in Section 4.3.2) and tree retention areas. The proposed phasing for this development is outlined on Drawing P01, Appendix B. To confirm that erosion and sediment control measures and vegetation retention objectives are met, the developer's Site Engineer, will oversee construction.

After the construction of each phase, guidelines will be utilized to encourage continued efficient nutrient removal within the publicly and privately owned BMPs. To ensure the vegetation survive without heavy fertilizer applications, a topsoil recommendation specification has been created (Appendix C) that provides the road builder and home builders with detailed information on the topsoil required to produce healthy and sustainable planting. Using adequate depth and quality topsoil is helpful in promoting healthy lawn and plant growth as it provides a good growing base for root structures and in turn mitigates the need for fertilizer application. Additionally, acceptable plant species will be outlined as to closely resemble pre-development conditions. The use of native planting species encourages sustained growth as it is understood that these species already thrive in their natural habitat, this mitigates the need for fertilizer application and promotes sustained growth. Lawn care best practices will be provided to the homeowners to help avoid lawns that are barren, which can lead to increased stormwater runoff and sediment transport. An example of a lawn care best management practices document is provided in Appendix D.

Some of the lawn care best management practices include details of which fertilizers are best to use, how homeowners can re-use rainwater in rain barrels, the benefit of providing rain gardens, how to manage your downspout water, and many more important lawn care practices. The public LID road section will provide a low maintenance strategy, as the planting within the enhanced grass swales will be selected as to closely mimic the natural top soil and vegetation. This will encourage consistent and cohesive growth. Additionally, the planting will be selected such that maintenance operation requirements such as mowing will be limited.

After the construction of each dwelling cluster is completed and each specific OSSDS has been commissioned, an OSSDS maintenance program will be put in place to ensure continuing optimal operation. The maintenance program will be completed by the owner through a service contract with the supplier. With extensive experience in OSSDS design, Strum Consulting is utilizing a 25 year life cycle for the on-site sewage treatment system and associated disposal beds. While systems occasionally last longer than this time horizon, their effectiveness is generally reduced, and a significant maintenance event is required.

4.0 METHODOLOGY

4.1 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, previously collected wetland mapping, and Halifax Water's published design storm rainfall amounts. Additionally, a geotechnical investigation that was completed in September 2018 by Stantec was also used, as well as topographical information collected by Servant, Dunbrack, McKenzie & MacDonald (SDMM) 2019. Design staff also visited the site during this analysis to gather photographic information to help determine existing land coverage and identify any existing hydraulic and hydrological features.

4.2 Hydrological Model

When analyzing stormwater quantity and quality impacts of a development, a thorough understanding of the hydrologic conditions is required. This includes understanding the topography and soil characteristics, and how each watershed reacts to rainfall. This understanding is required in determining peak runoff from a site, but also in considering sediment loading from a given watershed. Evaluating and understanding peak rainfall events, total annual precipitation, and first flush theory are key considerations undertaken in this analysis.

The analysis of TP and TSS loadings outlined in this report were completed using a concentration-based loading mass balance approach on areas altered by development. The areas considered in TP and TSS loading calculations are presented as post-development land uses in Drawing P02 in Appendix B, everything outside the shaded areas is considered un-disturbed through construction of the development. Only the developed (shaded) portion of the site are included in the PNLA calculations. Existing and post-development surface characteristics were classified and assigned runoff coefficients and are discussed further in Section 4.2.1 and 4.2.2.

The stormwater peak flow mitigation design completed for this project was completed in HydroCAD v10.00 using an SCS TR-20 analysis. This analysis has considered all areas which are tributary to each wetland and watercourse within the study area. Table 4.1 below summarizes the anticipated peak flows for both the pre and post-development scenarios. The discharge locations presented in the table below correspond with those shown on Drawings D01 and D02 in Appendix A. Discharge point A is located at the wetland between Cumberland Way and Windgate Drive, discharge point D is located at the wetland east of the Charleswood Drive extension, and discharge point E is located east of point D, discharging under Windsor Junction Road. All existing wetlands, drainage, watercourses, and surrounding water bodies were identified on Drawings D01 and D02 in Appendix A. Further information on drainage boundary selection and surface classification can found in the following sections.

Table 4.1: Anticipated Peak Stormwater Flows

Scenario	Discharge Point	Anticipated Flow (L/s)				
		2-year	5-year	10-year	25-year	100-year
Pre-Development	A	1,630	2,631	3,430	4,397	5,816
	D	472	797	1,062	1,385	1,864
	E	441	743	988	1,288	1,732
Post-Development	A	1,622	2,591	3,465	4,455	5,812
	D	483	794	1,044	1,347	1,794
	E	425	709	941	1,339	1,736

4.2.1 Catchment Delineation

Catchments were delineated by Strum using AutoCAD Civil3D and available LiDAR contour mapping blended with field survey data completed by SDMM. There are multiple catchments areas and outlets points that have been carefully selected to suit the natural drainage characteristics and existing watercourse and drainage conditions (refer to D01 and D02, Appendix A). As discussed in Section 4.2, the water quality model considers areas that will experience a change in land-use or surface type. Within these “disturbed areas”, sub catchments were delineated for each individual stormwater treatment element. This allowed Strum to properly size each stormwater BMP for optimal nutrient removal. Additionally, each group or cluster of dwellings was considered its own catchment area, or block, which allowed the investigation of TP and TSS loading to be completed for smaller areas that would each have their own dedicated BMP treatment system. Where each block is on private land they will be privately owned and maintained. Each of the proposed public road extensions (LID roadway) were also considered their own catchment area, which includes paved roadway, engineered grass shoulders, and grass swales and are to be considered publicly owned and maintained. Table 4.2 below summarizes each water quality study area (catchment) with land use breakdowns. Refer to Drawings D01 and D02 in Appendix A for the complete delineated catchment boundaries and Drawing P02 in Appendix B for a visual representation of the study areas and their associated land uses. BMPs located in areas denoted by "ROW Paving/Open Space" on Drawing P02 are considered publicly owned, all other BMPs will be privately owned and will drain to an outlet other than the public road ROW.

Table 4.2: Summary of TP Study Areas

Land Use	**Water Quality Study Area (Catchment) (m^2)**								
	Privately Owned							***Publicly Owned***	
	Block A	***Block B***	***Block C***	***Block D***	***Block E***	***Block F***	***Block G***	***Cumberland Way Extension***	***Charleswood Dr. Extension***
Dwelling/Structure	2,298	2,773	2,262	2,298	4,383	5,745	6,283	0	0
Hard Surface Paving	1,766	2,487	1,654	1,731	3,522	6,451	7,446	0	0
Open Space	7,851	10,482	7,766	7,951	18,637	32,233	35,825	0	0
ROW Paving/Open Space	0	0	0	0	0	0	0	13,503	16,813
Total	*11,915*	*15,742*	*11,682*	*11,980*	*26,542*	*44,429*	*49,554*	*13,503*	*16,813*

4.2.2 Runoff Coefficients

Runoff coefficients are used in determining the volume of rainfall that runs off of the site during the prescribed storm events. In the context of stormwater quality analysis, 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 rainfall to runoff and varies based on land use, soil type, infiltration ability, and land slope. Runoff coefficients are a value between 0 and 1 that can be taken 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 0.70-0.95 is used.

It is standard practice to increase the runoff coefficient during a high intensity, low frequency storm to account for the response to a rainfall of increased intensity. The anticipated percent increase can vary depending on the expected runoff coefficient during lower frequency storm events. The lower the runoff coefficient, the larger the change is expected.

Table 4.3 below summarizes the runoff coefficients used in our PNLA for each land use and rainfall event is outlined in Section 2.2.

Table 4.3: Site Runoff Coefficients

Development Condition	TP Study Area	Land Use	Runoff Coefficient	
			2, 5, 10, and 25 year rainfall events	**100 year rainfall event**
Pre-Development	Total Developed Area	Upland Forest	0.27	0.45
Post-Development	Block A	Low and Medium Density Residential	0.42*	0.65
	Block B		0.42*	0.65
	Block C		0.42*	0.65
	Block D		0.42*	0.65
	Block E		0.39*	0.65
	Block F		0.38*	0.65
	Block G		0.38*	0.65
	Cumberland Way	Paved Public Road	0.53**	0.85
	Charleswood Dr.		0.53**	0.85

*Weighted runoff coefficient based on multiple surface covers as outlined in Table 4.2
**Weighted runoff coefficient based on complete right-of-way cross section (i.e. paved roadway, grass shoulder, landscaped ditches)

A similar runoff coefficient was used in our stormwater quantity design. This factor, referred to as an "SCS curve number" is a number between 0 and 100, which approximates the relationship between rainfall and runoff. Further information on the SCS curve numbers utilized in our stormwater analysis can be found on Drawings D01 and D02 in Appendix A. Both Rational C values and SCS curve numbers have been selected with careful consideration of the native soil's ability to accept and infiltrate stormwater.

4.3 Water Quality Analysis - Stormwater

Through the use of desktop modeling processes and empirical data presented in the HRM Stormwater Management Guidelines, a stormwater concentration-based loading mass-balance simulation of TP and TSS production for the proposed development was completed in both the pre-development and post-development conditions. Considerations for our calculations included:

- Accurately identifying ground surface and soil characteristics
- Assigning TP and TSS nutrient loading values
- Nutrient removal rates for a range of different stormwater BMPs

A concentration-based mass-balance nutrient loading model was created that simulated anticipated TP and TSS, in kilograms, transported from the site through stormwater runoff during the 1 in 2, 5, 10, 25, and 100-year storms. This accepted methodology was previously used in Bedford South and the Parks of West Bedford, with analysis for those projects being completed by Stantec.

The majority of nutrient transport occurs in what is known as the first flush. The first flush is identified as the initial stages of a rainfall event, usually when rainfall intensities are low but steady. Nutrients that are situated at the surface are easily removed by the first flush and transported downstream. As the rainfall event increases in intensity it is understood that a large majority of the surface nutrients have already been removed and that the latter parts of the rainfall event only transport a small amount of nutrients downstream. In addition to the first flush, light rains that happen more regularly, with a short duration and lower intensity will transport sediment much in the same way. These storms are referred to as low intensity, high frequency storms and represent approximately 90% of the annual rainfall. Designing stormwater quality measures that consider these storms and encourage infiltration is considered a proactive approach to stormwater management and is one of the fundamental elements of LID.

4.3.1 Best Management Practices (BMPs)

BMPs are devices or features included in a stormwater system with the goal of improving water quality and quantity. 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 nutrient 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 nutrients, such as TP and TSS. BMP removal efficiencies used in this study are based on 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
- Credit Valley Conservation – Low Impact Development Guidance Documents

Refer to Appendices E, F, G, and H respectively for portions of the reports stated above.

There are generally three categories of BMPs; source control, conveyance control, and end of pipe control measures. Source control measures are on-site BMPs that control runoff at the source of generation, these include all measures that treat runoff before it reaches the conveyance system (i.e. permeable pavers). Conveyance control measures provide quality and/or quantity control of stormwater between the source and the outlet (i.e. enhanced grass swale). An end of pipe measure is anything that controls runoff at the downstream end of the stormwater conveyance system (i.e. detention facility).

Through the design process for this project, several stormwater BMPs were investigated, including; porous pavement, rain gardens, enhanced grass swales, pervious pipe systems, retention facilities, underground tanks, filter strips, and sand filters. After considering many stormwater BMP options, Strum carefully selected enhanced grass swales, vegetated filter strips, and a LID roadway cross section, as they best suited the project site, considering existing conditions, natural restraints, native soil infiltration ability, and overall site layout. For this particular project the vegetated filter strip has been considered the source control measure as it is the first to receive the water. Runoff is then directed towards the enhanced grass swales which are used as a conveyance measure as stormwater runs towards the system outlets through the treatment train. The proposed BMPs have also been chosen to provide a low maintenance solution with natural soils and native vegetation to closely replicate pre-disturbance conditions. The enhanced grass swales are also situated such that they intercept surface water from flowing over the on-site sewage disposal fields. It is intended that during construction the enhanced grass swales will be used as temporary erosion sediment control measures, with frequent check dams (temporary and permanent). At the completion of construction, the enhanced grass swales will be cleaned of excess sediment and nutrients and the temporary check dams will be removed, leaving the less frequent permanent check dams in place through the development's lifespan.

Table 4.4 and 4.5 below outline the BMPs selected for this project and their associated TP and TSS removal efficiencies. The values presented below have been compiled from the resources listed above.

Table 4.4: BMPs and Related TP Removal Efficiencies

Best Management Practice (BMP)	TP Removal Efficiency (%)
Enhanced Grass Swale	40
Vegetated Filter Strip	30*
LID Roadway	40**

*Based on New Jersey BMP Manual – 2004
**Based on implementing enhanced grass swales on each side of the public road

Table 4.5: BMPs and Related TSS Removal Efficiencies

Best Management Practice (BMP)	TSS Removal Efficiency (%)
Enhanced Grass Swale	85
Vegetated Filter Strip	70*
LID Roadway	85**

*Based on New Jersey BMP Manual - 2004
**Based on implementing enhanced grass swales on each side of the public road

The BMPs listed above can be incorporated into the site design and natural topography of the development but may need special consideration for placement due to size or soil characteristic requirements (i.e. a vegetated filter strip may require a minimum flow length or maximum slope for effective removal or an infiltration trench may require a minimum soil infiltration rate to achieve the published removal efficiency). Table 4.6 below outlines some special considerations required for each BMP presented above.

Table 4.6: BMPs Design Requirements and Considerations

Best Management Practice (BMP)	Design Considerations
Enhanced Grass Swale	• Contributing drainage <2 ha • Maximum 2.5:1 interior side slopes • Minimum depth of 750 mm • Minimum bottom width of 750 mm • Use of natural and native vegetation • Effective for stormwater treatment if length is at least 60 m • Requires permanent check dams at 60 m spacing • Longitudinal sloping should range between 0.5-5% • Requires regular inspection and maintenance of vegetation
Vegetated Filter Strip	• Contributing drainage <5 ha • Minimum flow length of 10 m • Sloping should range between 0.5-5%
LID Road Cross Section	• Grass shoulders • Use of enhanced grass swale ditches instead of traditional rock lined ditching to promote infiltration o Contributing drainage <2 ha o Maximum 2.5:1 interior side slopes o Minimum depth of 750 mm o Minimum bottom width of 750 mm o Use of natural and native vegetation o Effective for stormwater treatment if length is at least 60 m o Requires permanent check dams at 60 m spacing o Longitudinal sloping should range between 0.5-5% o Requires regular inspection and maintenance of vegetation

*Based on data provided in HRM Stormwater Management Guidelines – 2006

Industry standard for BMP design suggests that for enhanced grass swales to achieve the optimal published TP removal efficiency the swale should be 60 m long for tributary areas up to 2 ha. Therefore, it was determined that every 60 m of grass swale would act as a single enhanced grass swale BMP.

BMPs can act as stand-alone features that work to remove a defined percentage of waterborne nutrients, but they can also be arranged in a treatment train to increase the overall removal efficiency. When stormwater BMPs are laid out in series, each successive BMP sees water with a greatly reduced nutrient load. The downstream BMP removes its “target” percentage of nutrients from what remains in the water that it receives. Credit Valley Conservation has recommended the use of treatment trains, when combining source, conveyance, and end of pipe control measures to produce a more efficient nutrient removal system. BMPs provided in a train cannot simply have their removal efficiencies added together, but rather they require a specific equation to determine the cumulative, aggregate, removal efficiency. The total removal rate of the BMP treatment train is based on applying the removal rate of the second BMP to what results from the application of the first BMP. Equation 4-1 below describes this relationship and is used to determine the removal efficiency of BMPs in series:

$$R_{train} = R_a + R_b - \frac{R_a R_b}{100}$$ **Equation 4-1**

Where,
R_{train} = Total aggregate removal rate of train (%)
R_a = Removal rate of the upstream BMP (%)
R_b = Removal rate of the downstream BMP (%)

4.3.2 Construction Period and Erosion Sediment Control Plan

Construction should proceed with care to ensure that the prescribed erosion and sediment control measures are adhered to and enforced properly. Limits of disturbance will be clearly marked on site in an effort to prevent disturbance beyond the intended impact area. During construction of this development, the Site Engineer will monitor how and where material stockpiles are stored. If topsoil and grubbings are stored on site during construction, there is potential that increased phosphorus and sediment concentrations could be generated in surface water that contacts those materials.

To mitigate this potential concern, topsoil and grubbings piles on the site will be covered with tarps prior to rainfall events to limit exposure to precipitation and surface water. In order to deal with exposed soils that cannot be easily covered or removed from the site, other erosion and sedimentation controls (e.g. sediment fence) will be installed and maintained on the site during construction. This will limit the transport and loss of sediment from topsoil or grubbings that may contain elevated phosphorus concentrations.

Short-term erosion sediment control measures are designed to help minimize the amount of surface water that flows across the construction site and limit the exposure time to free sediment. Short-term measures that are proposed for this site include silt fencing, enhanced grass swales with temporary check dams, temporary spill-off ditches, and strawbale berms around catchbasins. These short-term measures are to be removed or cleaned once suitable vegetation is established near project completion. Long-term erosion sediment control measures to be used on the site include permanent check dams, placed within the enhanced grass swales, vegetated filter strips, catchbasin sumps, and flow dispersion areas at the end of the enhanced grass swales. Refer to the Erosion and Sedimentation Control Plan (ESCP) Drawings P05 and P06 in Appendix B and the Erosion and Sediment Minimalization Plan in Appendix I for details on each measure and complete installation and implementation details.

The locations of all proposed BMPs will be clearly marked on the site to avoid any unnecessary disturbance during construction. No vehicular traffic will be allowed within the BMP areas aside from those required to complete the construction of the BMPs. Final grading and final planting will not occur until the adjacent areas draining into the BMPs are stabilized. Construction runoff will be directed away from any BMPs by means of spill-off ditches that are designed to dissipate channel flow to sheet flow overland into established vegetated areas for sediment transport reduction. If BMPs are used during construction, temporary check dams will be added to limit downstream transport. When sediment gathers within the BMPs during construction, it is important that they be regraded and revegetated after construction has completed to establish the design cross section and ensure proposed nutrient removal characteristics. Where possible, final vegetation planting, with native planting, will be completed in the spring when vegetation can become established with minimal irrigation.

Other than topsoil and grubbings, the main sources of increased phosphorus loading during, and in the period shortly after, construction are through the introduction of fertilizers, biosolids, or other concentrated organics, and industrial wastes. The contractors constructing this project will not be permitted to utilize these items. With proper care and inspection by the Site Engineer during construction of the above noted erosion and sediment control measures, including modifications based on site constraints, it is expected that no net increase of phosphorus will occur during construction.

4.3.3 PNLA Model

The PNLA model has been completed using a concentration-based loading mass-balance approach that is widely accepted and originally adopted for use in Bedford South and The Parks of West Bedford by Jacques Whitford (Stantec). The concentration-based loading mass-balance approach is used to estimate the proposed development’s generation of TP and TSS in kilograms during prescribed storm events. Anticipated TP loading is dependent on the land use of a particular area and the stormwater management design. Land use and corresponding TP concentrations are outlined below and were selected from the HRM Stormwater Management Guidelines and other relevant literature. Using the provided TP and TSS concentrations, a mass of TP and TSS in kilograms was calculated using the estimated rainfall that fell on a given area during the different return period storm events. The anticipated pre-development TP and TSS mass were used as the target values during post-development balancing.

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

Pre and post-development land use and corresponding TP and TSS loading concentrations were assigned using the information presented in Table 5-5 of the HRM Stormwater Management Guidelines, see Appendix E for portions of the HRM document. Pre-development conditions used throughout the analysis are described in Section 2.0. Table 4.7 below summarizes the land uses and corresponding TP and TSS loading values utilized throughout the modelling process.

Table 4.7: Summary of Pre and Post-Development Land Uses

Development Condition	Land Use	Area (ha)	TP Loading (mg/L)	TSS Loading (mg/L)	Notes
Pre-Development	Upland Forest	20.16	0.20	19.7	Existing trees/wet areas
Post-Development	Low and Medium Density Residential	17.13	0.20	30.5	Combination pervious and impervious area
	Paved Public Roads	3.03	0.47*	57.8**	LID road cross section Includes complete right-of-way section (i.e. paved surface, shoulders, and road ditches)

*HRM Stormwater Management Guidelines does not have a TP loading provision for paved public roads, and since there are no local or provincial values readily available this information was gathered from Toronto Area Watershed Management Strategy Study Humber River Pilot Watershed Project; dated June 1986 by Pitt and McLean.

**HRM Stormwater Management Guidelines does not have TSS loadings for paved public roads specially, so the HRM published value for Highways was used.

Refer to Drawing P02 in Appendix B for a breakdown of the post-development land uses included in the water quality model.

4.4 Water Quality Analysis – On-site Sewage Disposal System (OSSDS)

Through the use of desktop modeling processes an OSSDS TP loading and removal model for the proposed development was completed. Considerations for our calculations included:

- Accurately identifying soil characteristics
- Assigning TP loading values for each proposed Block
- Nutrient removal rates for a biological wastewater treatment unit
- Nutrient removal rates for subsurface soil

For this proposed development, each condominium cluster, or Block, will have their own OSSDS designed by SDMM in accordance with Nova Scotia Environment (NSE) regulations. Each Block, as outlined in Section 4.2.1, has one shared OSSDS (BioPro AT-120 Oval) designed based on the demand produced by the dwellings. Conventional OSSDSs (i.e. septic tank followed by disposal field of sand) were initially analyzed as an option for wastewater treatment for this development, however, without additional phosphorus removal technology, the removal of phosphorus was inadequate. Conventional OSSDSs produced phosphorus removal rates of approximately 62% within a typical system design life. This level of treatment was insufficient to consider a no-net increase of TP from the development. As a result, the conventional OSSDSs were not used as an acceptable method of treatment, and alternative treatment technologies were explored. For this development, each OSSDS will consist of a BioPro unit (AT-120 Oval) followed by a disposal field that will allow the treated effluent to disperse into the local subsurface soil profile prior to entering the surrounding surface water features. The AT-120 Oval BioPro unit is a biological wastewater treatment unit that has the capability of removing approximately 75.6% of total phosphorus that is generated in domestic wastewater. The use of these BioPro systems has been proven locally, with NSE approving their use for similar applications on properties adjacent the Second Lake. Additional information for the AT-120 Oval BioPro unit can be found in Appendix J.

A standalone phosphorus loading model for the OSSDSs was developed based on previous work completed to estimate the TP loads that would result in the nearby wetlands and watercourses (Stantec 2016). Much like when treating TP as a result from stormwater, a treatment train is the most effective way to treat effluent from domestic wastewater. The OSSDS TP treatment train first consists of the removal of phosphorus within the AT-120 Oval BioPro unit, where it is then discharged to the disposal field, which contains sand that will provide sorption of phosphorus, and finally the sorption of phosphorus by the natural soil along the subsurface flow path leading to the nearest surface water feature.

The anticipated daily TP generated from each Block was calculated using Equation 4-2. This value represents what each Block produces in TP prior to entering the OSSDSs.

$$OSSDS\ P\ Generation = \frac{C_{SEPTIC} * Q_{SEPTIC}}{10^6}$$ **Equation 4-2**

Where,
OSSDS P Generation = phosphorus load generated as influent, prior to any form of treatment (kg)
C_{SEPTIC} = concentration of phosphorus in wastewater influent (mg/L)
Q_{SEPTIC} = daily flow rate of wastewater influent (L/day)
10^6 = mg to kg conversion

The values for C_{SEPTIC} and Q_{SEPTIC} were obtained from SDMM Ltd., the designers of the OSSDSs for this development.

In a letter signed by Daniel S. Gerard, P. Eng. of SDMM, dated November 22, 2019, Mr. Gerard suggests that a C_{SEPTIC} of 12.0 mg/L would be an expected effluent concentration from a conventional system (i.e. system with septic tank, which provides 20% TP removal). Due to the BioPro treatment units intaking raw sewage and not undergoing typical primary treatment in a septic tank, the level expected from the conventional system should be increased by 20%. Therefore, SDMM concluded that C_{SEPTIC} = 14.4 mg/L is suitable for the BioPro system.

Correspondence between NSE, SDMM, and Clayton Developments also determined that the following sewage generation numbers were acceptable for use in the development:

- 1,000 L/day for the first residential unit
- 750 L/day for each subsequent 2-bedroom residential unit
- 500 L/day for each subsequent 1-bedroomn residential unit.

These generation values were applied to each single-family dwelling and multi-unit townhome (detailed on drawings provided in Appendix B) to calculate the Q_{SEPTIC} for each Block.

Table 4.8 presents the input parameters provided by SDMM and approved by NSE, which were used in Equation 4-2 to determine the OSSDS P Generation loads for each of the Blocks prior to entering the BioPro treatment unit. SDMM's November 2019 letter states that the total daily wastewater flow (sum of all Q_{SEPTIC} values) for this proposed development is 139,500 L/day.

Table 4.8: OSSDS P Generation Input Parameters

Block ID	C_{SEPTIC} (mg/L)	Q_{SEPTIC} (L/day)
A	14.4	12,750
B		15,250
C		12,750
D		12,750
E		19,000
F		32,000
G		35,000

The OSSDS TP loading model consists of two computational components.

1. Calculating TP loads after BioPro treatment
2. Calculating TP loads after subsurface soil treatment

For the first computational component of the model, the TP being discharged from the BioPro treatment unit is calculated using the following equation:

$$OSSDS\ P\ Load = \frac{(1 - RED_{OSSDS,P}) * C_{SEPTIC} * Q_{SEPTIC}}{10^6} \qquad \textbf{Equation 4-3}$$

Where,
OSSDS P Load = remaining phosphorus load after BioPro treatment unit (kg)
$RED_{OSSDS,P}$ = removal rate of phosphorus
C_{SEPTIC} = concentration of phosphorus in wastewater influent (mg/L)
Q_{SEPTIC} = daily flow rate of wastewater influent (L/day)
10^6 = mg to kg conversion

$RED_{OSSDS,\ P}$ is assumed to be constant for the design life of the BioPro treatment unit (75.6%) as long as the unit is maintained and serviced under a service contract.

The OSSDS P Load value calculated represents the first computational component of the OSSDS TP loading model as it is the TP load from each of the Blocks after the BioPro treatment but prior to treatment from the subsurface soil.

Calculating the second computational component of the OSSDS TP loading model first requires the calculation of the mass of the soil involved in subsurface soil phosphorus treatment using the following equation, adapted from Stantec (2016).

$$M_{SSP} = E_{SSP} * \rho_b * D * \left\{\left[\left(W_{sys} * L_{path}\right) + \frac{\sigma_T * L_{path}}{2}\right] + L_{sys} * W_{sys}\right\}$$ **Equation 4-4**

Where,
M_{SSP} = mass of subsurface soil involved in the phosphorus treatment (kg)
E_{SSP} = ratio of effective mass involved in phosphorus treatment
ρ_b = bulk density of existing soil (kg/m³)
W_{sys} = width of OSSDS field, perpendicular to drainage path to surface water feature (m)
L_{path} = length of subsurface profile path from OSSDS field to surface water feature (m)
σ_T = width of transverse dispersion of plume (m)*
L_{sys} = length of OSSDS field (m)

*For detailed calculation of σ_T refer to Appendix K.

Table 4.9 presents the input parameters used in Equation 4-4 of the OSSDS model to determine the mass of soil involved in subsurface soil phosphorus treatment.

Table 4.9: Mass of Subsurface Soil Input Parameters

Block ID	**Parameters**						
	E_{SSP}	**ρ_b***	**D**	**W_{sys}****	**L_{sys}****	**L_{path}****	**σ_T**
	-	**kg/m³**	**m**	**m**	**m**	**m**	**m**
A	0.75	2202.4	0.3	63	6	33	3.88
B				68	6	36	4.17
C				90	6	35	4.07
D				64	6	19	2.39
E				74	8.2	72	7.30
F				109	14.7	72	7.30
G				186	17.5	74	7.46

*Based on field testing from Stantec
**Based on OSSDS design layout from SDMM

The final part of the second computational component involves a two-part piecewise linear model specifically developed to simulate removal of phosphorus loading from OSSDS in Nova Scotia soils. This piecewise equation was adapted from Stantec (2016) to estimate the total phosphorus removal for a given time period.

The following equation was used to calculate the mass of phosphorus removed by the soil through processes of sorption and precipitation:

$$\frac{P_{removed}}{M_{SSP}} = \begin{cases} \frac{P_{filter}}{M_{SSP}} * m_1 + b_1, \ when \ \frac{P_{filter}}{M_{ssp}} < S_{max,filter} \ (I) \\ \frac{P_{filter}}{M_{SSP}} * m_2 + b_2, \ when \ \frac{P_{filter}}{M_{SSP}} \geq S_{max,filter} (II) \end{cases}$$ **Equation 4-5**

Where,
$P_{removed}$ = the mass of phosphorus removed from the treated effluent (OSSDS P Load) by sorption and precipitation processes (mg)
P_{filter} = the phosphorus load entering the subsurface soil (OSSDS P Load) (mg)
M_{SSP} = mass of subsurface soil involved in the phosphorus treatment (kg)
m = slope [$m_1 = 0.86$, $m_2 = 0.29$]
b = Y-intercept [$b_1 = 0.0$, $b_2 = 157$] (mg/kg)
$S_{max,filter}$ = normalized maximum phosphorus sorption capacity of the existing soil [$S_{max,filter}$ = 276] (mg/kg)

The natural soils use both sorption and precipitation to remove phosphorus from the treated effluent plume up until the soil reaches its capacity for phosphorus sorption, $S_{max,filter}$.

Linear equation (I) represents when both sorption and precipitation are the predominant phosphorus removal mechanisms. When the numerical value of the linear equation reaches the $S_{max,filter}$ value, the two-part piecewise equation switches from linear equation (I) to linear equation (II). Linear equation (II) models precipitation being the main removal mechanism for phosphorus due to the maximum phosphorus sorption capacity of the soil ($S_{max,filter}$) being achieved.

The piecewise function is applied to each Block. These $P_{removed}$ values represent the amount of TP that has been removed through sorption and precipitation. The $P_{removed}$ for each Block is then subtracted from the anticipated TP load being discharged by the BioPro system (OSSDS P Load value calculated through Equation 4-3) to give the anticipated amount of TP that will be discharged to the nearest surface water feature. This TP discharge value is compared to the OSSDS P Generation baseline value that was previously calculated to determine the removal rate from generation to surface water features discharge.

The cumulative phosphorus loads to the surface water features within this development from OSSDSs were modeled for 10, 20, 30, 40, and 50 year time intervals. Section 5.3 presents a results summary for OSSDS phosphorus loading model with detailed model results presented in Appendix L.

5.0 RESULTS AND DISCUSSION

5.1 Hydrological Model Results

Stormwater peak flow management for this project has been completed concurrently by Strum to meet the requirements of Halifax Water. The objectives have been achieved through the use of lot grading design and on-site features to aid in attenuating the anticipated peak runoff. Several stormwater management features have been included to prevent adverse effects on adjacent properties or existing watercourses and wetlands. Post-development peak flows have been determined to match pre-development peak flows following the implementation of the various stormwater management features outlined in the design. Long term maintenance of the stormwater infrastructure is minimal and has been outlined in Section 5.4.

5.2 Water Quality Model Results - Stormwater

As has been outlined in Section 1.1, it was determined that stormwater BMPs were required in order to achieve a balanced site for both TP and TSS generation following project completion. As outlined in Section 4.3.2, to ensure no net increase of TP and TSS during construction, proper application of the erosion and sediment control measures as well as any required modifications will be monitored an enforced by the Site Engineer. Comparing the pre-development and the uncontrolled post-development values shows the project site requires the implementation of measures ranging from 47-49% TP removal efficiency in order to achieve Halifax's River-Lakes Secondary Planning Strategy requirement of no net increase in phosphorus after construction. To satisfy these removal efficiencies, several BMPs were investigated to help produce a post-development site that would meet this target removal efficiency ranges. Water quality model results related to stormwater, discussed below are outlined in further detail in Appendix M.

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 each cluster, or block, for each property and not within the public road right of way. For simplicity, each block of dwellings was analyzed as their own dedicated area for TP and TSS loading calculations and BMP design. The post-development TP and TSS loadings from each site were then summed to form a total post-development TP and TSS load leaving the developed site that was then compared to the pre-development values previously calculated.

Where this project contains the extension of two existing public roads, consideration was given to stormwater quality within the public roads as well, even though this is not a formal requirement of the PNLA guideline. The design of this project allowed for an opportunity to provide LID road construction within the public street parcel. A LID road cross section enabled the treatment of runoff generated solely by the public street, since stormwater runoff from each of the blocks is not being directed towards the public road ditches. The proposed LID road cross section includes replacing the standard open road-side ditches with enhanced grass swales and replacing standard gravel shoulders with engineered grass shoulders. Providing the changes to a typical road cross section and making it a LID cross section encourages stormwater treatment and nutrient removal. It also provides a road cross section that fits the natural aesthetic of the development and does not require an increased level of maintenance to maintain the BMPs nutrient removal capabilities.

Several iterations of the post-development water quality model were run with different combinations of BMPs to help find the best nutrient loading attenuation methods. Due to the open space constraints of the site and natural topography, 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 47-49% TP removal and 63-65% TSS removal rate was determined to be a treatment train of vegetated filter strips and enhanced grass swales. Table 5.1 summarizes the BMPs and TP/TSS removal efficiencies utilized on this project.

Table 5.1: BMP TP and TSS Removal Efficiencies

BMP	TP Removal Efficiency (%)	TSS Removal Efficiency (%)
Enhanced Grass Swale	40	85
Vegetated Filter Strip	30	70
LID Roadway	40	85

As outlined in Section 4.3.1, Equation 4-1 was applied to calculate the aggregate removal efficiency, as they will act as BMPs in series. Refer to Drawings P03 and P04 in Appendix B for preliminary BMP layout and typical detailing.

Similar to proven methodology employed for Bedford South and The Parks of West Bedford, a concentration-based loading mass-balance water quality model has been utilized for this analysis. This model was initially run in the pre-development scenario to determine the base-line, or budget, TP and TSS values. Then, a post-development model was created that ran uncontrolled with no allowance for nutrient loading attenuation features (BMPs). This provided an understanding of how the expected nutrient loading would be affected by a developed site. The equations below were used in calculating the concentration-based nutrient loads.

$$\mathrm{L} = \frac{R*\rho}{1000} \qquad \textbf{Equation 5-1}$$

Where,
L = Nutrient load (kg)
R = Site runoff volume (m^3)
ρ = Total phosphorus concentration (mg/L)

$$\mathrm{R} = \mathrm{A} * \mathrm{C} * \mathrm{P} \qquad \textbf{Equation 5-2}$$

Where,
R = Site runoff volume (m^3)
A = Tributary area (m^2)
C = Runoff coefficient (unitless)
P = Depth of precipitation (m)

For consistency with the SWMP (peak flow attenuation), event specific concentration-based loading mass-balance calculations were completed. Table 5.2 and 5.3 summarizes the pre and post-development TP and TSS values as well as the anticipated percent reduction required to provide balanced nutrient loads for the whole project site area.

Table 5.2: TP loadings for project site - Pre and Post-Development

Development Scenario	**Total Project Site TP Loading (kg)**				
	2 Year Storm	**5 Year Storm**	**10 Year Storm**	**25 Year Storm**	**100 Year Storm**
Pre-Development	0.91	1.17	1.36	1.59	3.20
Post-Development (Uncontrolled)	1.76	2.27	2.66	3.10	6.04
Percent Reduction Required	49%	49%	49%	49%	47%
Post-Development (Treatment Train)	0.85	1.10	1.28	1.50	2.97
Percent Reduction Provided	52%	52%	52%	52%	51%

Table 5.3: TSS loadings for project site - Pre and Post-Development

Development Scenario	**Total Project Site TSS Loading (kg)**				
	2 Year Storm	**5 Year Storm**	**10 Year Storm**	**25 Year Storm**	**100 Year Storm**
Pre-Development	89.2	115.1	134.4	157.0	315.4
Post-Development (Uncontrolled)	251.5	324.2	378.7	442.4	861.7
Percent Reduction Required	65%	65%	65%	65%	63%
Post-Development (Treatment Train)	46.9	60.5	70.6	82.5	165.0
Percent Reduction Provided	81%	81%	81%	81%	81%

5.3 Water Quality Model Results – On-Site Sewage Disposal System (OSSDS)

Section RL-22 of Halifax’s Municipal Planning Strategy for Planning Districts 14/17 states “*The River-Lakes Secondary Planning Strategy shall establish a no net increase in phosphorus as the performance standard for all large scale developments”.* This includes the production of TP due to the introduction of OSSDSs. It was determined that traditional OSSDSs would not remove adequate TP to consider a no-net increase. Therefore, BioPro AT-120 treatment units were utilized in the design to perform biological wastewater treatment and remove additional TP during treatment. Water quality model results related to OSSDSs, discussed below are outlined in further detail in Appendix L.

Following the methodology outlined in Section 4.4, all generated TP from domestic sewage will be treated through a treatment train consisting of a BioPro treatment unit followed by sorption and precipitation through the subsurface soil plume. Table 5.4 represents the expected TP loads at the nearest surface water feature as well as the reduction percentages as compared to the generation values calculated prior to treatment.

Table 5.4: OSSDS Phosphorus Loadings and Percent Reductions

Cumulative Phosphorus Loading						
Block ID		**Year**				
	Phosphorus Loading	*10*	*20*	*30*	*40*	*50*
A	*TP Load Generated (kg)*	670.1	1340.3	2010.4	2680.6	3350.7
	TP Load at Surface Water Feature (kg)	22.9	45.8	152.2	268.3	384.3
	% Removal	97%	97%	92%	90%	89%
B	*TP Load Generated (kg)*	801.5	1603.1	2404.6	3206.2	4007.7
	TP Load at Surface Water Feature (kg)	27.4	54.8	188.5	327.4	466.3
	% Removal	97%	97%	92%	90%	88%
C	*TP Load Generated (kg)*	670.1	1340.3	2010.4	2680.6	3350.7
	TP Load at Surface Water Feature (kg)	22.9	45.8	68.7	171.8	287.9
	% Removal	97%	97%	97%	94%	91%
D	*TP Load Generated (kg)*	670.1	1340.3	2010.4	2680.6	3350.7
	TP Load at Surface Water Feature (kg)	22.9	105.9	222.0	338.1	454.2
	% Removal	97%	92%	89%	87%	86%
E	*TP Load Generated (kg)*	998.6	1997.3	2995.9	3994.6	4993.2
	TP Load at Surface Water Feature (kg)	34.1	68.2	102.3	209.8	382.9
	% Removal	97%	97%	97%	95%	92%
F	*TP Load Generated (kg)*	1681.9	3363.8	5045.8	6727.7	8409.6
	TP Load at Surface Water Feature (kg)	57.5	114.9	172.4	409.8	701.2
	% Removal	97%	97%	97%	94%	92%
G	*TP Load Generated (kg)*	1839.6	3679.2	5518.8	7358.4	9198.0
	TP Load at Surface Water Feature (kg)	62.8	125.7	188.5	251.4	314.2
	% Removal	97%	97%	97%	97%	97%
Total	*TP Load Generated (kg)*	7332.1	14664.2	21996.4	29328.5	36660.6
	TP Load at Surface Water Feature (kg)	250.5	561.1	1094.6	1976.6	2990.9
	% Removal	97%	96%	95%	93%	92%

This OSSDS model evaluated the BioPro treatment unit with 75.6% phosphorus removal followed by subsurface soil treatment. At year 20, considering all Blocks of this development, the total treatment train is expected to be able to remove 96% of the total phosphorus that enters the system. It is understood that after approximately 25 years of treatment, most OSSDSs have lost sufficient capacity to adequately treat wastewater. Therefore, new filtration media or a new location for the disposal field may be necessary to satisfy both the continued requirement of typical sewage treatment criteria and no-net increase in phosphorus loading.

It should be noted that this model does not take into account treatment of the wastewater as it specifically passes through the disposal field filter media (sand). The model includes the total mass involved in the treatment, but it doesn't distinguish the soil parameters of the sand separately from the existing soil. In conventional OSSDSs, the majority of effluent treatment occurs within the sand in the disposal field. Because of this, it is expected that the OSSDS is likely to remove additional TP that has not be represented in this model. This coupled with the level of variability in additional treatment provided in the natural ecosystem between the discharge location and the lakes of significant concern it is our opinion that the reduction values achieved (95-97%) represent a no-net increase of TP.

5.4 Maintenance

5.4.1 Maintenance of Stormwater BMPs

In order to provide BMPs that maintain their TP and TSS removal potential throughout their lifespans it is important that regular maintenance be completed. For natural BMPs such as vegetated filter strips and enhanced grass swales, making sure they are free of debris and excess sediment will help 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.

The maintenance requirements for both vegetated filter strips and enhanced grass swales are similar in nature and require low level attention once mature vegetation is present. It is important to provide routine inspections to confirm dense mature vegetation is maintained and to confirm that no concentrated channels are created that allow surface runoff to bypass the vegetated side slopes intended for treatment. Vehicles should not be driven or parked on either the vegetated filter strips or enhanced grass swales. Also, the enhanced grass swales should not be scraped or re-graded and any routine mowing should be completed using the lightest possible equipment to avoid soil compaction.

Credit Valley Conservation of Ontario, Canada has published literature on typical maintenance and inspection activities for both vegetated filter strips and enhanced grass swale. Table 5.5 presents their recommendations below.

Table 5.5: Typical Maintenance Activities for Vegetated Filter Strips and Enhanced Grass Swales

Activity	Schedule
• Inspect for vegetation density (at least 80% coverage), damaged by foot or vehicular traffic, channelization, accumulation of debris, trash and sediment, and structural damage to pretreatment devices.	After every major storm event (>25 mm), quarterly for the first two years, and twice annually thereafter.
• Regular watering may be required during the first two years while vegetation is becoming established; • Mow grass to maintain height between 75 to 150 mm; • Remove trash and debris from pretreatment devices, the swale surface and inlet and outlets.	At least twice annually. More frequently if desired for aesthetic reasons.
• Remove accumulated sediment from pretreatment devices, inlets and outlets; • Replace dead vegetation, remove invasive growth, dethatch, remove thatching and aerate (PDEP, 2006); • Repair eroded or sparsely vegetated areas; • Replace mulch in spring; • Trim trees and shrubs; • Remove accumulated sediment on the swale surface when dry and exceeds 25 mm depth (PDEP, 2006); • If gullies or pools of standing water are observed along the swale, regrading and revegetating may be required.	Annually or as needed

5.4.2 Maintenance of OSSDSs

It is important to have regular maintenance on the BioPro treatment units throughout their usage. This will be achieved through service contracts between the owners and the supplier to mitigate degradation of performance of the system. It should also be noted that these systems are typically designed for life cycles of 25 year. At or prior to the 25 year milestone, it is understood that the systems will require a significant maintenance event to continue adequate treatment of TP.

5.5 PNLA Compliance and Certifications

A multi-phased approach is recommended for the owners to ensure that the PNLA compliance is achieved.

Compliance Phase 1 Grade Alteration-PNLA Permit

A detailed grade alteration plan shall be submitted to HRM for review and approvals prior to any site works. Plans shall include: existing and future grades, existing environmental features and conditions, limits of disturbance, erosion and sediment controls, water quality best management practices, topsoil depth and ground cover, and tree retention areas. The plans shall include details related to the conversion of any erosion and sediment controls into permanent stormwater management Best Management features to ensure water quantity and quality outcomes of the PNLA are achieved.

This Permit shall be in place with HRM prior to any tree-cutting or grade alteration activities within the area shown on the submitted plans.

A security is posted with HRM at $1,500 per acre bounded by the limits of disturbance shown on the plans and will only be released upon certification by a licensed engineer that all work has been completed in accordance with the Grade Alteration-PNLA permit.

Compliance Phase 2 Lot Grading Certificate
A detailed lot grading plan shall be submitted to HRM as part of the building permit application process. Plans shall include: detailed lot grading design which includes the limit of disturbance from the approved and certified grade alteration plans, plans shall include stabilization and landscaping details consistent with the native plantings as suggested. The final lot grading certificate shall be certified by a licensed engineer or surveyor and shall confirm that all work has been completed in accordance with grade alteration PNLA permit. An undertaking or security may be considered by HRM if weather conditions do not permit final plantings to be installed.

This permit is administered by the Development Officer, certification or an undertaking is required prior to the issuance of an occupancy permit.

6.0 CONCLUSIONS AND RECOMMENDATIONS

All aspects of the proposed development and existing site constraints and features have been considered in the management of stormwater quantity and quality as well as OSSDS effluent quality. A LID stormwater design has been adopted that focuses on mitigating nutrient generation from low intensity high frequency storms, recognizing that these events generally constitute approximately 90% of the annual rainfall. Additionally, OSSDSs have been designed such that they will adequately remove TP.

The design of the proposed development was thoughtfully prepared to minimize development impact and utilize LID strategies where possible. Stormwater quantity and quality balancing have been jointly achieved through the measures outlined in this document. This includes TP and TSS loadings that have been comprehensively considered and modeled to ensure all requirements of PNLA and RL-22 of Halifax Regional Municipality’s Municipal Planning Strategy for Planning Districts 14 and 17 (Shubenacadie Lakes) are satisfied.

Based on the data presented in this report, it is required that BMPs be introduced into the site design to treat site runoff and nutrients in order to achieve a balanced water quality site as required by the PNLA and RL-22. These BMPs will serve to mitigate both stormwater peak flow (water quantity) as well as stormwater quality throughout the project site. Using a treatment train consisting of a vegetated filter strip and enhanced grass swales as well as an innovative LID road cross section, an overall site TP removal efficiency of 51-52% can be achieved, reducing the post-development TP loadings to a value less than that experienced in the pre-development scenario. Both the private and publicly owned BMPs and erosion and sediment control measures provided in this project site have been designed to achieve a negligible impact on the existing surface flows from the development to any receiving watercourses or receiving bodies of water.

Additionally, the data presented in this report noted that conventional OSSDSs will not adequately remove TP as required by the PNLA and RL-22. To address this, specialized biological wastewater treatment units (AT-120 BioPro units) are required in order to provide additional TP removal efficiencies. Through the anticipated lifespan of the sewage treatment disposal field it is expected that 95-97% total TP removal efficiency will be achieved. There are also potential additional TP removal avenues that exist in the surrounding area and within the filtration sand that would further reduce the OSSDS TP loads into the downstream Second and Third Lakes. These may include removal through surface water features (i.e. wetlands), evapotranspiration, aquatic plant uptake, etc. The actual amount of TP removal expected from these additional features is difficult to quantify due to the numerous natural variables that exist. Given the margin of error that exists in determining removal efficiency, it is anticipated that these removal rates are acceptable for the consideration of a no-net increase of TP from the OSSDSs to the surrounding surface water features.

A thorough investigation into the development's design, phasing intentions, and finished product has been completed to provide erosion and sediment control measures that will mitigate sediment transport during and after construction. During construction, the Site Engineer, will be present to monitor all construction activities and ensure the suggested erosion and sediment control measures are performing adequately.

Stormwater peak flow management for this project has been completed to meet the requirements of Halifax Water through the use of lot grading design and on-site features to aid in attenuating the anticipated peak runoff. No adjacent properties will be adversely affected by the peak stormwater runoff produced by the project site. Several stormwater management features have been included to mitigate adverse effects on the existing watercourses and wetlands. Long-term maintenance of the stormwater infrastructure is not expected to be more than would be expected from a development that does not contain stormwater LID and BMP infrastructure.

The project site has a net-developable area as defined by HRM with overall land use plans provided on Drawing P02 in Appendix B. These plans also include the area identified as open space as required by HRM and all sensitive areas to be protected from disturbance and not suitable for development.

Stormwater quantity and quality balancing and OSSDS TP effluent mitigation have been jointly achieved through the measures outlined in this document. TP and TSS loadings that have been comprehensively considered and modeled during and after construction to ensure all requirements of section RL-22 of Halifax Regional Municipality's Municipal Planning Strategy for Planning Districts 14 and 17 (Shubenacadie Lakes) are satisfied.

7.0 STATEMENT OF QUALIFICATIONS AND LIMITATIONS

This Report (the “Report”) has been prepared by Strum Consulting (“Consultant”) for the benefit of Clayton Developments Limited (“Client”) in accordance with the agreement between Consultant and Client, including the scope of work detailed therein (the “Agreement”).

The information, data, recommendations, and conclusions contained in the Report (collectively, the “Information”):

- is subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the “Limitations”)
- represents Consultant’s professional judgement in light of the Limitations and industry standards for the preparation of similar reports
- may be based on information provided to Consultant which has not been independently verified
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued
- must be read as a whole and sections thereof should not be read out of such context
- was prepared for the specific purposes described in the Report and the Agreement
- in the case of subsurface, environmental, or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time

Consultant shall be entitled to rely upon the accuracy and completeness of information that was provided and has no obligation to update such information. Consultant accepts no responsibility for any events or circumstances that may have occurred since the date on which the Report was prepared and, in the case of subsurface, environmental, or geotechnical conditions, is not responsible for any variability in such conditions, geographically or over time.

Consultant agrees that the Report represents its professional judgement as described above and that the Information has been prepared for the specific purpose and use described in the Report and the Agreement, but Consultant makes no other representations, or any guarantees or warranties whatsoever, whether express or implied, with respect to the Report, the Information or any part thereof.

The Report is to be treated as confidential and may not be used or relied upon by third parties, except:

- as agreed in writing by Consultant and Client
- as required by law

- for use by governmental reviewing agencies

Consultant accepts no responsibility, and denies any liability whatsoever, to parties other than Client who may obtain access to the Report or the Information for any injury, loss, or damage suffered by such parties arising from their use of, reliance upon, or decisions or actions based on the Report or any of the Information (“improper use of the Report”), except to the extent those parties have obtained the prior written consent of Consultant to use and rely upon the Report and the Information. Any damages arising from improper use of the Report or parts thereof shall be borne by the party making such use.

This Statement of Qualifications and Limitations forms part of the Report and any use of the Report is subject to the terms hereof.

Should additional information become available, Strum requests that this information be brought to our attention immediately so that we can re-assess the conclusions presented in this report. This report was prepared by Richard Wile, P.Eng., Civil Engineer, and was reviewed by Chris Boudreau, P.Eng., Manager, Engineering.

8.0 REFERENCES

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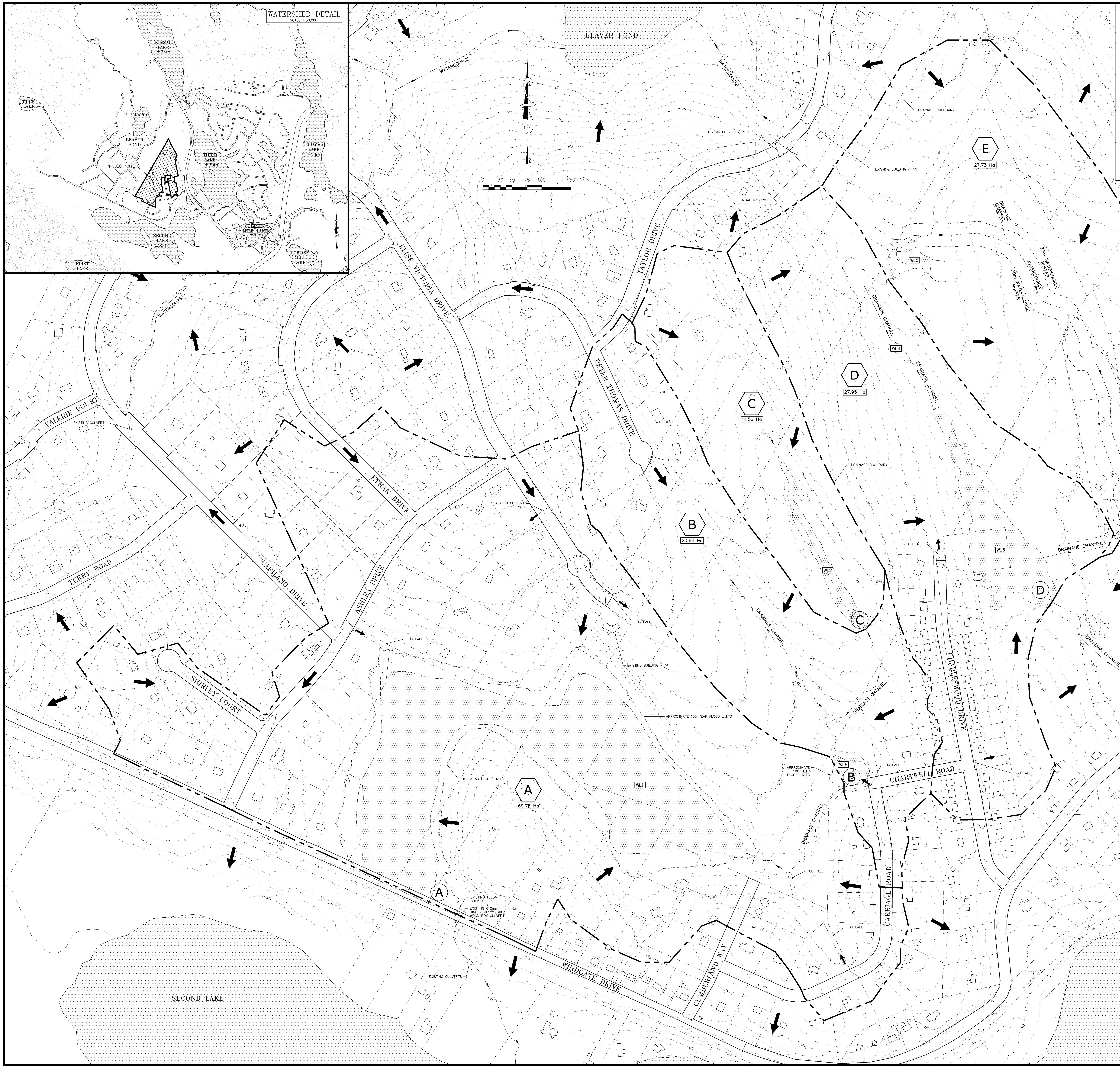
APPENDIX A
STORMWATER MANAGEMENT PLANS



CRITICAL POINTS CALCULATION TABLE (PRE DEVELOPED)

POINT	AREA		CN	TC	FLOW (L/s)				
	IDENTIFIER	HECTARES		(Min.)	2YR	5YR	10YR	25YR	100YR
A	Ⓐ+Ⓑ+Ⓒ	101.96	77	159.4	1630	2631	3430	4397	5816
B	Ⓑ+Ⓒ	32.20	75	142.6	634	1055	1393	1804	2411
C	Ⓒ	11.56	75	107.2	211	352	465	601	803
D	Ⓓ	27.95	74	108.4	472	797	1062	1385	1864
E	Ⓔ	27.73	74	120.1	441	743	988	1288	1732

STORMWATER MANAGEMENT NOTES

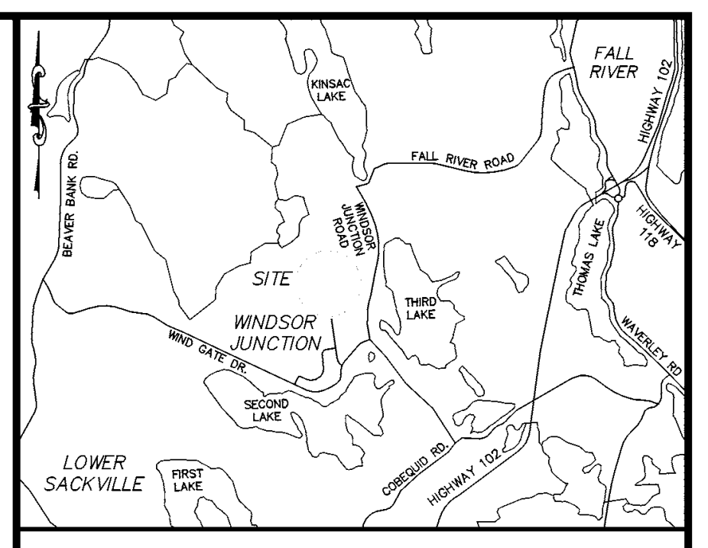
1. STORM WATER MODELED USING HYDROCAD V.10.00 SOFTWARE, USING THE USDA NATURAL RESOURCES CONSERVATION SERVICE METHOD (FORMALLY SCS),

2. 24HR MODIFIED CHICAGO STORM DISTRIBUTION USED, MODIFIED IN ACCORDANCE WITH HALIFAX WATER STANDARD SPECIFICATION.
   - 100 YEAR STORM – TOTAL RAINFALL : 176mm
   - 25 YEAR STORM – TOTAL RAINFALL : 146mm
   - 10 YEAR STORM – TOTAL RAINFALL : 125mm
   - 5 YEAR STORM – TOTAL RAINFALL : 107mm
   - 2 YEAR STORM – TOTAL RAINFALL : 83mm

3. Ia/S Ratio =0.2

4. ANTECEDENT MOISTURE CONDITION = 2 (AVERAGE (NORMAL) CONDITIONS)

5. COEFFICIENTS OF PERMEABILITY RANGE FROM $5x10^{-8}$ TO $5x10^{-6}$ cm/s FOR SOILS WITHIN THE PROJECT BOUNDARIES AND WERE USED DURING ANALYSIS.



Key Plan NOT TO SCALE

LEGEND

⬡X	DRAINAGE AREA IDENTIFIER
ⓧ	CRITICAL CALCULATION POINT
➡	FLOW DIRECTION
WLX	WETLAND IDENTIFIER
69.76 Ha	DRAINAGE AREA VOLUME IDENTIFIER
S##	VOLUME RATE IDENTIFIER
— · —	EXISTING LOTS
——	EXISTING ROW
LOW POINT	LOW POINT IN ROADWAY
HIGH POINT	HIGH POINT IN ROADWAY
——	PROPOSED LOTS
——	PROPOSED ROW

NOTES:

1. Contour interval is 2.0 Metre, based on LRIS mapping blended with actual field data provided by Servant Dunbrack Limited.

2. For storm drainage calculations refer to Strum Consulting storm drainage calculation sheets.

3. Wetlands and watercourses indicated on this plan within the general limits of the project have been delineated by Englobe Inc.

0.	Issued For Review	July 8, 2019	CNB
No	Description	Date	By

Revision or Issue

Strum
CONSULTING

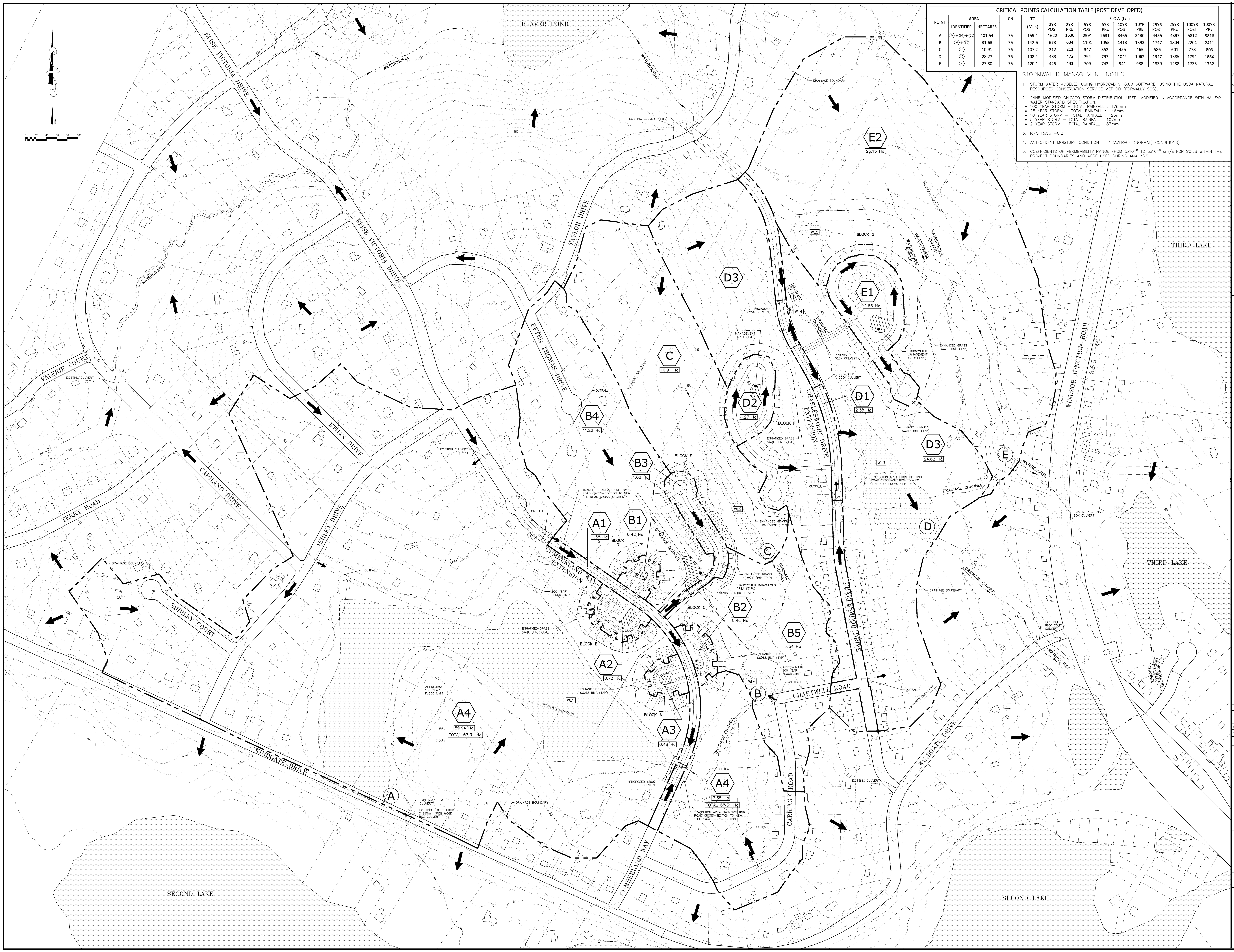
Project
CHARLESWOOD SUBDIVISION
WINDSOR JUNCTION
NOVA SCOTIA

Drawing
PRE–DEVELOPMENT DRAINAGE CONDITIONS

Scale 1:2500

DATE:07/08/19
C. N. BOUDREAU
7511

Date July 8, 2019		Drawn TJB
Design CNB	Check RAW	Approv. CNB
Project No. 19–6737		Sheet 1 Of 2
Drawing No. D01		Rev. 0

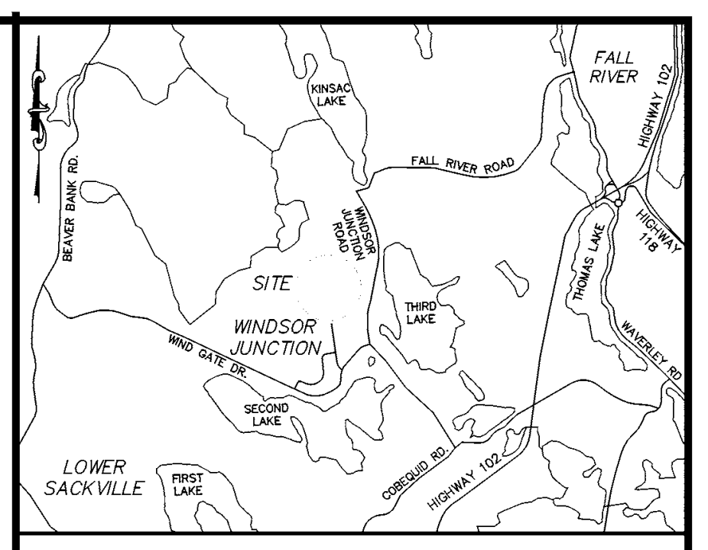


CRITICAL POINTS CALCULATION TABLE (POST DEVELOPED)

POINT	AREA		CN	TC	FLOW (L/s)									
	IDENTIFIER	HECTARES		(Min.)	2YR POST	2YR PRE	5YR POST	5YR PRE	10YR POST	10YR PRE	25YR POST	25YR PRE	100YR POST	100YR PRE
A	A+B+C	101.54	75	159.4	1622	1630	2591	2631	3465	3430	4455	4397	5812	5816
B	B+C	31.63	76	142.6	678	634	1101	1055	1413	1393	1747	1804	2201	2411
C	C	10.91	76	107.2	212	211	347	352	455	465	586	601	778	803
D	D	28.27	76	108.4	483	472	794	797	1044	1062	1347	1385	1794	1864
E	E	27.80	75	120.1	425	441	709	743	941	988	1339	1288	1735	1732

STORMWATER MANAGEMENT NOTES

1. STORM WATER MODELED USING HYDROCAD V.10.00 SOFTWARE, USING THE USDA NATURAL RESOURCES CONSERVATION SERVICE METHOD (FORMALLY SCS),
2. 24HR MODIFIED CHICAGO STORM DISTRIBUTION USED, MODIFIED IN ACCORDANCE WITH HALIFAX WATER STANDARD SPECIFICATION.
   - 100 YEAR STORM – TOTAL RAINFALL : 176mm
   - 25 YEAR STORM – TOTAL RAINFALL : 146mm
   - 10 YEAR STORM – TOTAL RAINFALL : 125mm
   - 5 YEAR STORM – TOTAL RAINFALL : 107mm
   - 2 YEAR STORM – TOTAL RAINFALL : 83mm
3. Ia/S Ratio =0.2
4. ANTECEDENT MOISTURE CONDITION = 2 (AVERAGE (NORMAL) CONDITIONS)
5. COEFFICIENTS OF PERMEABILITY RANGE FROM 5×10^{-8} TO 5×10^{-6} cm/s FOR SOILS WITHIN THE PROJECT BOUNDARIES AND WERE USED DURING ANALYSIS.



Key Plan NOT TO SCALE

LEGEND

X	DRAINAGE AREA IDENTIFIER
X	CRITICAL CALCULATION POINT
➡	FLOW DIRECTION
WLX	WETLAND IDENTIFIER
69.76 Ha	DRAINAGE AREA VOLUME IDENTIFIER
S##	VOLUME RATE IDENTIFIER
— · —	EXISTING LOTS
——	EXISTING ROW
LOW POINT	LOW POINT IN ROADWAY
HIGH POINT	HIGH POINT IN ROADWAY
——	PROPOSED LOTS
——	PROPOSED ROW
▨	STORMWATER MANAGEMENT AREA
— · —	ENHANCED GRASS SWALE BMP

NOTES:

1. Contour interval is 2.0 Metre, based on LRIS mapping blended with actual field data provided by Servant Dunbrack Limited.
2. For storm drainage calculations refer to Strum Consulting storm drainage calculation sheets.
3. Post developed flows to Points A through E have been balanced through on–site detention in areas indicated on the plan. Stormwater management areas sized to balance pre/post flows to critical points. Individual blocks not balanced.
4. Stormwater analysis includes allowances for infiltration of water through Enhanced Grassed Swales, Stormwater Filter Strips and LID Road Cross–Section Ditches.
5. For additional information on Water Quality Analysis, refer to PNLA report and supporting figures. prepared by Strum Consulting.
6. All Road cross–culverts to be sized for 1 in 10 year event except for cross–culvert at station 0+040 on Cumberland Drive which is designed for a 1 in 100 year storm. All driveway culverts to be sized for 1 in 10 year event.
7. Refer to Phosphorous Loading study dated July 8, 2019 by Strum Consulting for additional details on stormwater management and best management practices.

No	Description	Date	By
0.	Issued For Review	July 8, 2019	CNB

Revision or Issue

Strum
CONSULTING

Project
CHARLESWOOD SUBDIVISION
WINDSOR JUNCTION
NOVA SCOTIA

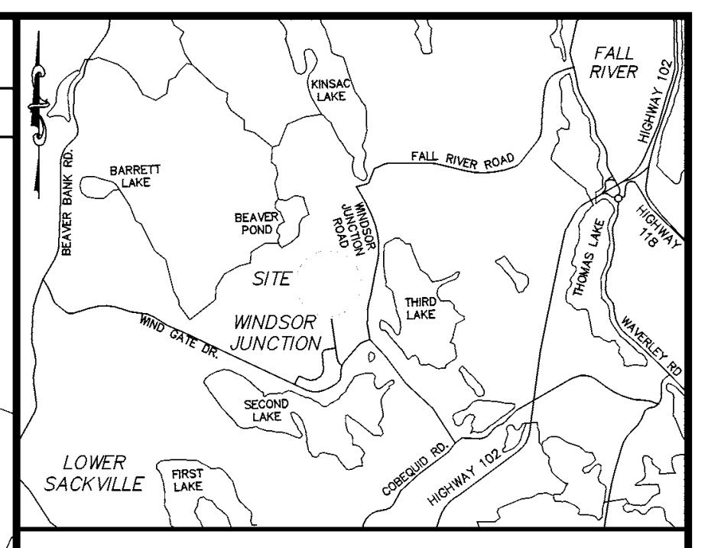
Drawing
POST–DEVELOPMENT DRAINAGE
CONDITIONS

Scale 1:2500

DATE:07/08/19
C. N. BOUDREAU
7511

Date July 8, 2019		Drawn TJB
Design CNB	Check RAW	Approv. CNB
Project No. 19–6737		Sheet 2 Of 2
Drawing No. D02		Rev. 0

APPENDIX B
PHASING, CONSTRUCTION, AND SEDIMENT CONTROL PLANS



Key Plan NOT TO SCALE

LEGEND

- PROPERTY LINE
- EXISTING PROPERTY LINE
- RIGHT OF WAY
- OHWM
- DRAINAGE CHANNEL
- EDGE OF WETLAND
- WATERCOURSE
- EXISTING BUILDING
- W SERVICED BY WELL

NOTES:

1. Contour interval is 2.0 metres based on Lidar, blended with topographic field data, provided by SDMM.

No	Description	Date	By
0.	Issued For Review	July 8, 2019	CNB

Revision or Issue

Strum CONSULTING

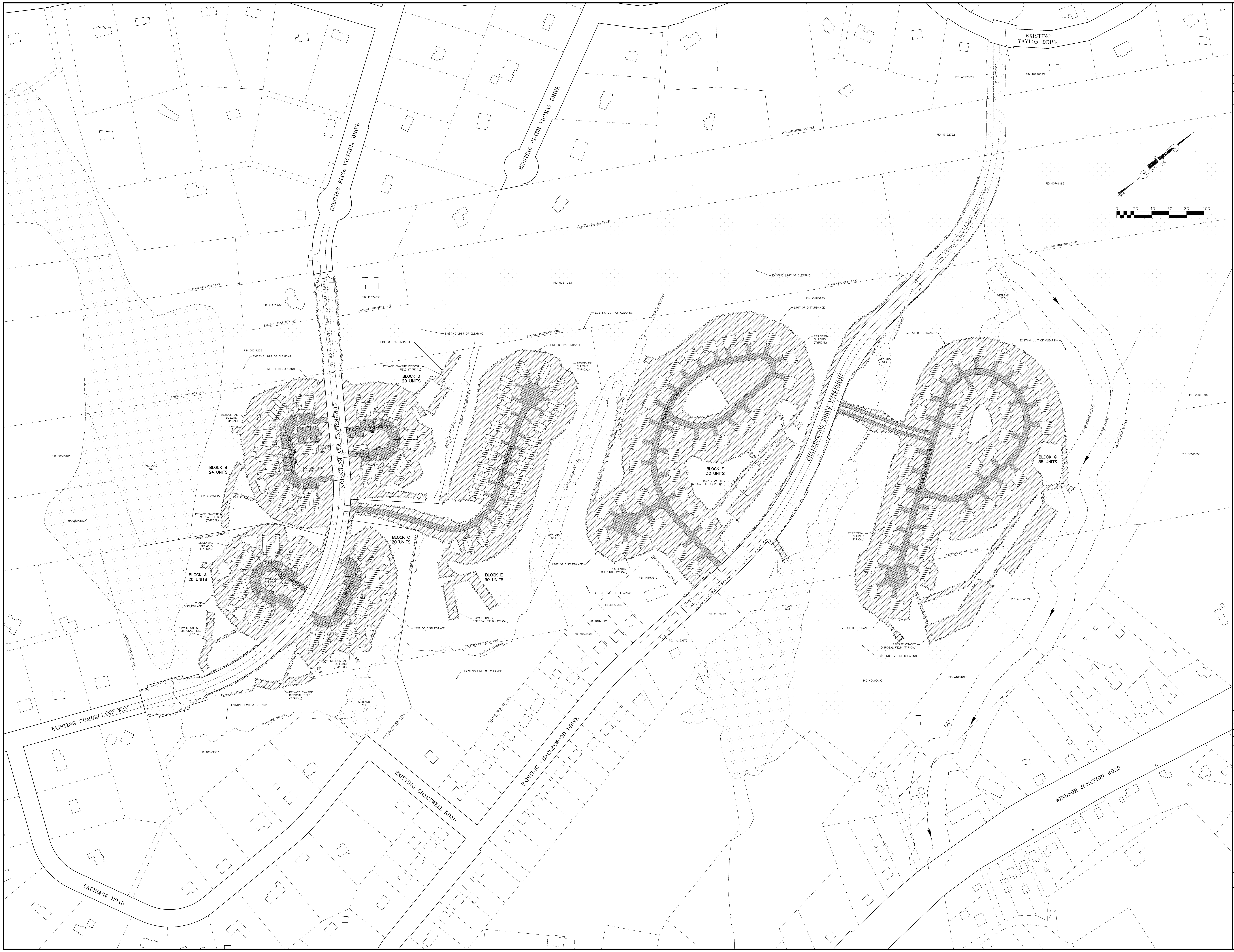
Project
CHARLESWOOD SUBDIVISION
WINDSOR JUNCTION, NOVA SCOTIA

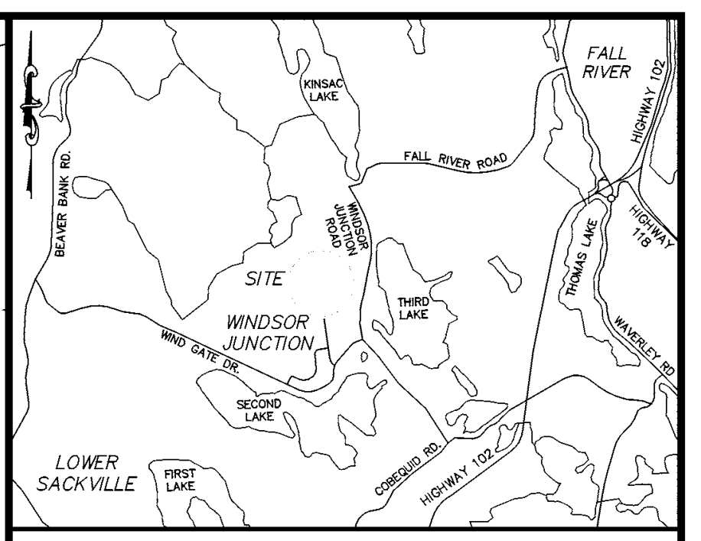
Drawing
SITE & PHASING CONTEXT PLAN

Scale 1:3000

REGISTERED PROFESSIONAL ENGINEER
DATE: 07/08/19
C. N. BOUDREAU
7511
PROVINCE OF NOVA SCOTIA

Date July 8, 2019	Drawn TJB
Design CNB / Check RAW	Approv. CNB
Project No. 19-6784	Sheet 1 Of 6
Drawing No. P01	Rev. 0





Key Plan NOT TO SCALE

LEGEND

- SANITARY M.H. & SEWER
- STORM M.H. & SEWER
- HYDRANT
- —W—⊗—W— GATE VALVE & WATERMAIN
- CATCHBASIN
- STREET TREE
- POWER POLE
- POWER POLE WITH LIGHT FIXTURE
- ANCHOR ON LIGHT POLE
- ALIANT PEDESTAL
- ALIANT FLUSH BOX
- N.S.P.I. URD BOX
- CONCRETE CURB & GUTTER
- SIDEWALK
- DRIVEWAY
- PEDESTRIAN RAMP
- PROPOSED ℄ FINISHED GRADE
- EXISTING CENTERLINE GRADE
- EXISTING GRADE (RT. SIDE R.O.W.)
- EXISTING GRADE (LEFT SIDE R.O.W.)
- PROPOSED U/G ELEC. LINES
- PROPERTY LINE
- EXISTING PROPERTY LINE
- LATERALS ,SAN.,STM. & WM.
- TEST PIT LOCATION

MEDIUM DENSITY RESIDENTIAL

- ▨ DWELLING / STRUCTURE
- ▩ HARD SURFACE PAVING
- ░ OPEN SPACE

PROPSED PAVED PUBLIC ROAD

- ☒ ROW PAVING / OPEN SPACE

OTHER AREAS

- NATURAL / UNDISTURBED
- WETLAND

NOTES:

1. On-site septic treatment systems and disposal fields to be designed by others.
2. Wetlands and existing drainage delineated be Englobe.
3. Site design completed as per HRM Classic Open Space Disturbance Limit of 40%.

0.	Issued For Review	July 8, 2019	CNB
No	Description	Date	By

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Strum
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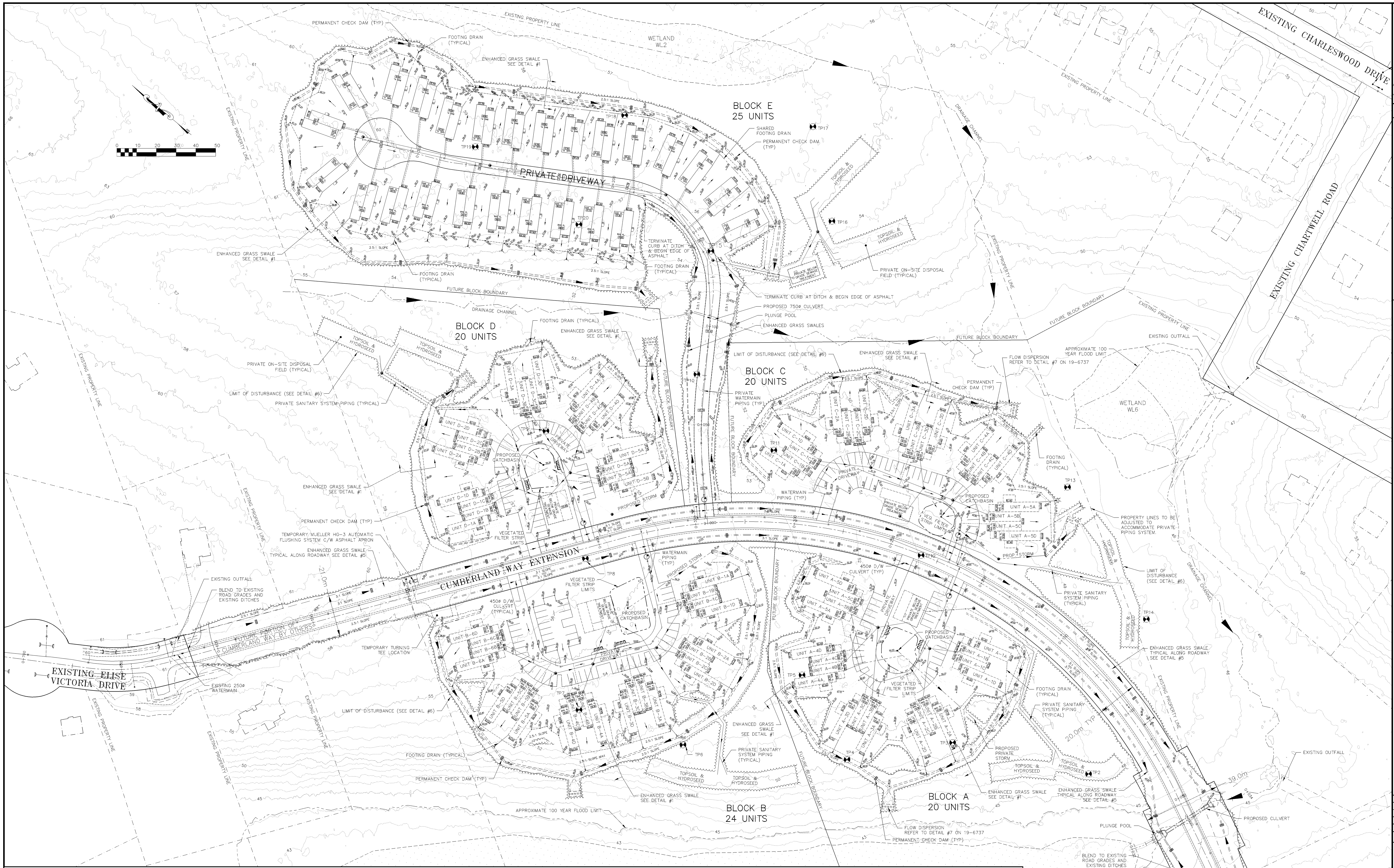
Project
CHARLESWOOD SUBDIVISION
WINDSOR JUNCTION
NOVA SCOTIA

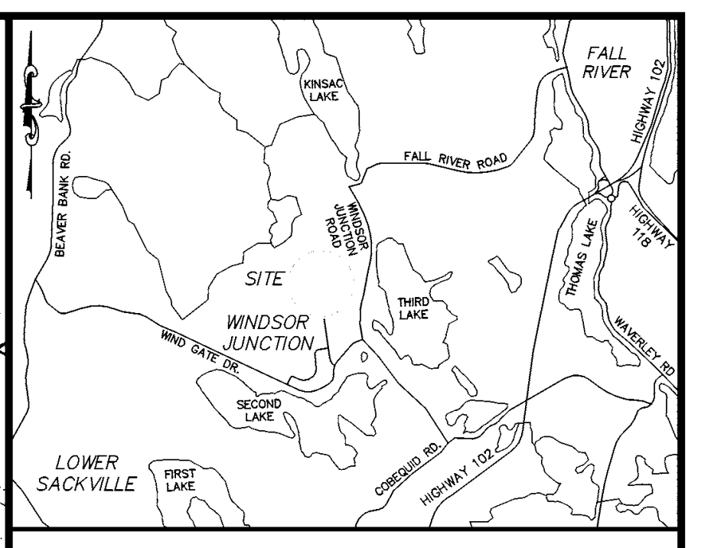
Drawing
LAND USE PLAN

Scale 1:1250

DATE:07/08/19
C. N. BOUDREAU
7511

Date July 8, 2019		Drawn TJB
Design CNB	Check RAW	Approv. CNB
Project No. 19-6737		Sheet 2 Of 6
Drawing No. P02		Rev. 0





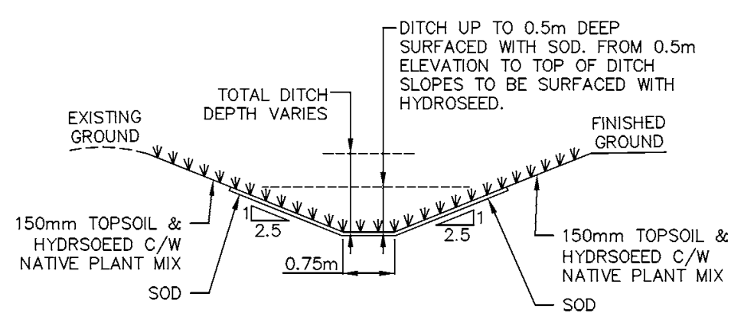
Key Plan NOT TO SCALE

LEGEND

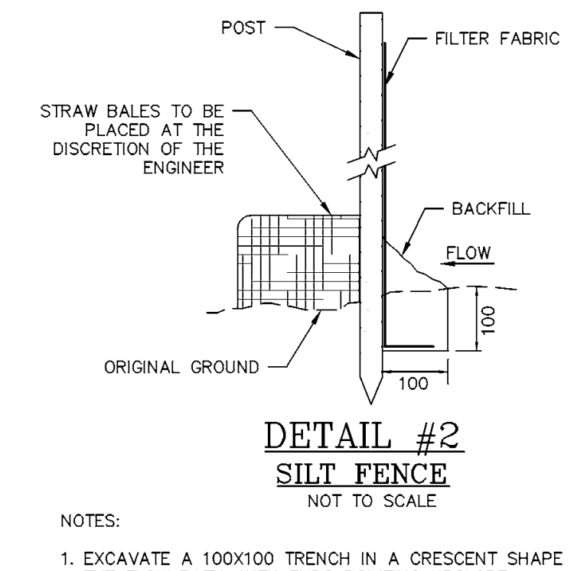
	SANITARY M.H. & SEWER
	STORM M.H. & SEWER
	HYDRANT
—W—⊗—W—	GATE VALVE & WATERMAIN
▬	CATCHBASIN
	STREET TREE
◉	POWER POLE
	POWER POLE WITH LIGHT FIXTURE
	ANCHOR ON LIGHT POLE
○	ALIANT PEDESTAL
⊠	ALIANT FLUSH BOX
▭	N.S.P.I. URD BOX
	CONCRETE CURB & GUTTER
	SIDEWALK
	DRIVEWAY
	PEDESTRIAN RAMP
	PROPOSED ℄ FINISHED GRADE
	EXISTING CENTERLINE GRADE
	EXISTING GRADE (RT. SIDE R.O.W.)
	EXISTING GRADE (LEFT SIDE R.O.W.)
	PROPOSED U/G ELEC. LINES
	PROPERTY LINE
	EXISTING PROPERTY LINE
	LATERALS ,SAN.,STM. & WM.
	TEST PIT LOCATION

NOTES:

1. Contour interval is 1.0 metres based on Lidar, blended with topographic field data, provided by SDMM.
2. All landscaped areas (grass, plantings, etc) are to utilize native plant species.
- LID Roadside Ditches
  150mm topsoil & hydroseed
- Enhanced Grass Swale or Filter Strip Areas
  150mm topsoil & hydroseed
- All other grassed areas
  100mm topsoil & hydroseed
3. Soil coefficients of permeability range from $5x10^{-8}$ to $5x10^{-6}$ cm/s for soils within the project boundaries.
4. All cut and fill slopes on site to be 2.5:1 unless otherwise noted. Slope stability to be confirmed on site by geotechnical engineer.
5. Sanitary sewer and treatment systems as per design by SDMM.
6. Roof leaders on single and semi-detached residential units shall be directed to vegetated areas where possible, rather than towards the storm drainage system.
7. Snow is not to be piled in vegetated filter strips.
8. All footing drains shall be connected to the storm sewer lateral, unless otherwise noted.
9. As part of the building permit stage, all grass surfaces within proposed lots shall be surfaced with 200mm of topsoil in front yards and 150mm in rear yards. Topsoil shall be rating A or B in accordance with the latest edition of the Landscape N.S. Horticultural Trades Association Standard Topsoil Triangle.
10. For silt fence locations refer to drawing 19-6737-P05.
11. No clearing or construction will occur within the protective green belts/protected sensitive areas.
12. Before grubbing commences, clearing limits, easements, setbacks, sensitive/critical areas and their buffers, trees and drainage courses shall be delineated with flagging tape and enviro-fences. This ensures workers can clearly recognize areas to be protected. Grubbing material to be disposed of at a location approved by the owner.
13. Vegetated filter strips shall not have buildings or structures constructed within them.
14. Private sewage treatment facilities and vegetated filter strips to maintain a minimum of 5.0m horizontal separation.



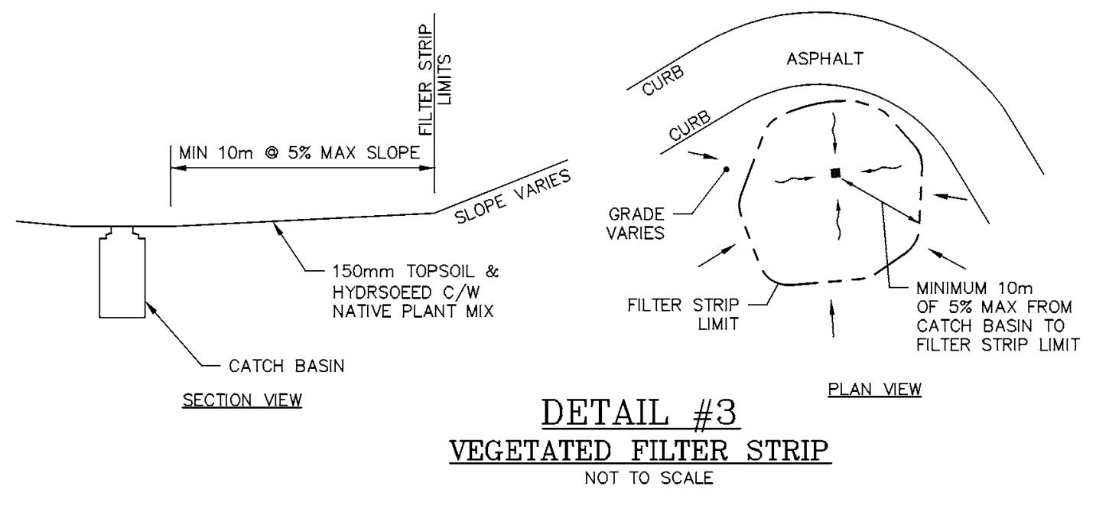
DETAIL #1
TYPICAL ENHANCED GRASS SWALE
N.T.S.



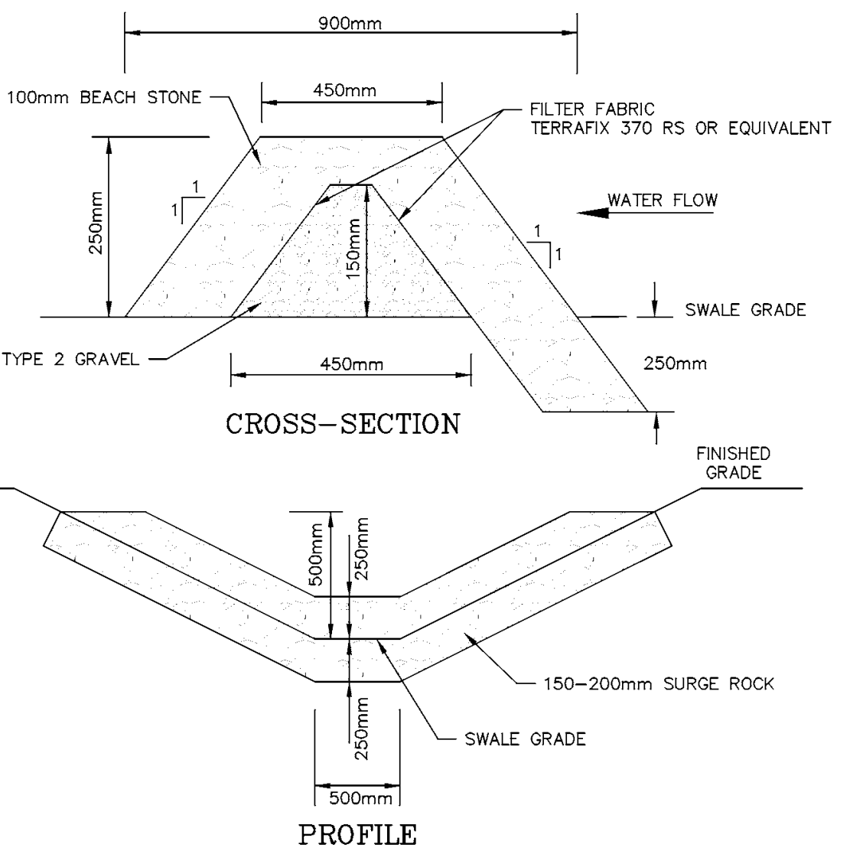
DETAIL #2
SILT FENCE
NOT TO SCALE

NOTES:

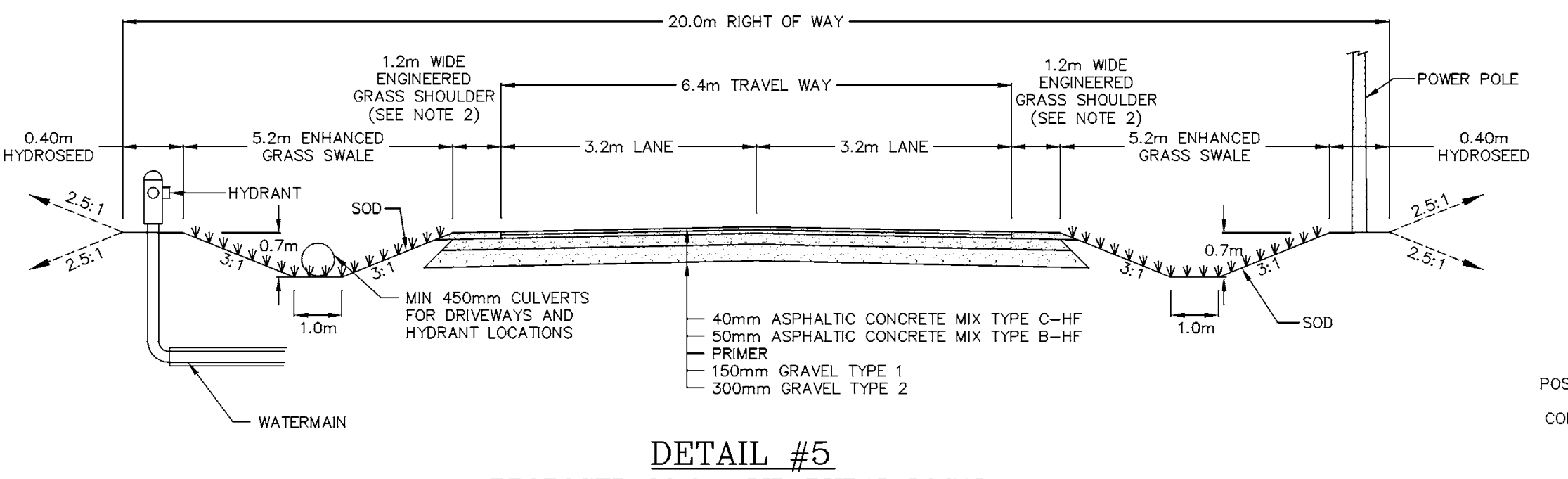
1. EXCAVATE A 100X100 TRENCH IN A CRESCENT SHAPE ACROSS THE FLOW PATH, WITH ENDS POINTING UPSLOPE.
2. SET WOOD STAKES SUPPLIED BY MANUFACTURER. DRIVE STAKES SECURELY INTO GROUND 900MM APART ALONG THE DOWNSLOPE SIDE OF THE TRENCH.
3. STAPLE FILTER FABRIC TO THE UPSTREAM SIDE OF THE STAKES, EXTENDING THE BOTTOM 200mm INTO THE TRENCH.
4. FILTER FABRIC SHOULD NOT EXCEED 900mm IN HEIGHT.
5. BACKFILL AND COMPACT THE SOIL IN THE TRENCH OVER THE FILTER FABRIC AND VEGETATE SOIL IMMEDIATELY.



DETAIL #3
VEGETATED FILTER STRIP
NOT TO SCALE



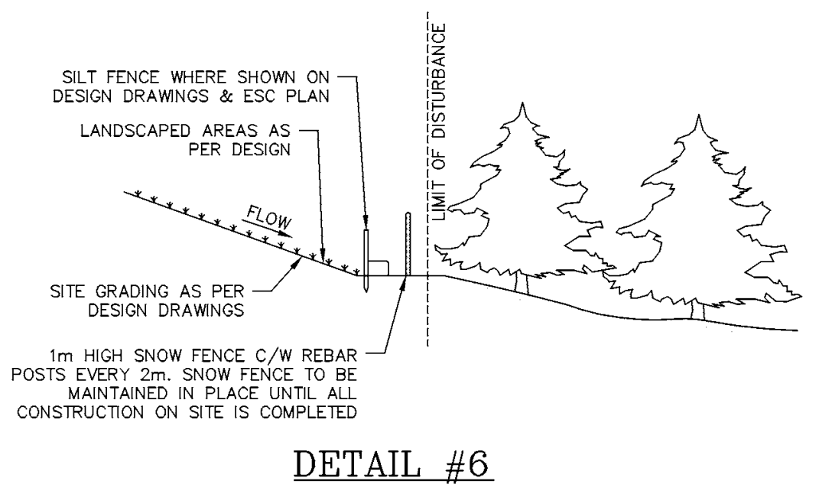
DETAIL #4
PERMANENT CHECK DAM
NOT TO SCALE



DETAIL #5
PROPOSED 20.0m LID RURAL LOCAL
N.T.S.

NOTES:

1. ENHANCED GRASS SWALES TO BE CONSTRUCTED WITH MIN. 150mm TOPSOIL AND HYDROSEED WITH NATIVE GRASS MIXTURE. PERMANENT CHECK DAMS TO BE INSTALLED AT TYPICAL 20m SPACING.
2. 1.2m WIDE SHOULDER ENGINEERED GRASS SHOULDER TO BE CONSTRUCTED TO ACCOMMODATE EMERGENCY OR TEMPORARY VEHICULAR LOADING.



DETAIL #6
TREE CLEARING PROTECTION LIMIT
NOT TO SCALE

No	Description	Date	By
0.	Issued For Review	July 8, 2019	CNB

Revision or Issue

Strum
CONSULTING

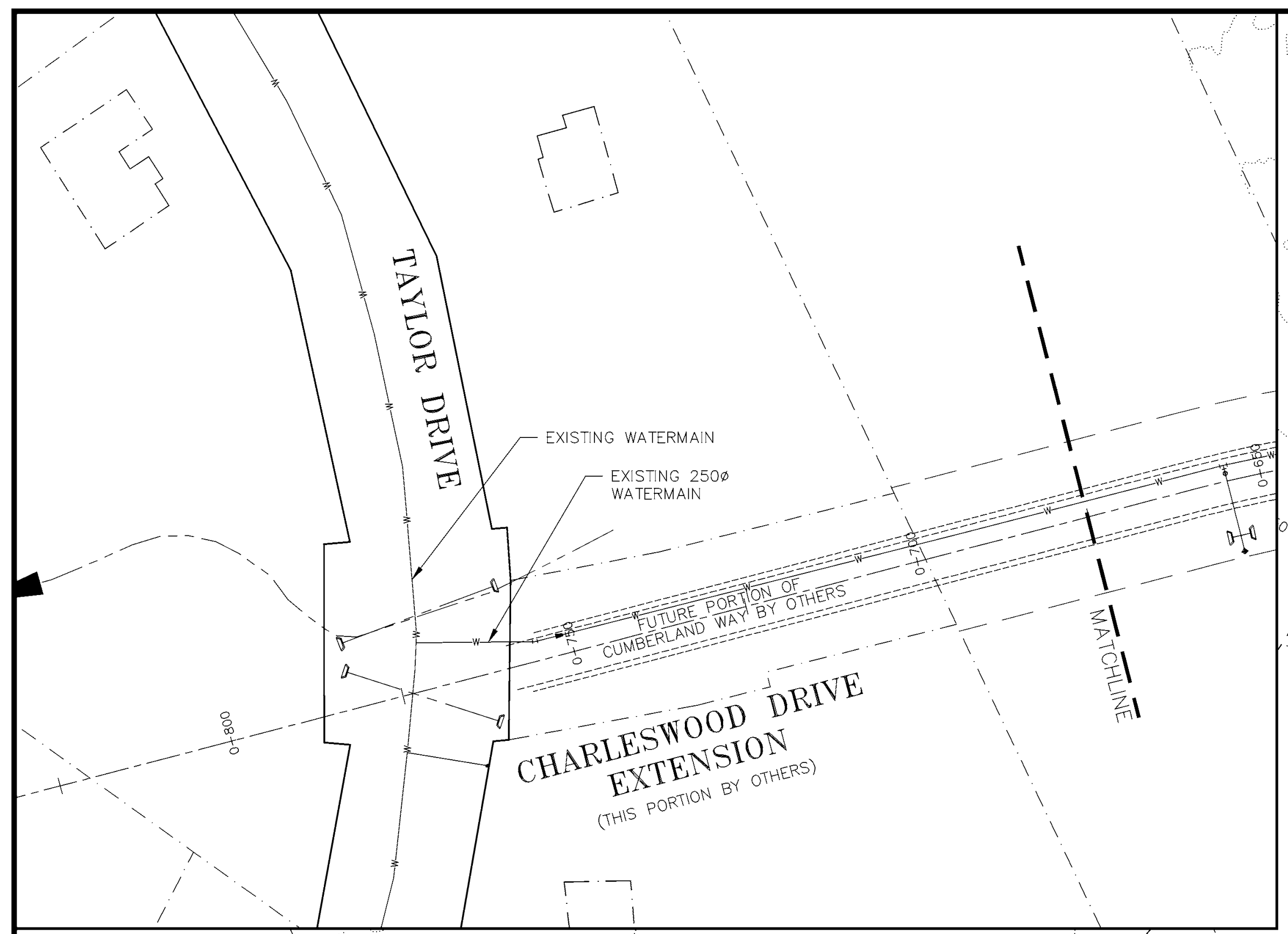
Project
CHARLESWOOD SUBDIVISION
WINDSOR JUNCTION
NOVA SCOTIA

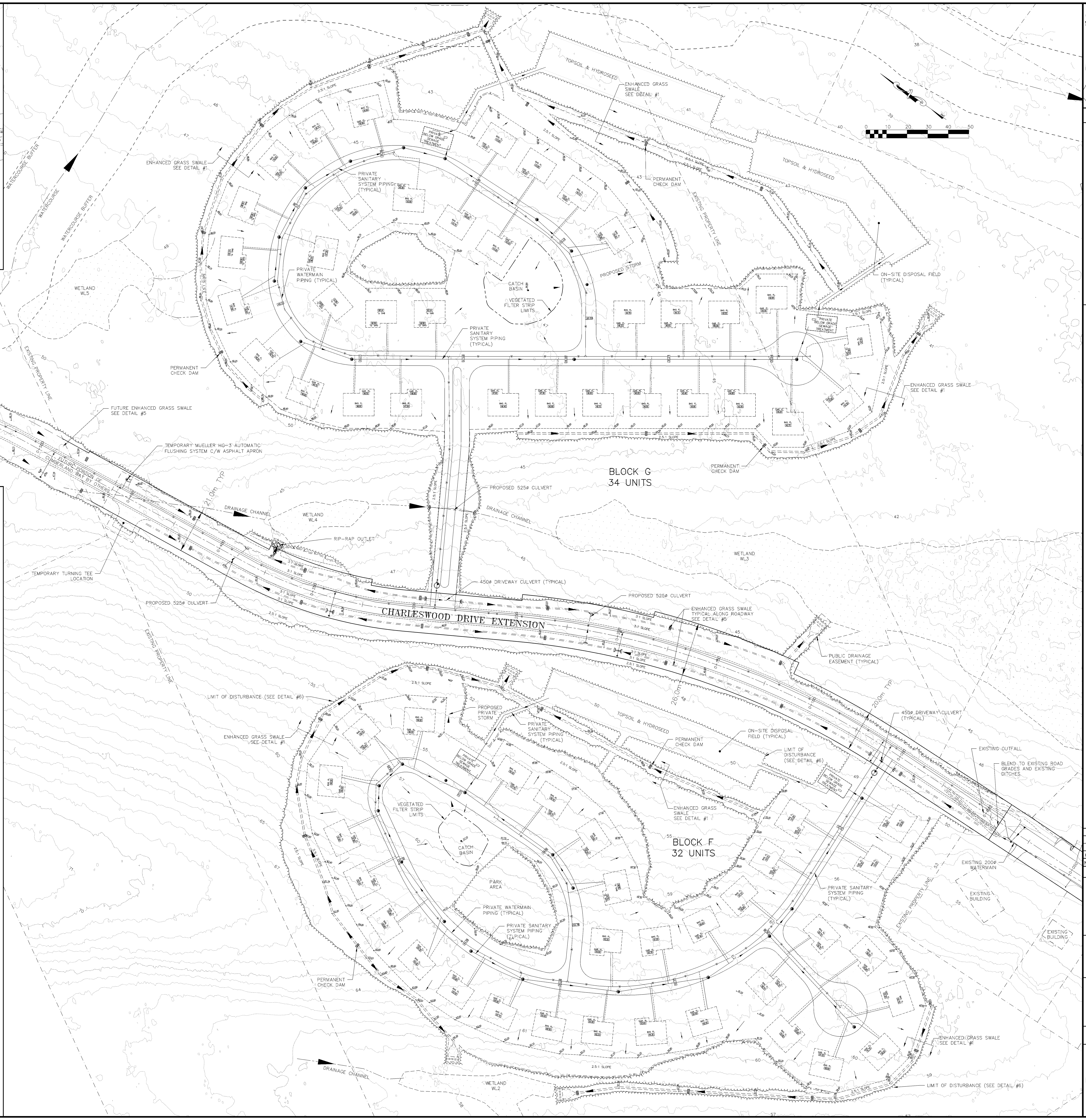
Drawing
BEST MANAGEMENT PRACTICES
AND PRELIMINARY GRADING
CUMBERLAND WAY

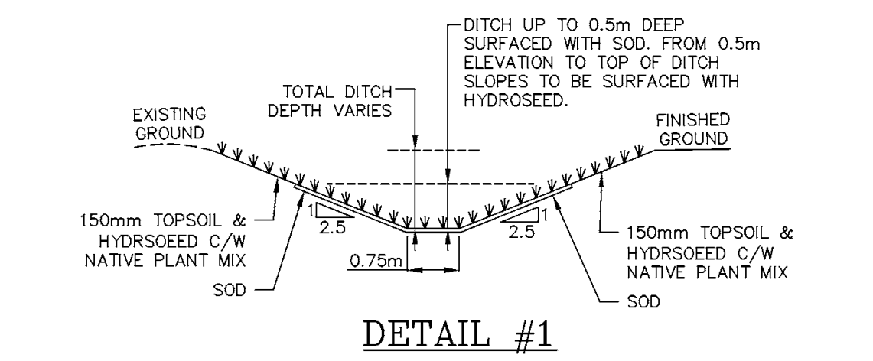
Scale 1:750

DATE:07/08/19
C. N. BOUDREAU
7511

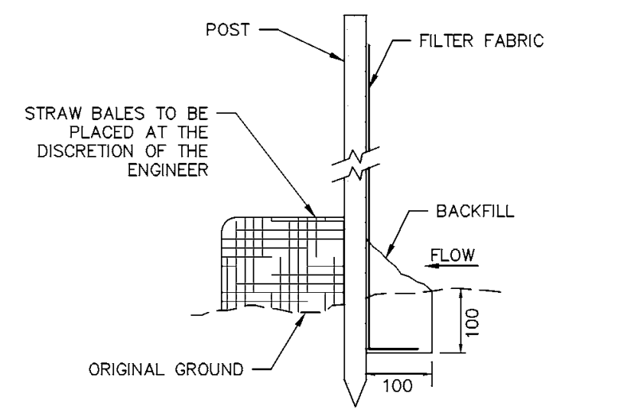
Date July 8, 2019		Drawn TJB
Design CNB	Check RAW	Approv. CNB
Project No. 19-6737		Sheet 3 Of 6
Drawing No. P03		Rev. 0







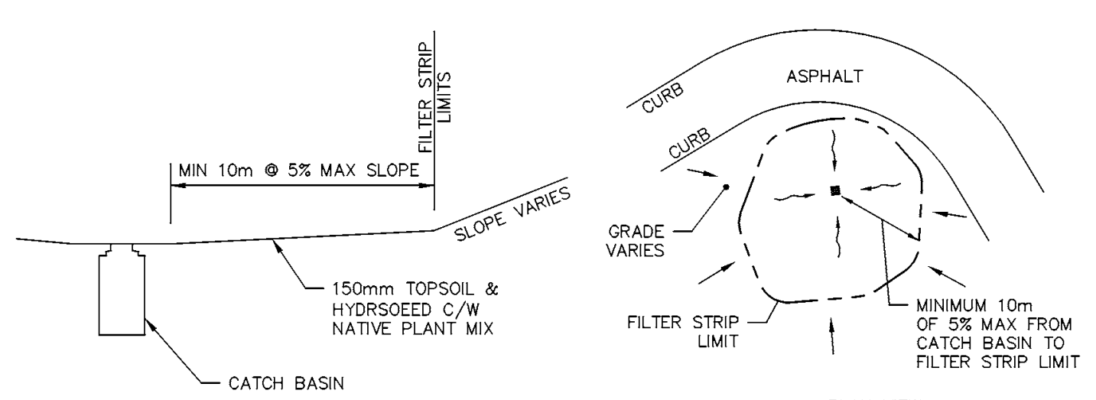
DETAIL #1
TYPICAL ENHANCED GRASS SWALE
N.T.S.



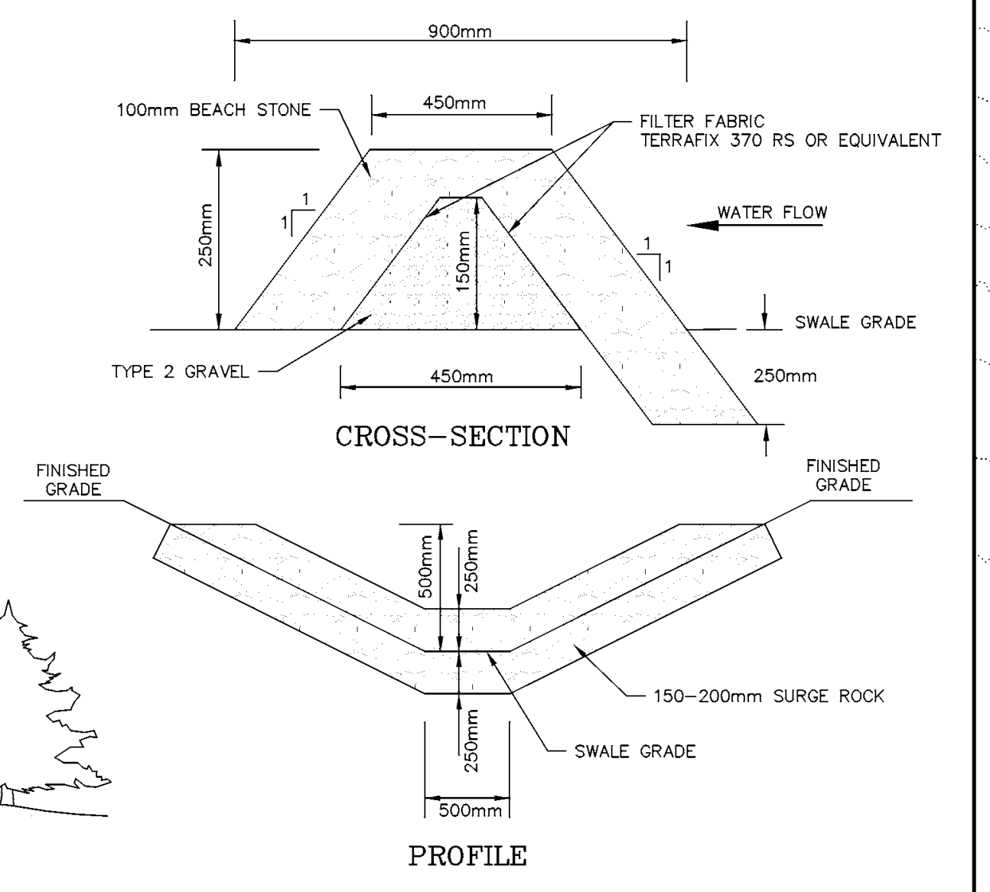
DETAIL #2
SILT FENCE
NOT TO SCALE

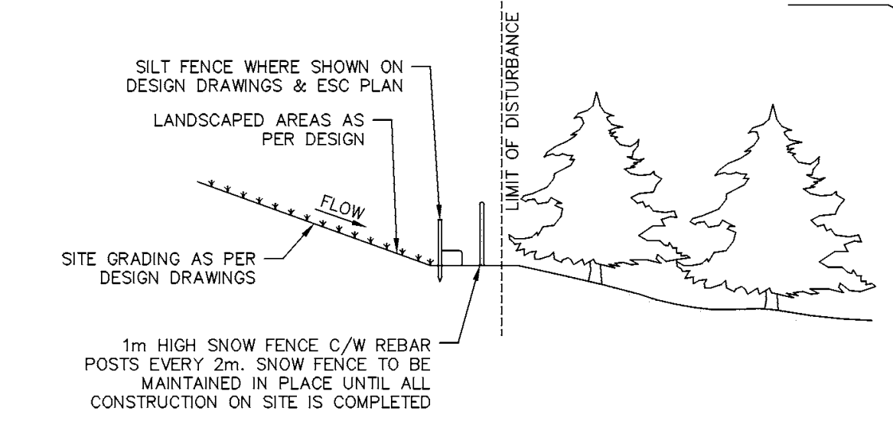
NOTES:

1. EXCAVATE A 100X100 TRENCH IN A CRESCENT SHAPE ACROSS THE FLOW PATH, WITH ENDS POINTING UPSLOPE.
2. SET WOOD STAKES SUPPLIED BY MANUFACTURER. DRIVE STAKES SECURELY INTO GROUND 900MM APART ALONG THE DOWNSLOPE SIDE OF THE TRENCH.
3. STAPLE FILTER FABRIC TO THE UPSTREAM SIDE OF THE STAKES, EXTENDING THE BOTTOM 200mm INTO THE TRENCH.
4. FILTER FABRIC SHOULD NOT EXCEED 900mm IN HEIGHT.
5. BACKFILL AND COMPACT THE SOIL IN THE TRENCH OVER THE FILTER FABRIC AND VEGETATE SOIL IMMEDIATELY.



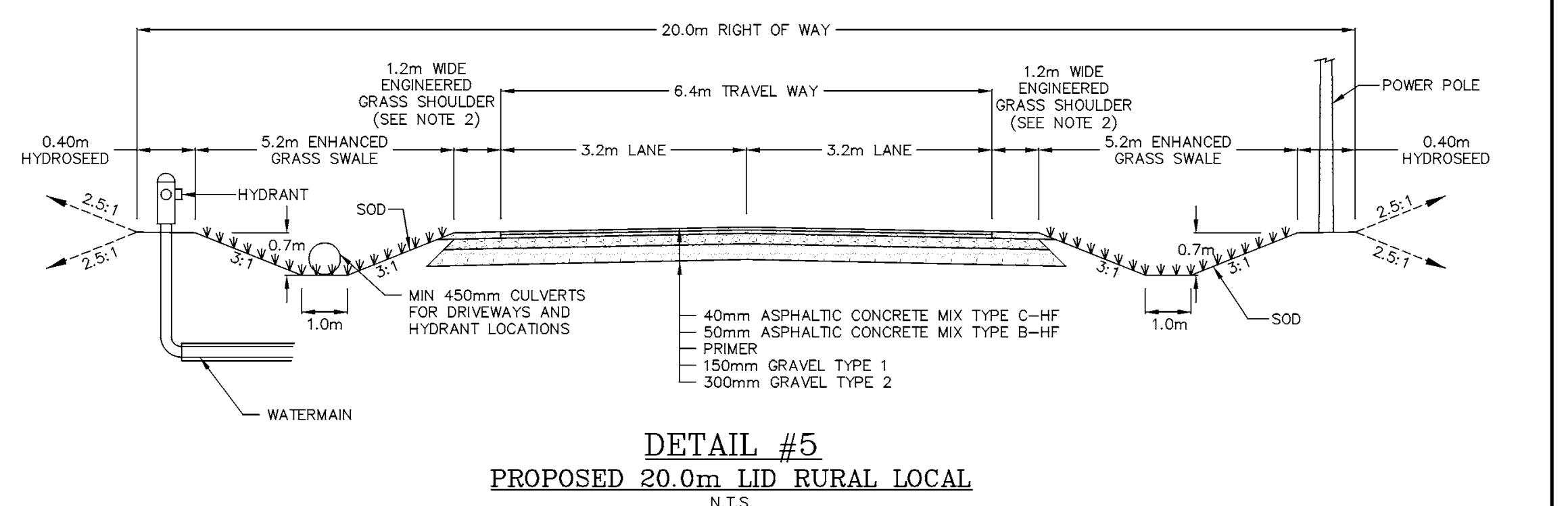
DETAIL #3
VEGETATED FILTER STRIP
NOT TO SCALE





DETAIL #6
TREE CLEARING PROTECTION LIMIT
NOT TO SCALE

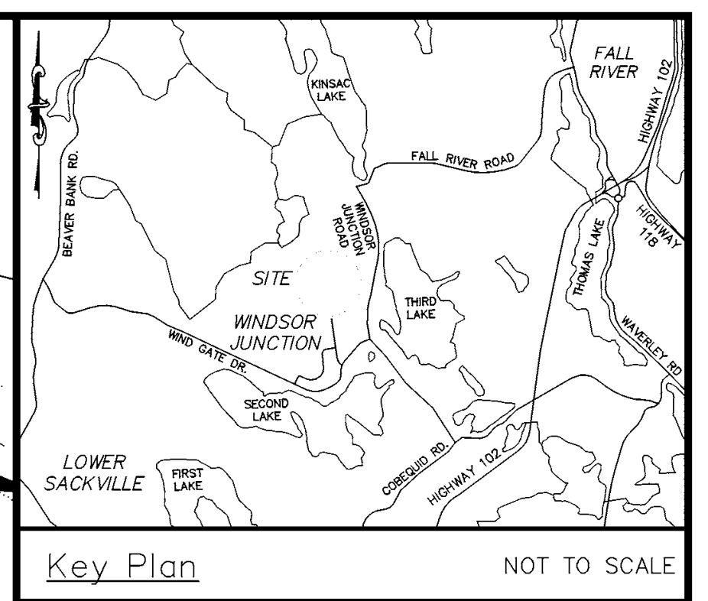
DETAIL #4
PERMANENT CHECK DAM
NOT TO SCALE



DETAIL #5
PROPOSED 20.0m LID RURAL LOCAL
N.T.S.

NOTES:

1. ENHANCED GRASS SWALES TO BE CONSTRUCTED WITH MIN. 150mm TOPSOIL AND HYDROSEED WITH NATIVE GRASS MIXTURE. PERMANENT CHECK DAMS TO BE INSTALLED AT TYPICAL 20m SPACING.
2. 1.2m WIDE SHOULDER ENGINEERED GRASS SHOULDER TO BE CONSTRUCTED TO ACCOMMODATE VEHICULAR LOADING.



Key Plan NOT TO SCALE

LEGEND

SANITARY M.H. & SEWER
STORM M.H. & SEWER
HYDRANT
GATE VALVE & WATERMAIN
CATCHBASIN
STREET TREE
POWER POLE
POWER POLE WITH LIGHT FIXTURE
ANCHOR ON LIGHT POLE
ALIANT PEDESTAL
ALIANT FLUSH BOX
N.S.P.I. URD BOX
CONCRETE CURB & GUTTER
SIDEWALK
DRIVEWAY
PEDESTRIAN RAMP
PROPOSED ℄ FINISHED GRADE
EXISTING CENTERLINE GRADE
EXISTING GRADE (RT. SIDE R.O.W.)
EXISTING GRADE (LEFT SIDE R.O.W.)
PROPOSED U/G ELEC. LINES
PROPERTY LINE
EXISTING PROPERTY LINE
LATERALS ,SAN.,STM. & WM.

NOTES:

1. Contour interval is 1.0 metres based on Lidar, blended with topographic field data, provided by SDMM.
2. All landscaped areas (grass, plantings, etc) are to utilize native plant species.
   - LID Roadside Ditches
     150mm topsoil & hydroseed
   - Enhanced Grass Swale or Filter Strip Areas
     150mm topsoil & hydroseed
   - All other grassed areas
     100mm topsoil & hydroseed
3. Soil coefficients of permeability range from $5x10^{-8}$ to $5x10^{-6}$ cm/s for soils within the project boundaries.
4. All cut and fill slopes on site to be 2.5:1 unless otherwise noted. Slope stability to be confirmed on site by geotechnical engineer.
5. Sanitary sewer and treatment systems as per design by SDMM.
6. Roof leaders on single and semi-detached residential units shall be directed to vegetated areas where possible, rather than towards the storm drainage system.
7. Snow is not to be piled in vegetated filter strips.
8. All footing drains shall be connected to the storm sewer lateral, unless otherwise noted.
9. As part of the building permit stage, all grass surfaces within proposed lots shall be surfaced with 200mm of topsoil in front yards and 150mm in rear yards. Topsoil shall be rating A or B in accordance with the latest edition of the Landscape N.S. Horticultural Trades Association Standard Topsoil Triangle.
10. For silt fence locations refer to drawing 19-6737-P06.
11. No clearing or construction will occur within the protective green belts/protected sensitive areas.
12. Before grubbing commences, clearing limits, easements, setbacks, sensitive/critical areas and their buffers, trees and drainage courses shall be delineated with flagging tape and enviro-fences. This ensures workers can clearly recognize areas to be protected. Grubbing material to be disposed of at a location approved by the owner.
13. Vegetated filter strips shall not have buildings or structures constructed within them.
14. Private sewage treatment facilities and vegetated filter strips to maintain a minimum of 5.0m horizontal separation.

No	Description	Date	By
0.	Issued For Review	July 8, 2019	CNB

Revision or Issue

Strum
CONSULTING

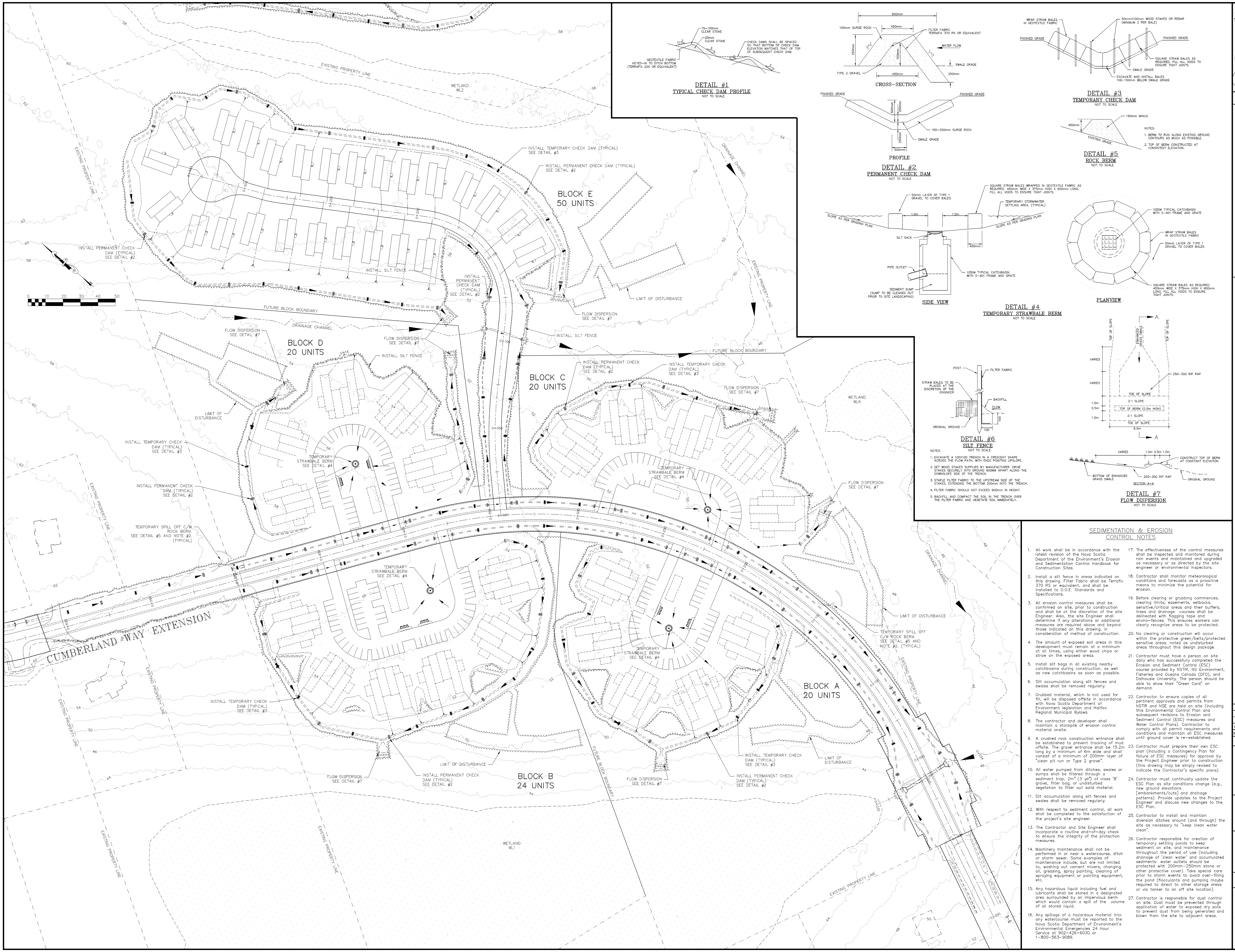
Project
CHARLESWOOD SUBDIVISION
WINDSOR JUNCTION
NOVA SCOTIA

Drawing
BEST MANAGEMENT PRACTICES
AND PRELIMINARY GRADING
CHARLESWOOD DRIVE

Scale 1:750

REGISTERED PROFESSIONAL ENGINEER
DATE: 07/08/19
C. N. BOUDREAU
7511
PROVINCE OF NOVA SCOTIA

Date		Drawn
July 8, 2019		TJB
Design	Check	Approv.
CNB	RAW	CNB
Project No.		Sheet
19-6737		4 Of 6
Drawing No.		Rev.
P04		0



DETAIL #1
TYPICAL CHECK DAM PROFILE
NOT TO SCALE

DETAIL #2
PERMANENT CHECK DAM
NOT TO SCALE

DETAIL #3
TEMPORARY CHECK DAM
NOT TO SCALE

DETAIL #4
TEMPORARY STRAWBALE BERM
NOT TO SCALE

SQUARE STRAW BALES WRAPPED IN GEOTEXTILE FABRIC AS REQUIRED. 450mm WIDE X 375mm HIGH X 900mm LONG. FILL ALL VOIDS TO ENSURE TIGHT JOINTS.

DETAIL #5
ROCK BERM
NOT TO SCALE

NOTES:
1. BERM TO RUN ALONG EXISTING GROUND CONTOURS AS MUCH AS POSSIBLE.
2. TOP OF BERM CONSTRUCTED AT CONSISTENT ELEVATION.

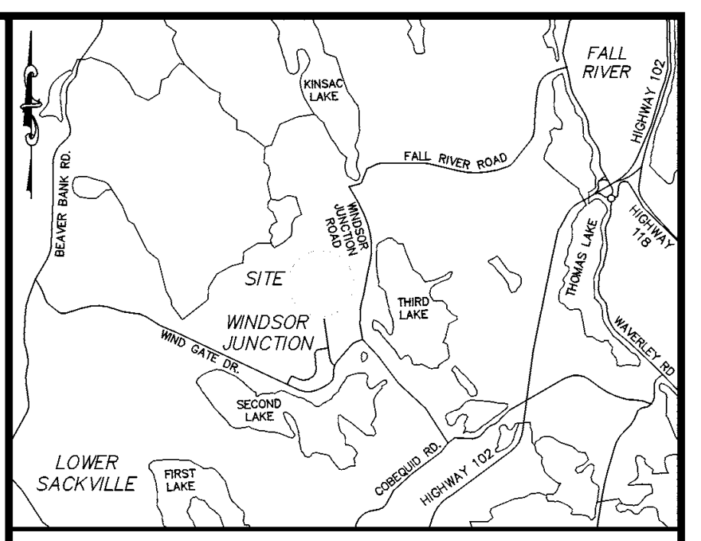
DETAIL #6
SILT FENCE
NOT TO SCALE

NOTES:
1. EXCAVATE A 100X100 TRENCH IN A CRESCENT SHAPE ACROSS THE FLOW PATH, WITH ENDS POINTING UPSLOPE.
2. SET WOOD STAKES SUPPLIED BY MANUFACTURER. DRIVE STAKES SECURELY INTO GROUND 900MM APART ALONG THE DOWNSLOPE SIDE OF THE TRENCH.
3. STAPLE FILTER FABRIC TO THE UPSTREAM SIDE OF THE STAKES, EXTENDING THE BOTTOM 200mm INTO THE TRENCH.
4. FILTER FABRIC SHOULD NOT EXCEED 900mm IN HEIGHT.
5. BACKFILL AND COMPACT THE SOIL IN THE TRENCH OVER THE FILTER FABRIC AND VEGETATE SOIL IMMEDIATELY.

DETAIL #7
FLOW DISPERSION
NOT TO SCALE

SEDIMENTATION & EROSION CONTROL NOTES

1. All work shall be in accordance with the latest revision of the Nova Scotia Department of the Environment's Erosion and Sedimentation Control Handbook for Construction Sites.
2. Install a silt fence in areas indicated on this drawing. Filter Fabric shall be Terrafix 370 RS or equivalent, and shall be installed to D.O.E. Standards and Specifications.
3. All erosion control measures shall be confirmed on site, prior to construction and shall be at the discretion of the site Engineer. Also, the site Engineer shall determine if any alterations or additional measures are required above and beyond those indicated on this drawing, in consideration of method of construction.
4. The amount of exposed soil areas in this development must remain at a minimum at all times, using either wood chips or straw on the exposed areas.
5. Install silt bags in all existing nearby catchbasins during construction, as well as new catchbasins as soon as possible.
6. Silt accumulation along silt fences and swales shall be removed regularly.
7. Grubbed material, which is not used for fill, will be disposed offsite in accordance with Nova Scotia Department of Environment legislation and Halifax Regional Municipal Bylaws.
8. The contractor and developer shall maintain a stockpile of erosion control material onsite.
9. A crushed rock construction entrance shall be established to prevent tracking of mud offsite. The gravel entrance shall be 15.2m long by a minimum of 6m wide and shall consist of a minimum of 200mm layer of "clean pit run or Type 2 gravel".
10. All water pumped from ditches, swales or sumps shall be filtered through a sediment trap, $2m^3$ ($3\ yd^3$) of class 'B' gravel, filter bag, or undisturbed vegetation to filter out solid material.
11. Silt accumulation along silt fences and swales shall be removed regularly.
12. With respect to sediment control, all work shall be completed to the satisfaction of the project's site engineer.
13. The Contractor and Site Engineer shall incorporate a routine end-of-day check to ensure the integrity of the protection measures.
14. Machinery maintenance shall not be performed in or near a watercourse, ditch or storm sewer. Some examples of maintenance include, but are not limited to, washing out cement mixers, changing oil, greasing, spray painting, cleaning of spraying equipment or painting equipment, etc.
15. Any hazardous liquid including fuel and lubricants shall be stored in a designated area surrounded by an impervious berm which would contain a spill of the volume of all stored liquid.
16. Any spillage of a hazardous material into any watercourse must be reported to the Nova Scotia Department of Environment's Environmental Emergencies 24 Hour Service at 902-426-6030 or 1-800-563-9089.
17. The effectiveness of the control measures shall be inspected and monitored during rain events and maintained and upgraded as necessary or as directed by the site engineer or environmental inspectors.
18. Contractor shall monitor meteorological conditions and forecasts as a proactive means to minimize the potential for erosion.
19. Before clearing or grubbing commences, clearing limits, easements, setbacks, sensitive/critical areas and their buffers, trees and drainage courses shall be delineated with flagging tape and enviro-fences. This ensures workers can clearly recognize areas to be protected.
20. No clearing or construction will occur within the protective green/belts/protected sensitive areas, noted as undisturbed areas throughout this design package.
21. Contractor must have a person on site daily who has successfully completed the Erosion and Sediment Control (ESC) course provided by NSTIR, NS Environment, Fisheries and Oceans Canada (DFO), and Dalhousie University. The person should be able to show their "Green Card" on demand.
22. Contractor to ensure copies of all pertinent approvals and permits from NSTIR and NSE are held on site (including this Environmental Control Plan and subsequent revisions to Erosion and Sediment Control (ESC) measures and Water Control Plans). Contractor to comply with all permit requirements and conditions and maintain all ESC measures until ground cover is re-established.
23. Contractor must prepare their own ESC plan (including a Contingency Plan for failure of ESC measures) for approval by the Project Engineer prior to construction (this drawing may be simply revised to indicate the Contractor's specific plans).
24. Contractor must continually update the ESC Plan as site conditions change (e.g., new ground elevations [embankments/cuts] and drainage patterns). Provide updates to the Project Engineer and discuss new changes to the ESC Plan.
25. Contractor to install and maintain diversion ditches around (and through) the site as necessary to "keep clean water clean".
26. Contractor responsible for creation of temporary settling ponds to keep sediment on site, and maintenance throughout the period of use (including drainage of 'clean water' and accumulated sediments: water outlets should be protected with 200mm-250mm stone or other protective cover). Take special care prior to storm events to avoid over-filling the pond (flocculants and pumping maybe required to direct to other storage areas or via tanker to an off site location).
27. Contractor is responsible for dust control on site. Dust must be prevented through application of water to exposed dry soils to prevent dust from being generated and blown from the site to adjacent areas.



Key Plan NOT TO SCALE

LEGEND

─◉─	SANITARY M.H. & SEWER
-◉-	STORM M.H. & SEWER
◎	HYDRANT
—W—⊗—W—	GATE VALVE & WATERMAIN
▬	CATCHBASIN
✿	STREET TREE
●	POWER POLE
☀	POWER POLE WITH LIGHT FIXTURE
☀—<	ANCHOR ON LIGHT POLE
○	ALIANT PEDESTAL
⊠	ALIANT FLUSH BOX
▭	N.S.P.I. URD BOX
━━	CONCRETE CURB & GUTTER
═══	SIDEWALK
⊓	DRIVEWAY
⊔	PEDESTRIAN RAMP
───	PROPOSED ℄ FINISHED GRADE
— — —	EXISTING CENTERLINE GRADE
-·—·-	EXISTING GRADE (RT. SIDE R.O.W.)
-··—··-	EXISTING GRADE (LEFT SIDE R.O.W.)
┈┈┈	PROPOSED U/G ELEC. LINES
───	PROPERTY LINE
—·—·—	EXISTING PROPERTY LINE
≡≡≡	LATERALS ,SAN.,STM. & WM.
⊕	TEST PIT LOCATION
▨	PERMANENT CHECK DAM
■	TEMPORARY CHECK DAM

NOTES:

1. Contour interval is 2.0 metres
2. Temporary spill offs to be completed during road construction c/w rock berm at end points to dissipate energy and encourage sheet flow into wooded area.
3. Contour interval is 2.0 metres based on Lidar, blended with topographic field data, provided by SDMM.
4. For a complete Erosion and Sediment Minimization Plan please refer to Appendix I of the Phosphorus Loading Study, Charleswood Subdivision Extension completed by Strum Consulting.
5. Land disturbance to be limited to a phase by phase basis.
6. Grade alteration plans to be submitted on a phase by phase basis.
7. Refer to section 5.4 of PNLA report for compliance notes.
8. Temporary strawbales to be removed from around catch basins prior to final landscaping. Any built up sediment around the strawbale berms shall be removed.
9. Temporary check dams to be removed and associated ditches to be cleaned after construction and prior to final landscaping.

No	Description	Date	By
0.	Issued For Review	July 8, 2019	CNB

Revision or Issue

Strum
CONSULTING

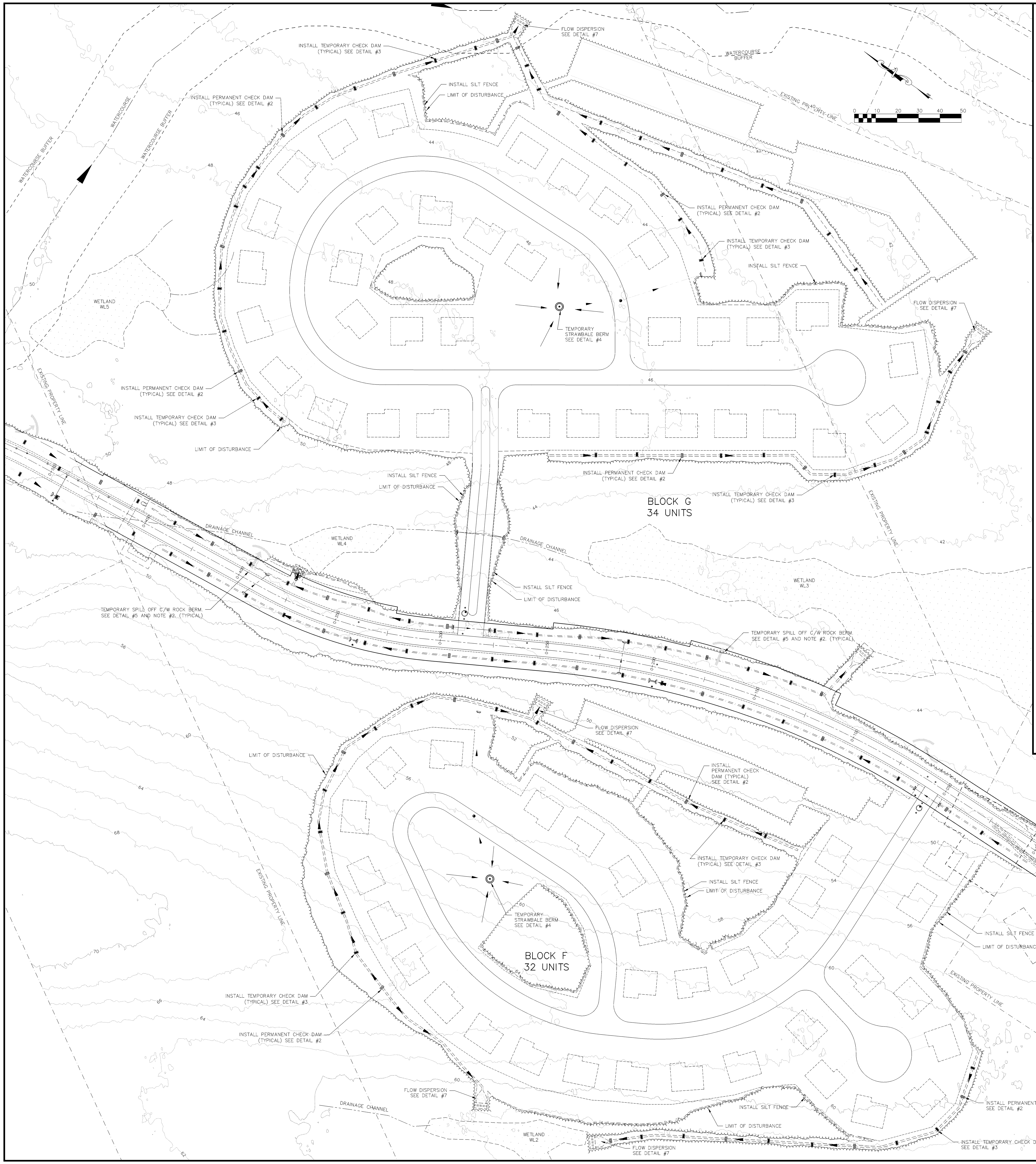
Project
CHARLESWOOD SUBDIVISION
WINDSOR JUNCTION
NOVA SCOTIA

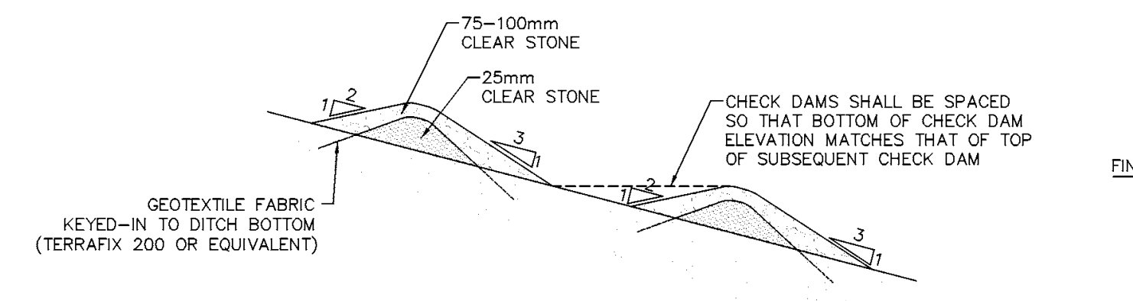
Drawing
SEDIMENTATION AND EROSION
CONTROL MEASURES
CUMBERLAND WAY

Scale 1:750

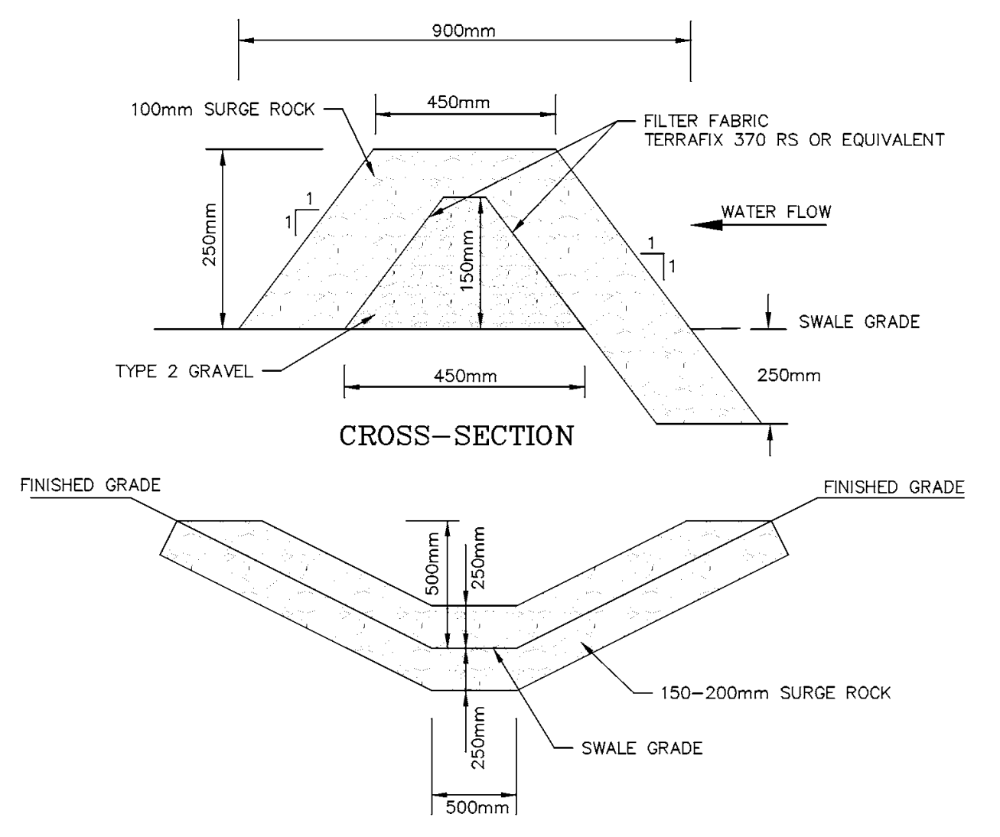
DATE: 07/08/19
C. N. BOUDREAU
7511

Date July 8, 2019	Drawn TJB
Design CNB / Check RAW	Approv. CNB
Project No. 19-6737	Sheet 5 Of 6
Drawing No. P05	Rev. 0

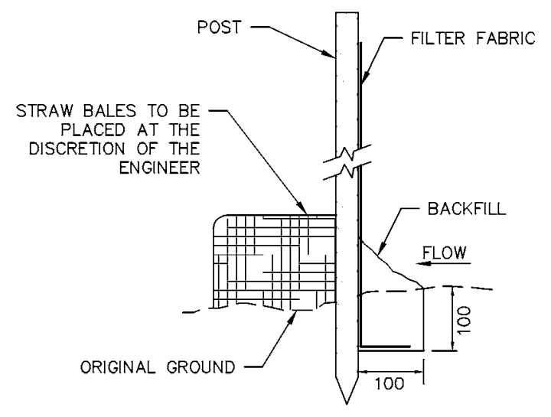




DETAIL #1
TYPICAL CHECK DAM PROFILE
NOT TO SCALE



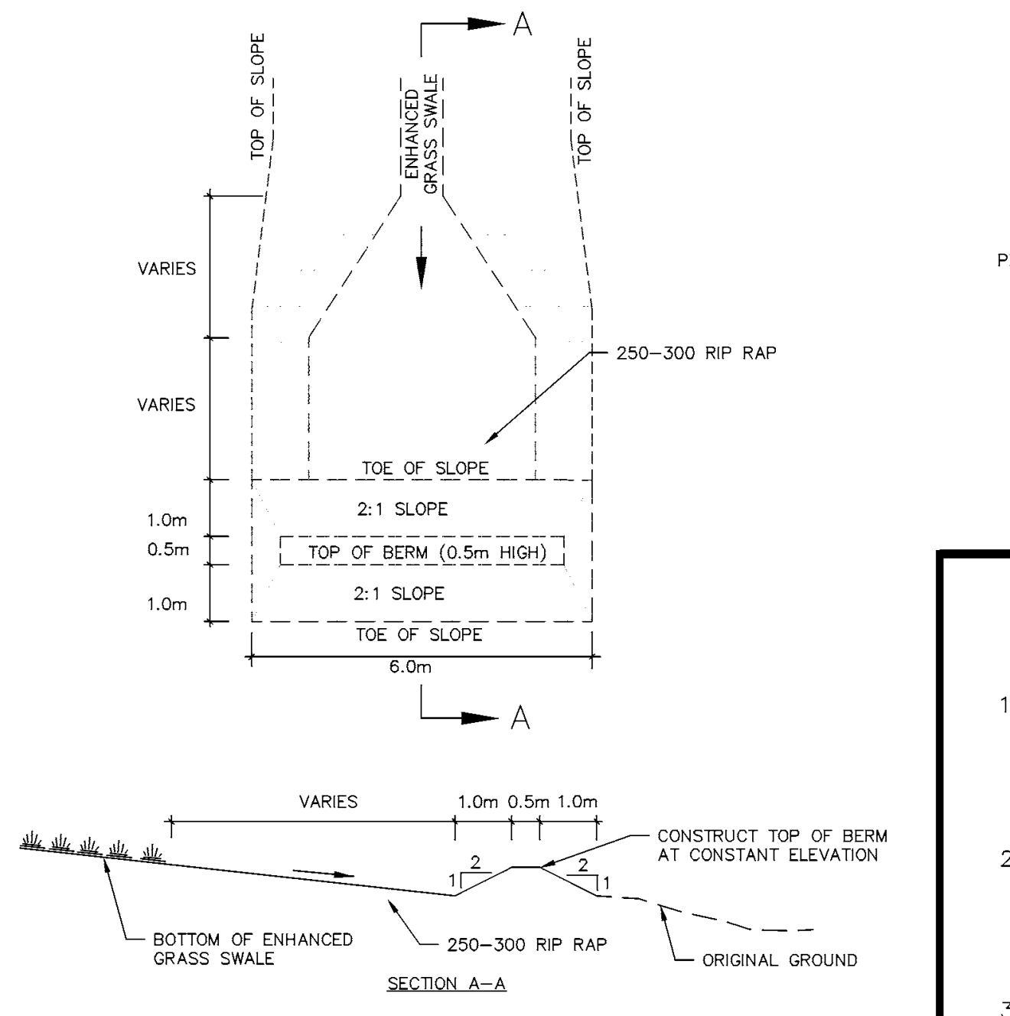
DETAIL #2
PERMANENT CHECK DAM
NOT TO SCALE



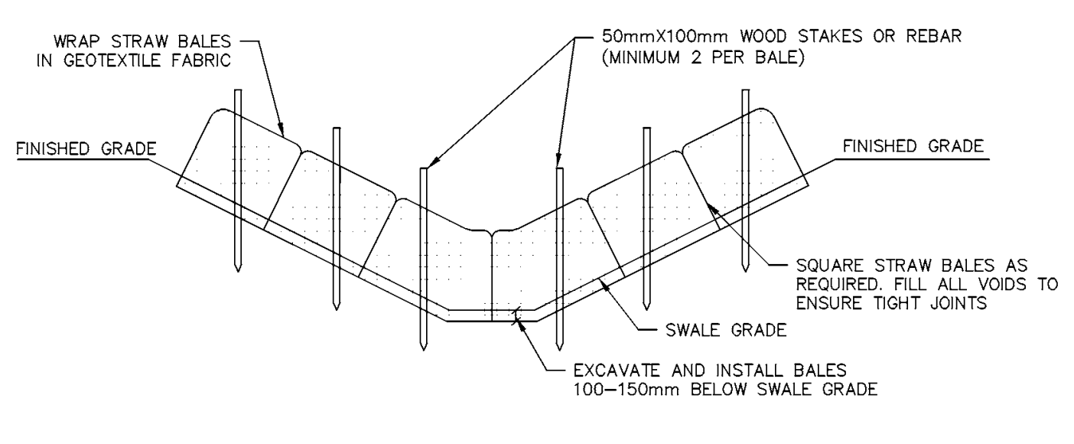
DETAIL #6
SILT FENCE
NOT TO SCALE

NOTES:

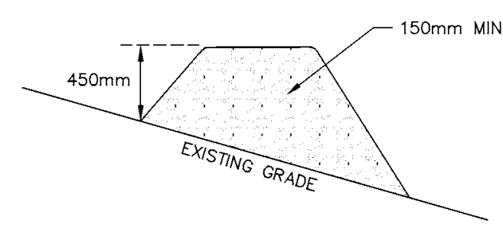
1. EXCAVATE A 100X100 TRENCH IN A CRESCENT SHAPE ACROSS THE FLOW PATH, WITH ENDS POINTING UPSLOPE.
2. SET WOOD STAKES SUPPLIED BY MANUFACTURER. DRIVE STAKES SECURELY INTO GROUND 900MM APART ALONG THE DOWNSLOPE SIDE OF THE TRENCH.
3. STAPLE FILTER FABRIC TO THE UPSTREAM SIDE OF THE STAKES, EXTENDING THE BOTTOM 200mm INTO THE TRENCH.
4. FILTER FABRIC SHOULD NOT EXCEED 900mm IN HEIGHT.
5. BACKFILL AND COMPACT THE SOIL IN THE TRENCH OVER THE FILTER FABRIC AND VEGETATE SOIL IMMEDIATELY.



DETAIL #7
FLOW DISPERSION
NOT TO SCALE



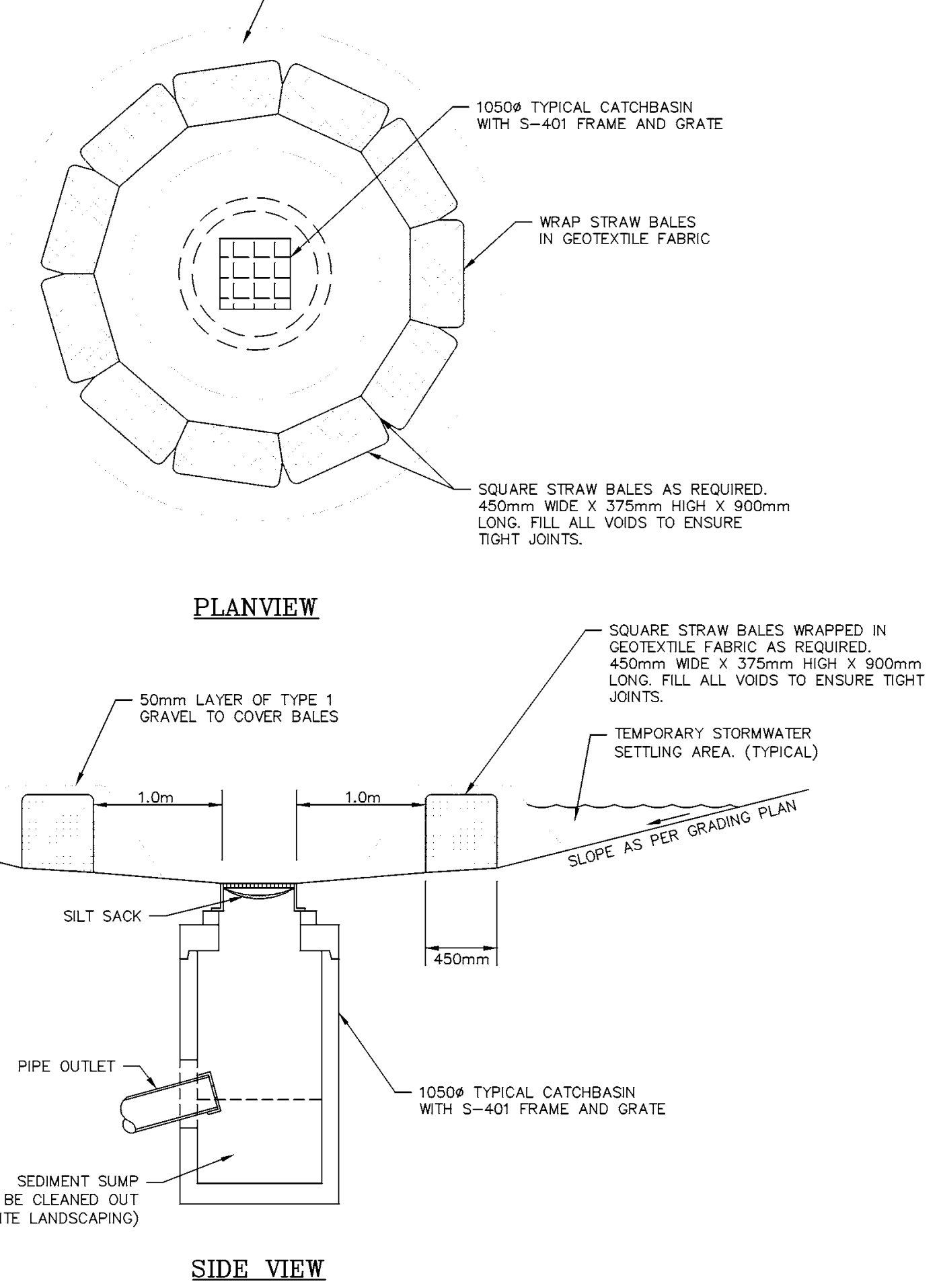
DETAIL #3
TEMPORARY CHECK DAM
NOT TO SCALE



NOTES:

1. BERM TO RUN ALONG EXISTING GROUND CONTOURS AS MUCH AS POSSIBLE.
2. TOP OF BERM CONSTRUCTED AT CONSISTENT ELEVATION.

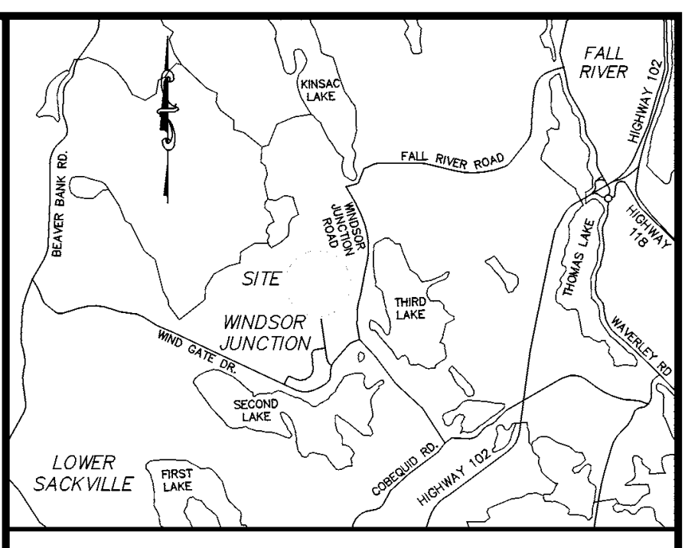
DETAIL #5
ROCK BERM
NOT TO SCALE



DETAIL #4
TEMPORARY STRAWBALE BERM
NOT TO SCALE

SEDIMENTATION & EROSION CONTROL NOTES

1. All work shall be in accordance with the latest revision of the Nova Scotia Department of the Environment's Erosion and Sedimentation Control Handbook for Construction Sites.
2. Install a silt fence in areas indicated on this drawing. Filter Fabric shall be Terrafix 370 RS or equivalent, and shall be installed to D.O.E. Standards and Specifications.
3. All erosion control measures shall be confirmed on site, prior to construction and shall be at the discretion of the site Engineer. Also, the site Engineer shall determine if any alterations or additional measures are required above and beyond those indicated on this drawing, in consideration of method of construction.
4. The amount of exposed soil areas in this development must remain at a minimum at all times, using either wood chips or straw on the exposed areas.
5. Install silt bags in all existing nearby catchbasins during construction, as well as new catchbasins as soon as possible.
6. Silt accumulation along silt fences and swales shall be removed regularly.
7. Grubbed material, which is not used for fill, will be disposed offsite in accordance with Nova Scotia Department of Environment legislation and Halifax Regional Municipal Bylaws.
8. The contractor and developer shall maintain a stockpile of erosion control material onsite.
9. A crushed rock construction entrance shall be established to prevent tracking of mud offsite. The gravel entrance shall be 15.2m long by a minimum of 6m wide and shall consist of a minimum of 200mm layer of "clean pit run or Type 2 gravel".
10. All water pumped from ditches, swales or sumps shall be filtered through a sediment trap, 2m^3 (3 yd^3) of class 'B' gravel, filter bag, or undisturbed vegetation to filter out solid material.
11. Silt accumulation along silt fences and swales shall be removed regularly.
12. With respect to sediment control, all work shall be completed to the satisfaction of the project's site engineer.
13. The Contractor and Site Engineer shall incorporate a routine end–of–day check to ensure the integrity of the protection measures.
14. Machinery maintenance shall not be performed in or near a watercourse, ditch or storm sewer. Some examples of maintenance include, but are not limited to, washing out cement mixers, changing oil, greasing, spray painting, cleaning of spraying equipment or painting equipment, etc.
15. Any hazardous liquid including fuel and lubricants shall be stored in a designated area surrounded by an impervious berm which would contain a spill of the volume of all stored liquid.
16. Any spillage of a hazardous material into any watercourse must be reported to the Nova Scotia Department of Environment's Environmental Emergencies 24 Hour Service at 902–426–6030 or 1–800–563–9089.
17. The effectiveness of the control measures shall be inspected and monitored during rain events and maintained and upgraded as necessary or as directed by the site engineer or environmental inspectors.
18. Contractor shall monitor meteorological conditions and forecasts as a proactive means to minimize the potential for erosion.
19. Before clearing or grubbing commences, clearing limits, easements, setbacks, sensitive/critical areas and their buffers, trees and drainage courses shall be delineated with flagging tape and enviro–fences. This ensures workers can clearly recognize areas to be protected.
20. No clearing or construction will occur within the protective green/belts/protected sensitive areas, noted as undisturbed areas throughout this design package.
21. Contractor must have a person on site daily who has successfully completed the Erosion and Sediment Control (ESC) course provided by NSTIR, NS Environment, Fisheries and Oceans Canada (DFO), and Dalhousie University. The person should be able to show their "Green Card" on demand.
22. Contractor to ensure copies of all pertinent approvals and permits from NSTIR and NSE are held on site (including this Environmental Control Plan and subsequent revisions to Erosion and Sediment Control (ESC) measures and Water Control Plans). Contractor to comply with all permit requirements and conditions and maintain all ESC measures until ground cover is re–established.
23. Contractor must prepare their own ESC plan (including a Contingency Plan for failure of ESC measures) for approval by the Project Engineer prior to construction (this drawing may be simply revised to indicate the Contractor's specific plans).
24. Contractor must continually update the ESC Plan as site conditions change (e.g., new ground elevations [embankments/cuts] and drainage patterns). Provide updates to the Project Engineer and discuss new changes to the ESC Plan.
25. Contractor to install and maintain diversion ditches around (and through) the site as necessary to "keep clean water clean".
26. Contractor responsible for creation of temporary settling ponds to keep sediment on site, and maintenance throughout the period of use (including drainage of 'clean water' and accumulated sediments: water outlets should be protected with 200mm–250mm stone or other protective cover). Take special care prior to storm events to avoid over–filling the pond (flocculants and pumping maybe required to direct to other storage areas or via tanker to an off site location).
27. Contractor is responsible for dust control on site. Dust must be prevented through application of water to exposed dry soils to prevent dust from being generated and blown from the site to adjacent areas.



Key Plan NOT TO SCALE

LEGEND

SANITARY M.H. & SEWER
STORM M.H. & SEWER
HYDRANT
—W—⊗—W— GATE VALVE & WATERMAIN
CATCHBASIN
STREET TREE
POWER POLE
POWER POLE WITH LIGHT FIXTURE
ANCHOR ON LIGHT POLE
ALIANT PEDESTAL
ALIANT FLUSH BOX
N.S.P.I. URD BOX
CONCRETE CURB & GUTTER
SIDEWALK
DRIVEWAY
PEDESTRIAN RAMP
PROPOSED ℄ FINISHED GRADE
EXISTING CENTERLINE GRADE
EXISTING GRADE (RT. SIDE R.O.W.)
EXISTING GRADE (LEFT SIDE R.O.W.)
PROPOSED U/G ELEC. LINES
PROPERTY LINE
EXISTING PROPERTY LINE
LATERALS ,SAN.,STM. & WM.
TEST PIT LOCATION
▨ PERMANENT CHECK DAM
▬ TEMPORARY CHECK DAM

NOTES:

1. Contour interval is 2.0 metres
2. Temporary spill offs to be completed during road construction c/w rock berm at end points to dissipate energy and encourage sheet flow into wooded area.
3. Contour interval is 2.0 metres based on Lidar, blended with topographic field data, provided by SDMM.
4. For a complete Erosion and Sediment Minimization Plan please refer to Appendix I of the Phosphorus Loading Study, Charleswood Subdivision Extension completed by Strum Consulting.
5. Land disturbance to be limited to a phase by phase basis.
6. Grade alteration plans to be submitted on a phase by phase basis.
7. Refer to section 5.4 of PNLA report for compliance notes.
8. Temporary strawbales to be removed from around catch basins prior to final landscaping. Any built up sediment around the strawbale berms shall be removed.
9. Temporary check dams to be removed and associated ditches to be cleaned after construction and prior to final landscaping.

0.	Issued For Review	July 8, 2019	CNB
No	Description	Date	By

Revision or Issue

Strum
CONSULTING

Project
CHARLESWOOD SUBDIVISION
WINDSOR JUNCTION
NOVA SCOTIA

Drawing
SEDIMENTATION AND EROSION
CONTROL MEASURES
CHARLESWOOD DRIVE

Scale 1:750

DATE: 07/08/19
C. N. BOUDREAU
7511

Date July 8, 2019		Drawn TJB
Design CNB	Check RAW	Approv. CNB
Project No. 19–6737		Sheet 6 Of 6
Drawing No. P06		Rev. 0

APPENDIX C
TOPSOIL RECOMMENDATION SPECIFICATION – JACQUES WHITFORD NAWE, INC.

Memo

Jacques Whitford NAWE, Inc
4444 Centerville Road, Suite 140 • White Bear Lake, MN • 55127
Phone: 651-255-5050 • Fax: 651-255-5060 • www.nawe-pa.com

To: Scott MacCallum

From: Shane Sparks

Date: July 31st, 2008

Re: Topsoil Recommendations

Scott,

Good quality topsoil is critical to the establishment of a low maintenance landscape. If the topsoil has sufficient amounts of air, water, and nutrients, it will reduce the need for maintenance activities such as aeration, irrigation, and fertilizer application. The purpose of this memo is to provide guidelines for the selection and installation of topsoil for future developments. Recommendations are divided into chemical and physical characteristics of the recommended topsoil.

Physical Characteristics:

1. *Texture* - Ideal topsoil contains a mixture of sand, silt, and clay. Acceptable soil textures are loam, sandy loams and loamy sands. These soil types have good permeability to prevent saturation, but also hold a significant amount of moisture to supply to the landscape.
2. *Organic Matter* – High quality topsoil typically has a minimum of 4% organic matter. Higher percentages are preferred for the soil as the organic matter supplies critical nutrients to the landscape above.
3. *Structure/Consistency* – Soil should crush/crumble easily when pressure is applied.
4. *Topsoil Thickness* – The minimum thickness for topsoil is 10 centimeters (cm). However, a range of 15-20 cm is ideal as all topsoil will compact following installation to approximately 50% of its original thickness

Chemical Characteristics:

1. *Salts* – High levels of salt, as measured by soil electrical conductivity (EC), can cause toxic effects on lawn vegetation. Sodium and chloride levels below 100 mg/kg of soil are recommended.
2. *pH* – Turfgrass tends to grow in slightly more acidic soils. Therefore, a pH of 6.3-6.8 is recommended for the topsoil.

3. *Nutrients* – Several nutrients are critical to reduce the need for fertilizer addition to lawn topsoil. Any potential topsoil sources should be tested by a certified soils lab before application to ensure that they meet the following nutrient requirements:
    a. Nitrogen: greater than 30 mg N/kg of soil (more organic matter = more nitrogen)
    b. Phosphorus: greater than 30 mg P/kg of soil
    c. Potassium: 120 to 250 mg K/kg of soil
    d. Calcium: 2,000 to 4,000 mg Ca/kg of soil
    e. Magnesium: 150 to 300 mg Mg/kg of soil
    f. Trace Elements: boron, cobalt, iron, copper, molybdenum, sulfur, manganese and zinc should be present in trace amounts

High quality topsoil is well balanced, rich in microbial life, and high in the essential nutrients for basic plant nutrition. The application of the guidelines above will result in the installation of high quality topsoil that is critical to a low maintenance landscape. If you have any questions regarding this document, or would like more information, please contact Shane Sparks at 651-255-5045.

Sincerely,

Shane Sparks
Hydrogeologist/Soil Scientist

APPENDIX D
LAWN CARE BEST MANAGEMENT PRACTICES – HOME OWNERS' GUIDE

The Parks of West Bedford

Lawn Care Best Management Practices

Home Owners' Guide

THE PARKS
OF WEST BEDFORD
EMBRACING NATURE. ENJOYING LIFE

West Bedford Holdings Limited

THE PARKS
OF WEST BEDFORD

EMBRACING NATURE. ENJOYING LIFE

West Bedford Holdings Limited – Our Commitment

West Bedford Holdings Limited is dedicated to developing residential communities that are sensitive to low impact and sustainable development. Our goal is to not only plan and design residential communities that are responsible, sustainable and functional, but to inspire our homeowners in the Community to learn from their decisions and to develop a greater appreciation for the environment and its resources. For this reason we challenge you the homeowner to better understand your environmental responsibility within the Papermill Lake watershed.

The following Homeowner's Best Management Guideline will serve as a critical educational tool that each family should review and understand in order to preserve and enhance our most precious natural resource....Water!

Stop Runoff

Use a Rain Barrel

Rain barrel usage can be important to the overall success of the stormwater management system. The benefits of using a rain barrel include:

- Stormwater that washes off rooftops and into downspouts is caught and retained.
- Homeowners use the water in the rain barrel as needed during the growing season.
- Water can be reused as needed in the garden or lawn landscape.
- Reduces stormwater runoff and pollution by providing treatment to the "first flush" of contaminants.
- Easy Installation – suitable for all property types.
- Reduces water bills by not using potable water for irrigation.
- Water generated is very soft (low in minerals), which is good for plant growth.

The proper design, siting and maintenance practices are necessary to ensure that the rain barrel is functioning appropriately and not becoming a nuisance or mosquito breeding ground in the development. The following guidance is intended to provide the proper siting, mosquito control and maintenance practices for your rain barrel.

Finding the best location for your rain barrel

To find the best location for your rain barrel, the following techniques are recommended:

- Place rain barrel on a hard, level, and pervious surface. Concrete blocks, bricks, decorative blocks, or flagstones work well as a base.
- Locate rain barrel at downspout nearest to the garden you want to irrigate.
- Rain barrels work using gravity to drain – The garden to be irrigated should be lower in elevation that the rain barrel.
- Ensure that the rain barrel overflow location directs water towards your yard and not your neighbors.

What about those pesky mosquitoes?

Many homeowners worry that rain barrels will create a breeding ground for mosquitoes. The following is a list of tried and trusted techniques that can be employed to control mosquitoes:

- Ensure that the mosquito proof screen on the rain barrel is installed and functioning correctly.
- Ensure that the base is pervious, so overflow does not collect and leave standing water for mosquito breeding.
- Inspect rain barrel weekly – ensure that the lid is securely closed and the water is free of organic material.
- Mosquito larvae require 6-9 days to hatch. Completely drain the barrel once per week and clean if necessary to prevent the formation of stagnant water.

When properly encased with a mosquito proof screen, rainbarrels will keep out any mosquitoes from breeding.

How do I take care of my rain barrel?

To properly care for your rain barrel, the following techniques are recommended:

- Keep spigot closed when not using water.
- Routinely inspect gutters, downspouts, rain barrel intake and mosquito screens for debris.
- Keep lid secured and screens clear of debris. Make sure the overflow tube and hose are functioning correctly.
- If odours develop, drain the rain barrel and spray with a hose until clean.
- Completely drain rain barrel before winter – leave spigot open during the cold months so water does not accumulate and freeze.
- Ensure that the overflow is draining properly and not causing erosion of the rain barrel base. An example overflow valve is shown in the above figure.
- Rain barrel water is not potable – *do not drink the water.*

Go-Toxic Free

Lawn Fertilizer

There are many natural ways to fertilize a lawn before reaching for a store-bought fertilizer. Compost and grass clippings are a cost-effective and environmentally friendly way to provide your lawn with nutrients. If you feel the need to purchase a fertilizer to care for your lawn, use organic fertilizers or slow release fertilizers.

- Clean Nova Scotia indicates that generally a 4:1:2 (the ratio of nitrogen to phosphorous to potassium) fertilizer applied at rate of 1 kilogram nitrogen per 100 square metres (2 pounds per 1000 square feet) provides the proper balance of nutrients.
- Combine the fertilizer with organic material (a mixture of good-quality soil, sand and a source of humus) and add this to your lawn's surface.
- Use a slow release or organic fertilizer before a rain (follow labels). If rain is not expected, water the lawn prior to fertilizing.
- Know your nutrient needs by understanding your soil and lawn conditions (most people apply too much fertilizer and this impacts water quality as well as lawn health).
- Go natural! Forget chemical fertilizers and replace your lawn with native plantings. There are over 1,500 to choose from for our region!

Organic fertilizers are often overlooked as an effective method for lawn care and maintenance.

Create Rain Gardens

A rain garden is a landscaping feature you can build to manage runoff. A rain garden will collect rain water and slowly filter water into the ground. They are usually a constructed depression (10-20 cm deep) that is designed to look like a natural area, but it will accept, infiltrate and clean stormwater. The rain garden will typically fill up with a few inches of water after a storm and within 1-2 days, the water will slowly filter into the ground. It is planted with wet and dry tolerant plants to absorb rain water. This technique encourages the recharge of the groundwater aquifer and uses the soil filters out any pollutants before the infiltrating water reaches the local groundwater table. When combined with a disconnected roof leader (downspout), the stormwater can be conveyed into the rain garden via a vegetated swale creating a high value natural landscape.

Rain gardens serve both a practical and aesthetic purpose; to clean and manage water run off, while creating a more beautiful landscape.

Keep it Green

Lawn Irrigation

One of the key ways you can help to keep lawn care more sustainable is by thinking about how you keep your lawn irrigated. Turf grasses and other plants in a native landscape need water for growth and development. By implementing proper irrigation practices, lawn quality and aesthetics will be improved, while at the same time, lowering water bills. By watering infrequently and deeply you can help improve the health of your lawn. The following techniques will put you on the path to proper lawn irrigation practices and prevent over watering:

- A typical turfgrass requires 2.5 cm of water per week (through rainfall or irrigation), which will soak the upper 10 cm of soil.
- Monitor your irrigation by placing a can in path of sprinkler flow and stop irrigation once 2.5 cm of water has accumulated in the can.
- Ideal irrigation times are when temperatures are cooler in the early morning or early evening and when wind speeds are low.
- Let lawn completely dry out between irrigation intervals. The soil should be difficult to penetrate before irrigation.
- Lawns require water when the grass turns light-green to brown in colour and the stalks remain bent over after being walked on.
- Stop irrigation when puddling or runoff occurs. Excessive moisture can potentially cause fungal disease in grasses and also prevents grasses from extending deep roots.
- Where possible, reuse collected stormwater from rain barrels for irrigation of gardens or smaller areas.
- Use sprinklers with uniform water application patterns. Do not aim sprinklers in a pattern that will water sidewalks, driveways, or the sides of homes.
- Without watering, most lawn grasses will go dormant over the hot summer months. This should not be a concern and the grasses will begin growing again during the cool season months.

Pet Clean-Up

Pet waste is a health hazard and a pollutant as it contains excess phosphorus and harmful bacteria which can harm lake water quality. The following guidelines will provide for the proper cleanup of pet waste and the elimination of any health concerns due to contact concerns:

- Clean up all animal waste whether on your lot or on trails or other places in the community.
- During walks, bring a bag and dispose of the waste in the toilet, garbage, or a designated pet compost area.
- In your yard, encourage pets to use one location. This will make clean-up easier and this area can be isolated from the rest of yard, which can prevent accidental contact with the pet waste.
- Do not feed Geese - It encourages them to frequent your yard and generate waste in your yard, driveway, or sidewalks.
- Pick up after pets before cleaning patios, sidewalks or driveways. Do not spray waste onto streets or into gutters.

Pesticide Use

Pesticides should be applied only as a last resort, or not at all. The major source of pesticides in urban streams is home applications to kill insects and weeds in the lawn and garden. If you need pesticides, certain pesticides may be permitted. Visit the HRM website, http://www.halifax.ca/pesticides/rules.html for more information.

Naturalize

Use Native Species

Many native species are suited to growing in a wide range of ecological conditions and they are usually best suited to the Nova Scotia climate. Because of this, once they are established they usually require less care and are a key element in creating a low maintenance and sustainable landscape. The species listed below are considered to be the types of species that would most usually found in the Parks of West Bedford area, however, use of other native species may also be appropriate. Final planting decisions should be made based on specific site conditions, species availability, and advice from landscape specialists.

Native Trees & shrubs best suited for certain site conditions:

- Dry/Poor Sites: Black Spruce, Balsam Fir, White Pine, Red Pine, White Birch, Grey Birch, Red Oak, Trembling Aspen, and Largetooth Aspen.
- Moist/Poor Sites: Black Spruce, Red Maple, Eastern Larch, and Balsam Fir.
- Average Sites: Red Spruce, White Spruce, Eastern Hemlock, White Pine, White Birch, Yellow Birch, Red Oak, Red Maple, and Sugar Maple.
- Moist/Rich Sites: Red Spruce, White Spruce, Eastern Hemlock, Yellow Birch, Red Maple, Sugar Maple, White Ash, and Ironwood.
- Native Shrubs: Wild Raisin, Serviceberry, False Holly, Canada Holly, Velvetleaf Blueberry, Lowbush Blueberry, Lambkill, Bush Honey Suckle, Huckleberry, Witch Hazel, Speckled Alder, Labrador Tea, Rhodora, Mountain Ash, Teaberry, Spirea, Striped Maple, Mountain Maple, and Beaked Hazelnut.

Lawn Mowing

The frequency, height, pattern and condition of a lawn mower can impact the quality and sustainability of a lawn landscape. The following items provide a recommendation for maintaining your lawn through proper lawn mowing practices:

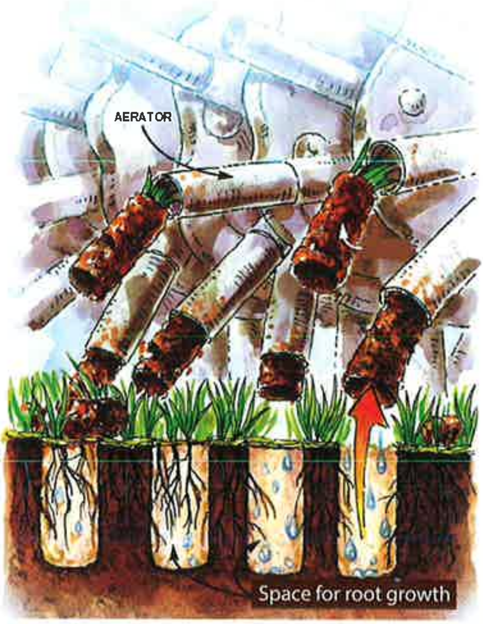
- Always use a sharp blade – A dull blade will damage the remaining grass blades, potentially stunting future growth.
- Always mow when the grass is dry
- Mow at regular intervals (every 5-7 days).
- Cut grasses to a height of 6-8 cm. Higher cut grass will shade out weeds and encourages deep root growth.
- Never mow more than 1/3 of the grass blade – This puts additional stress on the grass, potentially stunting growth.
- Use a mulching lawn mower and leave grass clippings on yard. The cut grass will contribute nitrogen to the soil and reduce fertilizer use on the yard.
- Avoid mowing when turf is under heat and drought stress.
- Alter the pattern with each mowing event to reduce wear on the grass surface.
- Wear appropriate safety gear, which includes long pants and shirt and eye/ear protection.
- Use a low emission lawn mower. According to Canada's **Clean Air Foundation**, a standard gas mower will emit the same amount of air pollutants in one hour as driving a new car for over 550 kilometers.

Keep it Green

Dethatching

Thatch is a layer of living and dead organic material that lies on top of the soil that can be a home to insects and fungus spores as well as prevent water, fertilizer and air from reaching the soil. The information below provides information how to avoid thatch formation and the removal of thatch should it become a problem:

- Avoid over fertilization and excess pesticide application. Thatch buildup is typically due to excess nitrogen and pesticide in the growing zone.
- Mulching lawnmowers do not cause thatch buildup. If thatch buildup becomes a problem, maintenance will be required on a yearly basis. The following options are available for thatch removal/control:
  - Aeration - Mechanical aeration equipment will break up the thatch, allowing air to penetrate the soil and enhance thatch decomposition.
  - Heavy Raking- A manual removal method for thin thatch layers.



Regular ground aeration is vital for a long-lasting and healthy lawn.

Manage your downspouts

Roof leaders (downspouts) at the Parks of West Bedford where ever possible are directed to lawns and vegetated areas to recharge groundwater. The installation of a downspout diverter can help you to direct water to certain areas on your lot. Benefits of this technique include:

- Low cost alternative that directly reduces stormwater runoff.
- Allow management/use of stormwater on the property.
- Reduce water bills by using stormwater to irrigate lawns and gardens.
- Reduce the volume of stormwater runoff to end of pipe facilities.

Downspouts should drain the water away from any impervious areas, such as the foundation or driveway, and into vegetated zones.

Get with the Program

Get to know your site

Getting to know your site is critical in helping you to create a more sustainable landscape. Consider the following options in caring for your land:

- Be sure you are not removing desirable native plants that are already well adapted to your site.
- Consider how much sunlight your site gets over the course of a day.
- Know your soil type! Does your soil hold moisture? How quickly does it drain? This can help you in choosing the right species and stormwater management techniques.
- Plant a diverse mix of native species and understand how your chosen plants might 'creep' into adjacent areas.
- Over time, the cost of using native plants for landscaping is less than non-native plants. Think of our plants as long-term investments that can be phased in as your budget allows.
- Make sure plants are not dug from the wild. This depletes the resource and many species do not thrive after transplanting.
- Consider interseeding (no till) or plugging plants into existing vegetation in places such as thin lawns, or sparsely vegetated old fields. This can result in fewer new weeds.
- Consider using shade trees to screen your home from the sun. They help keep you comfortable, and save money on air conditioning.

Green Bin Composting

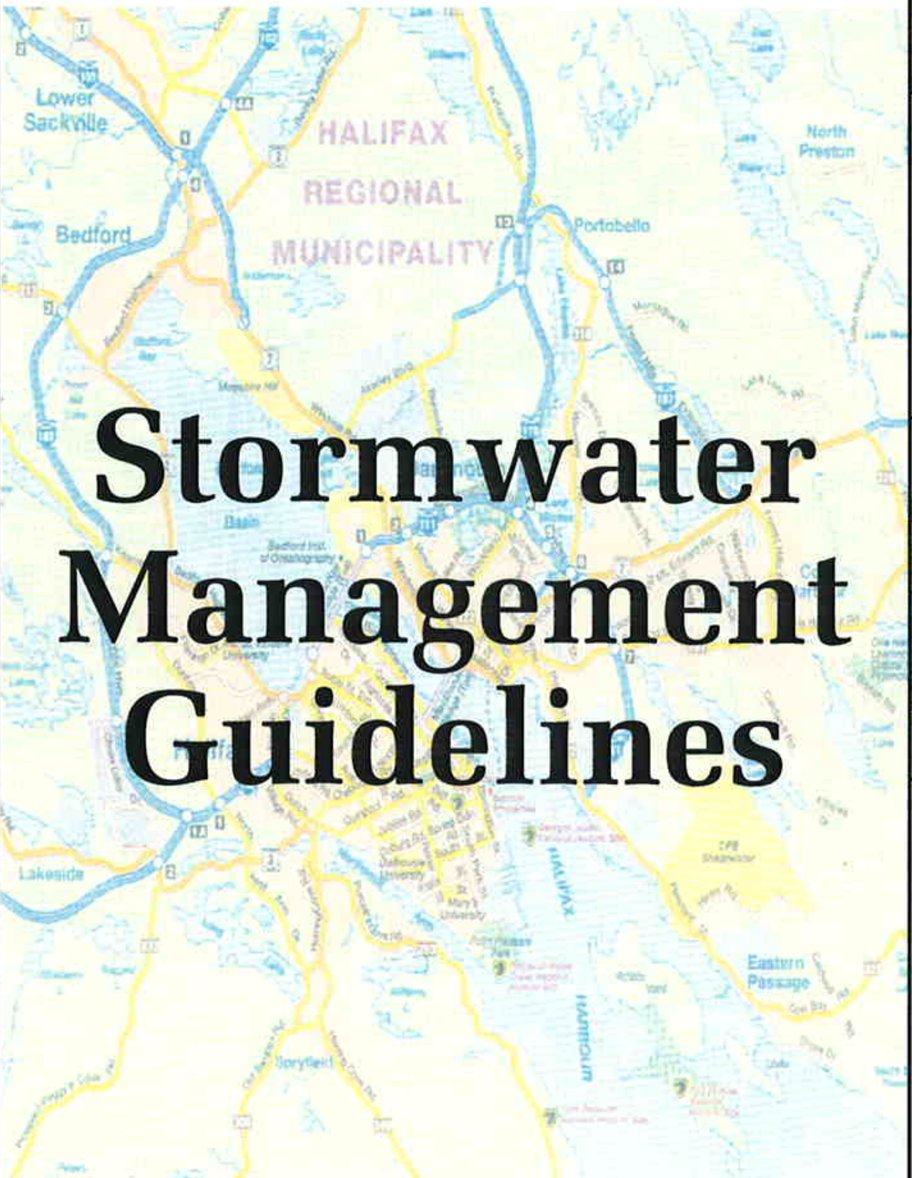
We are lucky in HRM to have an advanced recycling program than can help us in managing our waste. Significant accumulations of grass clippings, leaves, pruned branches, and other vegetative material are typically produced during the growing season. The following guidelines outline the proper handling of these materials to help sustain a low maintenance landscape:

- Use your green bin for leaves & brush, and house & garden plant waste.
- Excess leaf & yard material can be placed alongside the cart using orange or clear plastic bags or heavy paper bags - 20 bag limit, 25 kg (55 lb) maximum weight per bag.
- Branches should be tied in armload - sized bundles - maximum 5 bundles. Each bundle not exceeding 34 kg (75 lb) and no individual piece in the bundle more than 4 feet long (1.2 m) or larger than 8 inches (0.2m) in diameter.
- Create your own compost for your landscape needs. Learn more from HRM at http://www.halifax.ca/wrms/backyardcompost.html or the Resource Recovery Fund Board at www.putwasteinitsplace.ca
- Leave grass clippings on the grass. If possible, use a mulching mower, which will spread the grass clippings through the grass and put nutrients back into the soil.
- If a mulching mower is not available, dispose of grass clippings in your green bin or compost, or spread clippings in a vegetable or flower garden, as a mulch under bushes or add to the soil.
- Rake leaves, seeds, and grass clippings out of the street and gutter.
- Do not dispose of organic debris by dumping it in or near water bodies or sewers.

THE PARKS
OF WEST BEDFORD
EMBRACING NATURE ENJOYING LIFE

APPENDIX E
PORTIONS OF HALIFAX REGIONAL MUNICIPALITY STORMWATER MANAGEMENT GUIDELINES PREPARED BY DILLON CONSULTING IN MARCH 2006

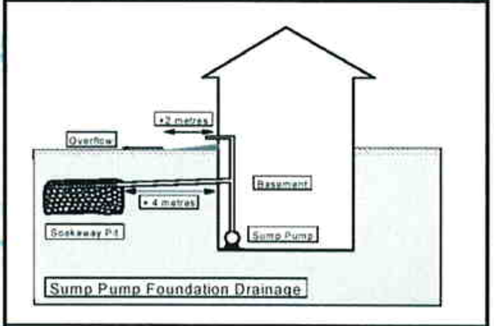
HALIFAX
REGIONAL MUNICIPALITY

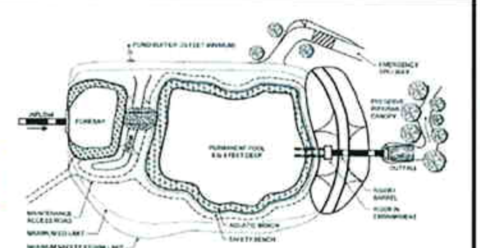


Stormwater Management Guidelines

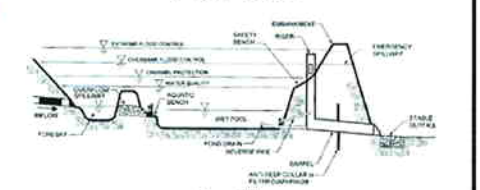
March 2006

DILLON
CONSULTING

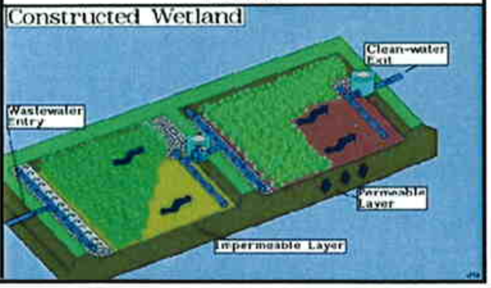




Plan View



Profile



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**.**

DILLON
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ISO 9001 Registered

March 29, 2006

HALIFAX REGIONAL MUNICIPALITY
P. O. Box 1749
Halifax, Nova Scotia
B3J 3A5

ATTENTION: Tony Blouin
Manager of Environmental Performance (Water)

Stormwater Management Guidelines
Final Report

Please find enclosed the Stormwater Management Guidelines. This report provides guidance to the selection and use of Best Management Practices (BMPs) for stormwater management within HRM. The BMPs recommended have been based on a review of practices within HRM and in other jurisdictions in Canada and the United States. It provides a list of alternatives and a methodology for selecting appropriate BMPs for different situations. It must be understood that when the BMPs are utilized, in order for them to operate efficiently, they must be maintained. HRM must endeavour to develop maintenance plans for the BMPs to achieve the stormwater management objectives.

It has been a pleasure to work with HRM and we hope we can be of further service in the future. Please do not hesitate to contact the undersigned if you have any questions concerning this report.

Yours truly,

DILLON CONSULTING LIMITED

S Devereaux

Sarah Devereaux, M.Eng., P.Eng.
Project Manager

I. Lorant

F. Ivan Lorant., P.Eng.
Water Resource Specialist

SLD:jep
Our File: 05-4680-0400

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Dillon Consulting
Limited

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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.

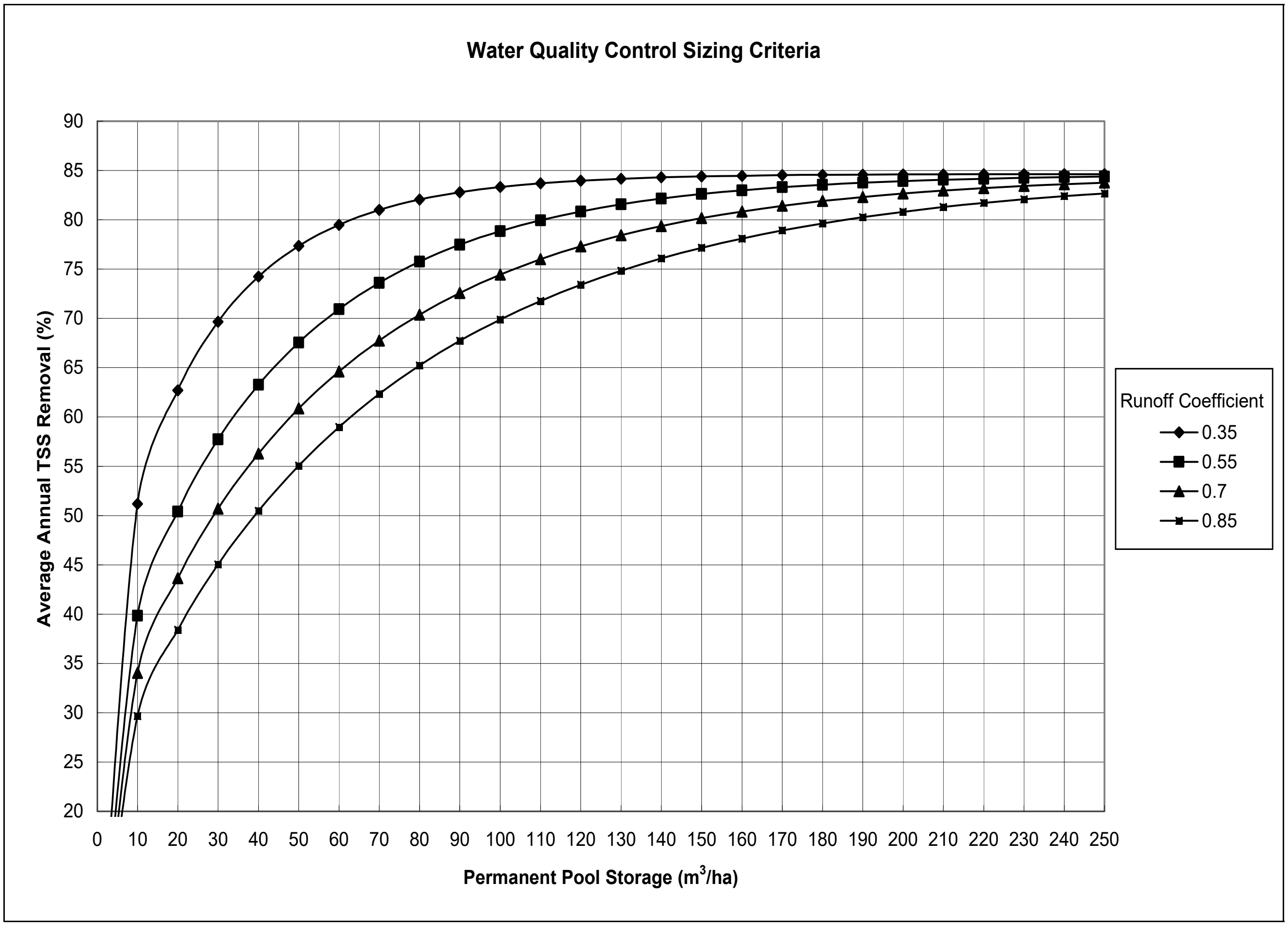

Figure 5-1 **Example of Sizing Permanent Pool Storage for Water Quality Control**

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 F
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

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March 2013

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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.

5.0 Stormwater Management Guidelines

5.1 General

This section provides a brief summary of the design standards and guidelines for storm drainage systems in Alberta. Detailed stormwater management standards and guidelines are described in the AESRD publication entitled, Stormwater Management Guidelines for the Province of Alberta.

5.2 Stormwater Collection

5.2.1 Dual Drainage Concept

Dual drainage concept (minor and major systems) should be followed in the design of the collection systems. The minor system (underground pipe systems, roof leaders, gutters, lot drainage, etc.) provides a basic level of service by conveying flows during minor storm events; the major system (lot drainage, roads and gutters, storage facilities, etc.) conveys runoff from the extreme events in excess of the minor system capacity.

There is always a major system, whether or not one is planned. Failure to plan for a major system often results in unnecessary flood damage.

5.2.1.1 Design Capacity

The establishment of capacity criteria for the minor system is largely a trade-off between cost and convenience in terms of level of service. For larger municipalities, the minor system should be designed to carry the peak flow resulting from a one in 5-year rainfall event; for several communities faced with limited financial reserves, the use of the 2-year event may be practical.

For the major system, the design should be based on a one in 100-year rainfall event.

5.2.2 Storm Sewers

Storm sewers shall be designed as a separate sewer system. Effluent from sanitary sewers or any potentially contaminated drainage from industrial, agricultural, or commercial operations shall not be discharged to storm sewers.

Contaminated drainage means, the introduction of any foreign, undesirable physical, chemical or biological substance into the environment which results or is likely to result in deleterious effects.

5.2.2.1 Sewer Hydraulics

Storm sewer pipe shall be designed to convey the design flow when flowing full with the hydraulic grade-line at the pipe crown. Crown elevations should match at manhole junctions.

5.2.2.2 Flow Velocities and Minimum Slope

Storm sewer flow velocities shall not be less than 0.60 m/s when flowing full. Refer to Table 5.1 for minimum slopes of gravity storm sewers.

If sewer flow velocities exceed 3 m/s, special consideration shall be given to prevent scouring.

TABLE 5.1
MINIMUM DESIGN SLOPES FOR STORM SEWERS

Sewer Diameter (mm)	Minimum Design Slope (m/100m)
300	.194
375	.145
450	.114
525	.092
600	.077
675	.065
750	.057
900	.045
1050	.036
1200	.031
1350	.027
1500	.023
1650	.020
1800	.018
1950	.016
2100	.015
2250	.013
2400	.012
2550	.011
2820	.010

Note: Design slopes based on a minimum velocity of 0.60 m/s for pipe flowing at least half full

5.2.2.3 Pipe Size

The minimum diameter for storm sewers shall be 300 mm. The minimum diameter for catch basin leads shall be 250 mm.

5.2.2.4 Pipe Material

The selection of pipe material, pipe classes and bedding types should be based on loading conditions. The designer should be particularly careful to specify sulphate resistant concrete pipe in areas of sulphate soil.

Storm sewer pipe shall have been manufactured in conformity with the latest standards by the American Society for Testing Materials (ASTM) or the Canadian Standards Association (CSA).

5.2.2.5 Pipe Cover

The minimum depth of cover to pipe crown shall be 1.2 m.

5.2.2.6 Curved Sewers

Curved sewers shall match the roadway curvature by means of deflection at the joints only. Joint deflections shall not exceed the manufacturer's specified allowable deflection. Consideration should also be given to increasing the grade of curved sewers to offset increased head loss.

5.2.2.7 Change in Flow Direction

For storm sewer pipes greater than 600 mm in diameter, changes in flow direction at manholes should not exceed 45°. This limitation may be exceeded if care is taken to design a proper transition manhole.

5.2.2.8 Extraneous Flows

Roof leaders shall not be connected to storm sewers in residential areas, but shall discharge to grassed or pervious areas. Roof leaders from multi-family, commercial, and industrial sites and foundation drains may be connected to storm sewers at the discretion of the Local Authority.

5.2.2.9 Sewer Maintenance

Control should be provided to minimize sediment discharge to storm sewers. This control may be in the form of properly graded and surfaced streets and lanes, landscaping, catch basin sumps, or sediment control structures at pond and lake inlets.

5.2.3 Storm Manholes

The design of storm manholes should conform in all respects to Section 4.2.2 pertaining to the design of sanitary sewer manholes, with the following exception:

- For storm sewers, 1.0 m in diameter or larger, a bend may be installed instead of a manhole at all changes in grade or alignment.

5.2.4 Catch Basins and Gutters

5.2.4.1 Collection of Surface Runoff

Surface water should not be permitted to run a distance greater than 300 m along roadways without interception by the first catch basin. From this first point of interception, surface runoff should not run a distance greater than 120 m between catch basins.

5.2.4.2 Catch Basin Capacity

The inlet capacity of each catch basin should be sufficient to receive the calculated surface stormwater flow at that location. The minimum inside diameter of catch basin leads shall be 250 mm.

5.2.4.3 Catch Basin Construction

All catch basin bodies shall be of either 600 mm or 900 mm pre-cast concrete sections. Where a sump cleaning maintenance program is in effect, the body shall be constructed so as to provide a 600 mm sump to trap silt and gravel.

5.2.4.4 Gutters

The minimum grade of gutters used to intercept stormwater runoff should be 0.40%. Gutters of less than 20 m in length or curved gutters of short radius should have a minimum grade of 0.60%.

5.2.5 Stormwater Pumping Stations

Being that stormwater pumping is an uncommon practice, there are no specific criteria in these standards with respect to the design and operation of stormwater pumping stations. The proponent of a pumping station should contact the Regional Director of Alberta Environment and Sustainable Resource Development before commencing with detailed design.

5.3 Stormwater Best Management Practices (BMPs)

5.3.1 Introduction

5.3.1.1 General

Stormwater Best Management Practices (BMPs) are methods of managing stormwater drainage for adequate conveyance and flood control and are economically acceptable to the community. BMPs are stormwater management methods that retain as much of the "natural" runoff characteristics and infiltration components of the undeveloped system as possible and reduce or prevent water quality degradation.

Stormwater BMPs that may be considered for stormwater quantity and quality controls are discussed in the following order:

- source control BMPs
- lot-level BMPs
- conveyance system BMPs

- end-of-pipe BMPs.

5.3.1.2 Design Criteria for Stormwater Quality Control

It is considered that storing the volume of runoff from a 25-mm storm over the contributing area is appropriate for Alberta for stormwater quality control using detention devices such as dry ponds, wet ponds, and constructed wetlands. A detention time of 24 hours should also be used for detention facilities. The runoff from a 12-mm storm over the contributing area is considered appropriate for infiltration BMPs.

5.3.2 Source Control BMPs

Removal of stormwater contaminants at their source may, in some instances, be a practical solution to the mitigation of pollutant impacts. There are three main pollutant removal activities that are normally practiced by a municipality for source control including street sweeping, catch basin cleaning, and animal litter removal through enforcement of bylaws.

5.3.3 Lot-Level BMPs

Stormwater lot-level controls are practices that reduce runoff volumes and / or treat stormwater before it reaches a subdivision / development conveyance system. This type of controls can be readily incorporated into the design of future developments. With all development, the applicability of stormwater lot-level controls should be investigated before conveyance and end-of-pipe systems are examined.

Traditional lot-level controls aimed at stormwater quantity management and the reduction of peak runoff rates include:

- restricting numbers of roof drains to provide rooftop detention of stormwater
- installing catch basin restrictors or orifices in the storm sewer to promote parking lot detention
- over sizing storm sewers and installing orifices in the sewer to create pipe storage
- installing catch basin restrictors in rear yard catch basins to create rear yard storage.

The above-noted lot-level measures are primarily designed to reduce runoff peaks. Other stormwater management criteria, such as the preservation of water quality, protection from erosion, and the maintenance of base flow are not adequately addressed through these techniques. Lot-level controls that help preserve the natural hydrologic regime include:

- reduced lot grading
- directing roof leaders to rear yard ponding or soak away pits
- sump pumping foundation drains to rear yard ponding areas.

5.3.3.1 Reduced Lot Grading

1. Purpose

The purpose of reducing lot grades is to reduce the volume of runoff from developed lots by increasing the travel time of runoff, and increasing the availability and opportunity for depression storage and infiltration. A significant reduction in lot-level runoff volumes would also affect the other minor stormwater system components and the major system components by reducing the conveyance and treatment requirements.

2. Description

Typical development standards require a minimum lot grade of two percent to drain stormwater away from buildings. In flat areas, a reduction to minimum lot grades should be evaluated. In hilly areas, alterations to natural topography should be minimized. To avoid foundation drainage problems, the grading within 2 to 4 m of buildings should be maintained at two percent or higher. Areas outside of this envelope should be graded at less than two percent.

Reduced lot grading BMPs promote depression storage and natural infiltration and reduce risks associated with flooding and erosion. The maintenance of natural infiltration could have positive impacts on base flow depending on local evapotranspiration rates.

3. Applicability

Reduced lot grades can be recommended as a lot-level stormwater BMP for any new developments and in re-grading or re-landscaping of existing lots in established developments.

4. Effectiveness

Very little information is available in regard to the impact that reductions in lot grades may have on the overall runoff volumes from a developed area. It has been recommended that reductions in lot grading may increase the pervious depression storage by as much as 1.5 mm for a 0.5 percent to 2.0 percent change in grade. Reduction of on-lot runoff will also reduce downstream erosion potential.

5. Water Quantity

Reduced lot gradings limit the volumes of runoff normally directed toward minor drainage systems. On-lot drainage rates are also reduced. This will reduce the requirements for end-of-pipe detention storage. Effective on-lot drainage reductions on a subdivision basis will lower and flatten the receiving water inflow hydrograph.

Increased infiltration of stormwater also provides recharge to the local groundwater that may, in turn, discharge to local streams thus enhancing base flows.

6. Water Quality

Reduced lot gradings limit the volumes of runoff from smaller storm events that are normally the major contributor of receiving water contaminants. The effectiveness of reduced lot grades in limiting contaminant runoff is also dependent on land use.

7. Design Considerations

Design guidelines for on-lot grade reductions are shown in Figure 5.1. Grades within 4 m of structures should be maintained at two percent. Grades beyond 4 m of structures should be reduced to 0.5 percent. Consideration should also be given to tilling soils in flatter grade areas to a depth of 30 mm prior to seeding or sodding to reduce soil compaction and increase infiltration potential.

5.3.3.2 Surface Ponding and Rooftop Storage

1. Purpose

Roof leaders that discharge to surface ponding areas reduce the potential for downstream flooding and erosion and help maintain pre-development end-of-pipe discharge rates. The same benefits can result from the use of rooftop storage, which are likely suitable for commercial, industrial, and institutional buildings.

2. Description

Roof leaders are directed toward rear lot depressions that allow stormwater to infiltrate or evaporate. For rooftop storage roof, drains on flat roofs are raised to allow ponding on the rooftop.

3. Applicability

Surface ponding areas can be recommended as a lot-level stormwater BMP for any new developments and in re-grading or re-landscaping of existing lots in established developments. Surface ponding may also be used for parking lots or park areas. Rooftop storage can be recommended for industrial, commercial, or institutional buildings with flat roofs.

4. Effectiveness

Rear lot ponding of stormwater or rooftop storage effectively limits runoff by a volume equal to the amount of impervious depression storage provided.

5. Water Quantity

Rear lot ponding and rooftop storage limit the volumes of runoff normally directed toward minor drainage systems. On-lot drainage rates are also reduced. This will reduce the requirements for end-of-pipe detention storage. Effective on-lot drainage reductions on a subdivision basis will lower and flatten the receiving water inflow hydrograph.

Increased infiltration of stormwater from rear lot ponds also provides recharge to the local groundwater which may in turn discharge to local streams thus enhancing base flows.

6. Water Quality

Rear lot ponding and rooftop storage limit the volumes of runoff from smaller storm events that are normally the major contributor of receiving water contaminants.

7. Design Considerations

Design guidelines for rear lot ponds are shown in Figure 5.2. Maximum depths should be maintained at 100 mm. Flow paths should be provided to direct overland flow to the pond. To maintain the pond, catch basins can be elevated to the required height or grassed swales can be created. More complex designs may incorporate an infiltration trench beneath the ponded area to enhance infiltration. The pond should be sized to accommodate a minimum of 5 mm and a maximum of 20 mm of rainfall covering the roof area. Rooftop ponding can be accomplished by raising roof hoppers to create a maximum ponding depth of 10 mm.

5.3.3.3 On-lot Infiltration Systems

1. Purpose

On-lot infiltration systems are used for detention of stormwater from relatively small catchment areas. Infiltration systems may be used in areas without adequate minor system conveyance. They also provide enhancement to water quality and reductions in overland flow.

2. Description

Infiltration systems may be simply designed pits with a filter liner and rock drain material or more complex systems with catch basin sumps and inspection wells. Stormwater flow from roof drains is directed to the infiltration system.

3. Applicability

Infiltration systems are recommended for relatively small detention volumes. If larger detention volumes are required a series of infiltration basins may be employed. Infiltration basins should not be built under parking lots or other multi-use areas, if the groundwater table is within 0.6 m of the infiltrating surface, if bedrock is located within 1.2 m of the infiltration surface, if the infiltrating surface is located on top of fill material and if the underlying soils have a fully saturated percolation rate of less than 1.3 mm.

4. Effectiveness

Infiltration systems have a number of advantages over rear yard ponding including increased groundwater recharge and less inconvenience to homeowners. Infiltration systems may have increased maintenance requirements over ponds and a more uncertain operating life. On-lot infiltration systems accept only roof runoff and are therefore subjected to minimal levels of suspended solids.

5. Water Quantity

On-lot infiltration systems limit the volumes of runoff normally directed toward minor drainage systems. On-lot drainage rates are also reduced. This will reduce the requirements for end-of-pipe detention storage. Effective on-lot drainage reductions on a subdivision basis will lower and flatten the receiving water inflow hydrograph.

Increased infiltration of stormwater from rear lot ponds also provides recharge to the local groundwater which may in turn discharge to local streams thus enhancing base flows.

6. Water Quality

On-lot infiltration systems limit the volumes of runoff from smaller storm events that are normally the major contributor of receiving water contaminants.

7. Design Considerations

Figures 5.3 and 5.4 illustrate two different applications of infiltration systems. The total void volume should be calculated from the storage required for the 2-year design storm which is calculated from the effective porosity of the infiltration fill material. The infiltration surface area required (bottom surface area) to drain the system within 48 hours is calculated from the 24-hour sustained percolation rate. An overland flow path should be provided for overflow volumes during saturated or frozen conditions. A pre-treatment filter (Figure 5.3) or sump (Figure 5.4) should be provided to limit solids input into the system. Design void space volumes are calculated from the volume of water required to fill a known volume of drain rock. A suitable quality filter fabric or geotextile must also be incorporated into the design.

In locating infiltration systems, consideration should be given to proximity to septic fields.

5.3.3.4 Sump Pumping of Foundation Drains

1. Purpose

Many current development standards allow foundation drains to be directly connected to the storm sewer. By pumping foundation drainage to surface or subsurface ponding / soak away areas, infiltration, flooding, and erosion water management concerns may be reduced.

2. Description

Foundation drainage is sometimes pumped to the storm sewer network, to a suitable infiltration system, or to the surface where it is conveyed to a catch basin and then to a storm sewer.

3. Applicability

Sump pumps are not feasible in areas where the seasonal high groundwater table is within 1 m of the foundation drain. Sump pumps are not feasible in areas where bedrock is within 1 m of the foundation drain. Application under these conditions may cause excess pumping. Under other conditions where infiltration systems are appropriate or where overland flow paths are available, sump pumps can be recommended to discharge to either the infiltration system or to the surface.

4. Effectiveness

Foundation drainage is normally relatively clean water and is well suited to the optimal operation of infiltration systems or overland flow to rear yard ponds.

5. Water Quantity

The impact of foundation drain discharge on downstream stormwater management facilities is dependent on the original discharge location. If foundation drainage was originally discharged to the storm sewer network or to the sanitary sewer, there will be some reduction in stormwater flow in the sewer. There will also be additional groundwater recharge and potentially base flow augmentation in the local receiving stream if foundation drainage was originally discharged to either the storm sewer or sanitary sewer networks.

6. Water Quality

Foundation drainage is relatively clean water and if flow is removed from either the storm sewer network or the sanitary sewer network there is likely to be some impact on the dilution of contaminants provided by the foundation drainage.

7. Design Considerations

Sump pump drainage to an infiltration system is illustrated in Figure 5.5. The location of the infiltration system should conform to infiltration design considerations. Yard grades should conform to design considerations for infiltration ponds. Sump pump discharges should be located at least 2.0 m away from foundations and be discharged to rear yards away from sidewalks to prevent icing conditions during winter months. Discharges should also be located at least 0.5 m above ground to prevent blockage from ice and snow during the winter.

5.3.4 Stormwater Conveyance System BMPs

Stormwater conveyance systems transport drainage from developed areas through sewer or grassed swale systems. Stormwater conveyance controls are applied as part of the stormwater conveyance system and can be classified into three categories:

- pervious pipe systems
- pervious catch basins
- grassed swales.

5.3.4.1 Pervious Pipe Systems

1. Purpose

Pervious pipe systems are intended to convey and infiltrate road drainage.

2. Description

Pervious pipe systems are perforated along their length, thereby promoting exfiltration of stormwater as it is conveyed downstream. The system is very similar to a conventional tile drainage system.

Pervious pipe networks are components of roadway drainage systems. Because roadway drainage usually carries a high level of suspended sediments there are associated pre-treatment components. Roadway runoff is normally directed toward grassed areas that act as sediment filters prior to flowing into the stormwater catch basin. The stormwater catch basin is raised to allow some ponding and further sediment removal. The catch basin is connected to the pervious pipe.

3. Applicability

Pervious pipe systems, although being implemented in several municipalities, are still considered experimental in nature.

4. Effectiveness

Pervious pipe systems for the exfiltration of road runoff have not proven very reliable. Pervious pipe systems experience clogging due to the high solids loads especially during construction of the pervious pipe system in new developments.

5. Water Quantity

Stormwater runoff from road surfaces contributes a substantial amount of discharge to the stormwater conveyance systems because road surfaces are normally quite impervious. Any stormwater infiltrated through the pervious pipe network reduces the total end-of-pipe discharge and therefore, any storage / treatment requirements.

6. Water Quality

Road runoff normally carries high levels of solids, oils, greases, metals, and chlorides if road salt is applied during the winter months. Removal of these contaminants prior to end-of-pipe can enhance the performance of any storage or treatment facilities. Stormwater quality can substantially improve at the end-of-pipe discharge point.

Infiltration of road runoff may, however, present a groundwater contamination problem.

7. Design Considerations

Implementation of a pervious pipe system is illustrated in Figure 5.6. Design considerations must include the pre-treatment of road runoff for solids removal. Pre-treatment can be accomplished by incorporating grassed boulevards as pre-treatment areas. To be an effective method of infiltration the surrounding soils must have a high infiltration potential. The infiltration pipe must be a sufficient height above the groundwater table to prevent groundwater from flowing into the pipe and allow for proper infiltration.

The minimum storage volume should be equal to the runoff from a 5-mm storm over the contributing drainage area. The storm volume should be accommodated in the pervious pipe bedding / storage media without overflowing. The maximum storage area should be equal to the runoff from a 25-mm storm over the contributing drainage area. The exfiltration storage bedding depth should be 75 mm to 150 mm deep above the crown of the pervious pipe and the bedding should drain 24 hours. The minimum diameter for the pervious pipe should be 200 mm and the pipe should be smooth walled to reduce the potential for clogging

5.3.4.2 Pervious Catch basins

1. Purpose

Pervious catch basins are intended to convey and infiltrate road drainage.

2. Description

Pervious catch basins are normal catch basins with larger sumps that are physically connected to an exfiltration storage media. The storage media is generally located beneath or beside the catch basin.

3. Applicability

Pervious catch basins are still considered to be experimental.

4. Effectiveness

Maintenance requirements for pervious catch basins are dependent on the clogging frequency of the infiltration media which can be high given the sediment load normally associated with road runoff. Pervious catch basins are easier to construct in new developments because they can be plugged during construction to prevent solids clogging the system.

5. Water Quantity

Stormwater runoff from road surfaces contributes a substantial amount of discharge to the stormwater conveyance systems because road surfaces are normally quite impervious. Any stormwater infiltrated through pervious catch basins reduces the total end-of-pipe discharge and therefore, any storage / treatment requirements.

6. Water Quality

Road runoff normally carries high levels of solids, oils, greases, and metals. Chlorides may also be a problem if road salt is applied during the winter months. Removal of these contaminants prior to end-of-pipe can enhance the performance of any storage or treatment facilities. Stormwater quality can substantially improve at the end-of-pipe discharge point.

7. Design Considerations

The application of a pervious catch basin for road runoff control is illustrated in Figure 5.7. The most important design consideration is the provision of adequate pre-treatment of solids to prevent frequent clogging. Design specifications recommend construction at least 1 m above the groundwater table and the use of appropriate unwoven geotextile and clear 50-mm stone to promote filtration with a low clogging frequency. To be an effective method of infiltration the surrounding soils must have a high infiltration potential. Storage volume criteria should be the same as that for pervious pipe. The depth of the exfiltration storage is dependent upon the native soil characteristics. Maximum depths can be calculated based on the native soil percolation rate. The physical dimensions of the storage will depend on the area of land available.

5.3.4.3 Grassed Swales

1. Purpose

Grassed swales store, infiltrate and convey road and on-lot stormwater runoff. Grassed swales are normally associated with more rural low-density developed drainage basins.

2. Description

Grassed swales are natural depressions or wide shallow ditches. The grass or emergent vegetation in the swale acts to reduce flow velocities, prevent erosion, and filter stormwater contaminants.

3. Applicability

Grassed swales are typically used in more rural areas with rolling or relatively flat land but can be used in place of or as an enhancement to any stormwater curb and gutter system except in strip commercial and high-density residential areas. In rural areas and in urban applications, grassed swales have been shown to effectively infiltrate runoff and remove pollutants. Grassed swales are being designed more frequently to replace curb and gutter controls and can be recommended for consideration in both rural and urban drainage basins.

4. Effectiveness

Grassed swales have been reported to provide effective quantity and quality control of urban and rural runoff. Grassed swales must be properly maintained to ensure effectiveness and prevent ponding of water. If water is allowed to pond in the swale, wetland vegetation may grow and mosquitoes may become a problem.

5. Water Quantity

Grassed swales infiltrate stormwater and reduce the end-of-pipe discharge volumes normally associated with curb and gutter controls. Significant amounts (up to 95 percent) of runoff reduction are reported in the literature pertaining to grassed swales. Grassed swales also significantly lower peak discharge rates associated with frequent storms. The changes in runoff discharge volumes and rates also reduce erosion in downstream systems.

6. Water Quality

Grassed swales can be effective in filtering and detaining stormwater runoff from a variety of catchment types. Grassed swales are effective for stormwater treatment as long as minimum channel slope is maintained and a wide bottom width is provided. Many stormwater contaminant particulates are effectively filtered by grassed swales including heavy metals, COD, nitrate nitrogen, ammonia nitrogen, and suspended solids. Other contaminant nutrients such as organic nitrogen, phosphorus, and bacteria have been reported to bypass grass swales.

7. Design Considerations

General design considerations for a grassed swale are shown in Figure 5.8. An illustration of a grassed swale with a check dam is shown in Figure 5.9.

Swales should be designed with minimum longitudinal slopes (1 to 2 percent) to promote infiltration and filtering characteristics but still maintain conveyance requirements to prevent flooding and local ponding in the swale. Check dams, as shown in Figures 5.8 and 5.9, are normally used when the longitudinal slope exceeds 2 to 4 percent. Figure 5.8 shows a perforated pipe enhancement to the swale that ensures the swale remains dry between storm events. Side slopes should be no greater than 2.5 to 1 but are optimally less than 4 to 1. A minimum bottom width of 0.75 m and minimum water depth of 0.5 m should be maintained. The maximum velocity in the swale should be 0.5 m/s. Where velocities are greater than 0.5 m/s the use of check dams (Figure 5.9) can promote infiltration and settling of pollutants. Grass should be local species or standard turf grass where a more manicured appearance is required. The grass should be allowed to grow higher than 75 mm so that suspended solids can be filtered effectively.

5.3.5 End-of-Pipe Stormwater BMPs

End-of-pipe stormwater BMPs provide water quality enhancement to stormwater prior to discharge into a receiving water body. A number of end-of-pipe alternatives are available for application depending on the characteristics of the upstream catchment and the requirements for water quality enhancement. Eight general categories of end-of-pipe BMP facilities are discussed:

- wet ponds
- dry ponds
- wetlands
- infiltration trenches
- infiltration basins
- filter strips
- sand filters
- oil / grit separators.

All references to "wet ponds", "wetlands", or "dry ponds" assume that extended detention storage is provided. Extended detention refers to the dry or active storage provided by these facilities. Extended detention ponds reduce the rate of stormwater discharge by storing the stormwater runoff temporarily and releasing it at a controlled rate. Water quality treatment is provided through enhanced settling and biological processes. As such, extended detention storage provides benefits related to water quality, erosion protection, and flooding potential.

5.3.5.1 Wet Ponds

1. Purpose

The purpose of wet ponds is to temporarily store stormwater runoff in order to promote the settlement of runoff pollutants and to restrict discharge to predetermined levels to reduce downstream flooding and erosion potentials.

2. Description

Wet ponds can be created as an impoundment by either constructing an embankment or excavating a pit. They are often designed as a two-stage (dual-purpose) facility, where the upper stage (flood fringe area) is designed to store large, infrequent storms, and the lower stage (extended detention stage) is designed to store, and promote sedimentation, of smaller, more frequent storms. The deep, permanent pond is the wet pond's primary water quality enhancement mechanism. Runoff entering the retention basin is designed to displace water already in the permanent pool and remain there until another storm event. Runoff entering the basin is slowed by the permanent pool and suspended pollutants are allowed to settle. Biologic processes, such as nutrient uptake by algae, are established in the permanent pool and help reduce concentrations of soluble contaminants. A vegetative planting strategy should provide shading, aesthetics, safety, and enhanced pollutant removal.

3. Applicability

A reliable source of runoff or groundwater discharge must be available to maintain the permanent pool of a wet pond. As such, wet ponds are generally considered for drainage areas greater than 5 ha. Because of a wet pond's ability to reduce soluble pollutants, it is generally applicable to residential, commercial, or industrial areas where nutrient loadings may be expected to be relatively high. Wet ponds may not be appropriate, or may require specialized design, where receiving water temperatures are a concern.

4. Effectiveness

Wet ponds are probably the most common end-of-pipe management facility for the control of peak runoff discharges and the enhancement of water quality. Wet ponds are very effective in controlling runoff and improving water quality when proper design considerations are made for those two objectives.

5. Water Quantity

As a detention facility, a wet pond typically flattens and spreads the inflow hygrograph, thus lowering the peak discharge. Wet ponds are effective in controlling the post-development peak discharge rate to the desired pre-development levels for design storms. Watershed / subwatershed analyses should be performed to coordinate subcatchment / pond release rates for regional flood control. Wet ponds are relatively ineffective for volume reduction, although some infiltration and / or evaporation may occur. Wet ponds are generally effective in controlling downstream erosion if designed such that the duration of post-development "critical impulses" does not exceed a pre-determined erosive threshold.

6. Water Quality

Wet ponds have been cited as providing the most reliable end-of-pipe BMP in terms of water quality treatment. This reliability is attributed to a number of factors including:

- performance does not depend on soil characteristics
- permanent pool prevents re-suspension
- permanent pool minimizes blockage of outlet
- promotes biological removal of pollutants

- permanent pool provides extended settling.

Wet ponds have a moderate to high capacity to remove most urban pollutants depending on how large the volume of the permanent pool is in relation to the runoff produced from the contributing drainage area. The establishment of vegetative zones in and around a wet pond can enhance its pollutant removal capability.

7. Design considerations

Wet ponds must be designed to meet specific water quality and / or discharge rate objectives. Wet ponds designed to control peak discharge rates do not normally provide optimum water quality enhancement. Flood control or peak flow control wet ponds are typically designed to control the large infrequent event storms. Water quality wet ponds need to be designed to capture and treat the more frequent smaller storms with which the majority of the contaminant loadings are associated. Wet ponds can be designed to meet both flood control and water quality objectives.

One of the primary criteria for the proper design of a wet pond for peak runoff control is the provision of adequate detention storage volume. The primary design consideration for a wet pond for water quality enhancement is the settling velocity of the particulates in the stormwater entering the pond. The wet pond surface area is directly related to this required settling velocity. Ponds designed only for peak flow reduction do not normally provide adequate facility for water quality enhancement.

The design of a wet pond requires careful consideration of the required design objectives for flood control and water quality enhancement. Figure 5.10 illustrates some of the basic requirements for a wet pond. Detailed designed requirements should be evaluated for each individual application based on site-specific constraints and objectives.

Some general design parameters are:

- minimum water surface area of 2 ha
- maximum side slopes above active storage zone are 4:1 to 5:1
- maximum interior side slopes in active storage zone are 5:1 to 7:1
- maximum exterior side slopes are 3:1.

Some water quality control design parameters are:

- permanent pool sized to store the volume of runoff from a 25-mm storm over the contributing area
- detention time of 24 hours
- length to width ratio shall be from 4:1 to 5:1
- minimum permanent pool depth of 2.0 m
- maximum permanent pool depth of 3.0 m. The maximum water level should be below adjacent house basement footings
- maximum active detention storage depth of 1.5 m.

Some water quantity control design parameters are:

- 1-in-100-year storm stored within 2 m above the permanent pool (Alternatively, the 2 m can be used to store the 1-in-25-year storm. In such cases an emergency overflow drainage system should be constructed with the capacity to carry storm runoff from the 1-in-100-year storm event to receiving streams or downstream stormwater management facilities)
- Detention time of 24 hours.

Also, a wet ponds water quality control performance can be improved by providing a pre-treatment sump or forebay and a backup water supply to maintain the minimum storage volume. During the design process, other design considerations should be evaluated that relate to ease of maintenance. The forebay should be designed with the following parameters:

- Length to width ratio of 2:1 or greater

- Forebay surface area not to exceed one-third of the permanent pool surface area
- Forebay length, L_{fb} as follows:

$$L_{fb} = [rQ_p/V_s]^{0.5}$$

where:

r = Length to width ratio of forebay
Q_p = Peak flow rate from the pond during the design quality storm (m^3/s)
V_s = Settling velocity (dependent on the desired particle size to settle)

- Dispersion length, L_{dis} as follows:

$$L_{dis} = (8Q)/(dV_f)$$

where:

Q = inlet flow rate (m^3/s)
d = depth of permanent pool in the forebay (m)
V_f = desired velocity at the end of the forebay

- Forebay Bottom Width, $W = L_{dis}/8$

- Forebay berm should be 0.15 to 0.3 metres below the permanent pool elevation.

5.3.5.2 Dry Ponds

1. Purpose

The purpose of a dry pond is to temporarily store stormwater runoff in order to promote the settlement of runoff pollutants and to restrict discharge to predetermined levels to reduce downstream flooding and erosion potential.

2. Description

Dry ponds are impoundment areas constructed by an embankment or through excavating a pit. They are often designed as a two-stage (dual-purpose) facility, where the upper stage (flood fringe area) is designed to store large, infrequent storms, and the lower stage (extended detention stage) is designed to store, and promote sedimentation, of smaller, more frequent storms. Unlike a wet pond, however, the lower stage is designed to empty completely between storm events.

3. Applicability

Dry ponds may be applied where topographical or planning constraints exist that limit the land available for wet ponds. Drainage areas greater than 5 ha are generally recommended for dry ponds. The use of dry ponds for combined water quantity and quality control is discouraged without the use of sediment forebays that include a permanent pool.

A dry pond's limited effectiveness in removing soluble contaminants is an important factor in considering its application. For example, in low-density residential areas where soluble nutrients from fertilizers and pesticides are a concern, dry ponds in isolation may not be appropriate.

4. Effectiveness

Dry ponds do not provide water quality enhancement because of the bottom scour that occurs with each storm event. Dry ponds do provide effective stormwater flow attenuation.

5. Water Quantity

As a detention facility, a dry pond typically flattens and spreads the inflow hygrograph, thus lowering the peak discharge. Dry ponds are effective in controlling the post-development peak discharge rate to the desired pre-development levels for design storms. Watershed / subwatershed analyses should be performed to coordinate subcatchment / pond release rates for regional flood control. Dry ponds are relatively ineffective for volume reduction, although some evaporation may occur. Dry ponds are generally effective in controlling downstream erosion if designed such that the duration of post-development "critical impulses" does not exceed a predetermined erosive threshold.

6. Water Quality

Because dry ponds have no permanent pool of water, the removal of stormwater contaminants in dry ponds is a function of the pond's draw down time. The removal of soluble pollutants does not generally occur in a dry pond. Without a permanent pool, re-suspension of contaminants is a concern. Dry ponds operating in a continuous mode are generally less effective at pollutant removal compared to wet ponds, whereas dry ponds operating in a batch mode have been reported to be similarly effective. In general, dry ponds should only be implemented if it is determined that a wet pond cannot be implemented due to topographical or planning constraints.

7. Design Considerations

The design of a dry pond has many site-specific requirements that must be considered. These design considerations are dependent on the constraints of a particular site and the objectives for the pond.

Figure 5.11 illustrates some of the basic requirements for a dry pond.

Some general design parameters are:

- storage capacity for up to the 1-in-100-year storm
- detention time of 24 hours
- maximum active retention storage depth of 1.0 to 1.5 metres. The maximum water level should be below adjacent house basement footings
- maximum interior side slopes of 4:1 to 5:1
- maximum exterior side slopes of 3:1
- minimum freeboard of 0.6 m
- minimum ratio of effective length to effective width of 4:1 to 5:1
- Minimum slope in the bottom of the pond of 1 percent (2 percent is preferred).

During the design process, other design considerations should be evaluated that relate to ease of maintenance and use. For example, a weeping tile system could be installed under the bottom of the pond to improve the rate at which the pond bottom dries out between storm events.

5.3.5.3 Constructed Wetlands

1. Purpose

By retaining runoff for a prolonged period of time and uptaking, altering, and storing pollutants, constructed wetlands serve to improve water quality and control peak discharge rates.

2. Description

There are five basic stormwater wetland designs: shallow marsh, pond / wetland, extended detention wetland, pocket wetland, and fringe wetland. All are essentially surface flow systems, with varying emergent marsh and deep pool habitat, hydraulic capacity, residence time, and travel routes.

Constructed wetlands can be created as an impoundment by either constructing an embankment or excavating a pit. Relatively deep permanent pools are maintained at the inlet and outlet and along low flow paths to minimize the resuspension and discharge of settled pollutants from the facility. Relatively shallow extended detention storage areas with extensive plantings (submergent and emergent) make up the majority of a constructed / artificial wetland's permanent storage. Sedimentation, filtration and biological processes account for the water quality benefits afforded by wetlands. Planting strategies are also implemented for shoreline fringe areas and / or flood fringe areas (if a combined facility) providing shading, aesthetics, safety, and enhanced pollutant removal.

3. Applicability

Generally wetlands can be considered for drainage areas greater than 5 ha because of a wetland's ability to reduce soluble pollutants, they are generally applicable to residential, commercial, or industrial areas where nutrient loadings may be expected to be relatively high. Constructed / artificial wetlands may not be appropriate, or may require specialized design, where receiving-water temperatures are a concern. The application of constructed / artificial wetlands may be further constrained by existing planning designations or topography that limits land availability. Potential ancillary benefits provided by wetlands include aviary, terrestrial, and aquatic habitat.

Wetland water treatment systems are not recommended for all applications. Such systems are most appropriate under the following conditions:

- large tracts of suitable land are readily available
- the influent does not contain high levels of industrial toxic pollutants as defined by provincial and federal agencies
- there is a shortage of local groundwater or surface water supplies
- a water body with impaired water quality is located in the area
- the region has a history of wetland loss
- regulatory agencies are interested in the potential benefits of the technology.

4. Effectiveness

Stormwater wetland water treatment systems provide several major benefits:

- they require less maintenance and are less expensive to maintain than traditional treatment system
- with proper design, portions of the wetland treatment system may provide additional wetland wildlife habitat, as well as recreational opportunities such as bird watching, hiking, and picnicking
- wetland treatment systems are viewed as an asset by provincial and federal agencies in many regions and as a potentially effective method for replacing wetlands lost through agricultural practices, industrial and municipal development, and groundwater withdrawal.

5. Water Quantity

As a detention facility, wetlands typically flatten and spread the inflow hygrograph, thus lowering peak discharges. Wetlands are effective in controlling the post-development peak discharge rate to the desired pre-development levels for design storms. Watershed / sub watershed analyses should be performed to coordinate subcatchment / pond / wetlands release rates for regional flood control. Wetlands are relatively ineffective for volume reduction, although some infiltration and / or evaporation may occur. Wetlands are generally effective in controlling downstream erosion if designed such that the duration of post-development "critical impulses" does not exceed a predetermined erosive threshold.

6. Water Quality

In general, wetland water treatment systems have been found to lower BOD, TSS, and total nitrogen concentrations to 10 to 20 percent of the concentrations entering the systems. For total phosphorus, metals, and organic compounds, removal efficiencies vary widely, typically from 20 to 90 percent. Removal of these latter constituents appears to be limited by substrate type, the form of the constituents, the presence of oxygen, and the entire chemical makeup of the water to be treated.

7. Design Considerations

The design of a constructed wetland for dealing with urban stormwater requires a detailed study to determine from the outset what the goals of the wetland are. If the function is primarily to store water during storm events and release it later, then the size of the catchment area, permeability of the urban surfaces, and recorded flow rates will be used to determine the water volume storage capacity required. This, together with the expected frequency of large storm events, will provide an indication of the suggested draw down rates for the wetland and the diameter of outflow pipes. If, on the other hand, improving water quality is a major goal, then subsurface water flow through one or more cells may be worth incorporating into the design specifications. Should the wetland operate in the fall, winter, and early spring as well as in summer? If so, then a configuration of wetland that is deep and permits water flow during low winter temperatures may be appropriate.

Several goals may be identified for a constructed wetland, but the available site may limit the achievement of all the goals. In this case priorities must be set. The general location of a constructed wetland is an important consideration. Is it to be constructed in a residential, industrial, or rural area? Considerations such as safety, aesthetics, potential toxic spills, or wildlife mean that different design criteria must be considered. To achieve water management goals, social as well as technical issues must be addressed, for "social" problems may be more difficult to solve than physical and technical ones, and managers should involve local interest groups in the early planning stages of projects.

It is important that a pre-treatment area be provided for the collection of sediment and for the protection of the constructed wetland from accidental spills. Data is available on the construction of a pre-treatment area for oil separation and sediment removal prior to allowing water to flow into a wetland.

A constructed wetland could contain a number of cells, either of similar construction and function, or of different structure and purpose. Figure 5.12 illustrates the major components of a constructed wetland.

General design considerations are:

- wetland size should be approximately five (5) percent of the watershed area that it will be servicing
- approximately 10 percent of the wetland surface area should be a 1.5 to 2.0 m deep sediment forebay upstream of the wetland area for settleable solids removal
- average permanent water wetland depth is 0.3 m with 1 m deep zones for flow redistribution and for fish and submerged or floating aquatic vegetation habitat
- active storage is 0.3 to 0.6 m deep

- vegetation can be cost effectively transplanted from local donor sites including ditches maintained by the Province and construction sites where small pocket wetlands are to be removed
- length to width ratios can be as low as 1:1
- shape of the treatment cell(s) can vary and depends on landscaping features required for attracting wildlife and for public enjoyment, and shape of available land
- bottom slope of 0.5 to 1.0 percent is recommended and a flat bottom to promote sheet flow through the system
- gravity flow is the preferred method of movement of water into, through, and out of the treatment wetland
- incorporate a bypass that will collect first flush flows and divert high flows during extreme rainfall events around the wetland
- regulated inflow and outflow structures are required that will take into account a wide range of rainfall intensities
- landscaped features will provide an attractive park-like setting
- ancillary benefits include provision for wildlife habitat, wildlife viewing opportunities, hiking areas, educational opportunities, and restoration of lost wetland areas
- mosquito control includes introducing or making habitat available for baitfish (fathead minnows), dragonflies, purple martins, swallows, and bats
- odour control is not required since the treatment wetlands, if designed properly, do not generate odours
- nuisance wildlife including carp and muskrat will require control since they will destroy or consume the wetland vegetation and will, in the case of the carp, re-suspend settled materials
- freezing conditions during the winter months will not adversely affect the treatment wetland
- design and implement with designated objectives constantly and clearly in mind
- design more for function than for form. A number of forms can probably meet the objectives, and the form to which the system evolves may not be the planned one
- design relative to the natural reference system(s), and do not over-engineer
- design with the landscape, not against it. Take advantage of natural topography, drainage patterns, etc.
- design the wetland as an ecotone. Incorporate as much "edge" as possible, and design in conjunction with a buffer and the surrounding land and aquatic systems
- design to protect the wetland from any potential high flows and sediment loads
- design to avoid secondary environmental and community impacts
- plan on enough time for the system to develop before it must satisfy the objectives. Attempts to short-circuit ecological processes by over-management will probably fail
- design for self-sustainability and to minimize maintenance.

5.3.5.4 Infiltration Trenches

1. Purpose

The purpose of an infiltration trench is to collect and provide temporary storage of surface runoff for a specific design frequency storm and to promote subsequent infiltration. The three basic trench systems are complete exfiltration, partial exfiltration, and water quality exfiltration. Each system is defined by the volume of annual runoff diverted to the trench and the degree to which the runoff is exfiltrated into the soils. Infiltration trenches differ from on-lot infiltration systems in that they are generally constructed to manage stormwater flow from a number of lots in a developed area, not a single property.

2. Description

Infiltration trenches can be constructed at ground surface level to intercept overland flow directly, or constructed as a subsurface component of a storm sewer system. Infiltration trenches are generally composed of a clear stone storage layer and a sand or peat filter layer. There are other options for the type of filter used such as a non-woven filter fabric.

3. Application

Infiltration trenches are best utilized as recharge devices for compact residential developments (< 2 ha), rather than as a larger-scale, water quality treatment technique. Normally, infiltration trenches are not used in commercial or industrial areas because of the potential for high-contaminant loads or spills that may result in groundwater contamination.

4. Effectiveness

Infiltration trenches are effective in managing runoff from small residential areas. They are also effective when constructed under grassed swales to increase the infiltration potential of the swale. Clogging of the filter material can be a frequent problem if solids inputs are high and no pre-treatment in the form of grassed filter strip for surface trenches or a suitable oil / grit separator for subsurface trenches is employed. Groundwater mounding may also become a problem if infiltration volumes are too high.

5. Water Quantity

Infiltration trenches provide marginal water quantity control. As such, the application of infiltration trenches is likely only appropriate as a secondary facility where the maintenance of groundwater recharge is a concern.

Infiltration trenches limit the volumes of runoff normally directed toward minor drainage systems. On-lot drainage rates are also reduced. This will reduce the requirements for end-of-pipe detention storage. Effective on-lot drainage reductions on a subdivision basis will lower and flatten the receiving water inflow hydrograph.

Increased infiltration of stormwater from infiltration trenches also provides recharge to the local groundwater that may in turn discharge to local streams, thus enhancing base flows.

6. Water Quality

Pre-treatment BMPs such as filter strips or oil / water separators are often used in combination with infiltration trenches to minimize the potential for suspended sediments to clog the trench. Infiltration trenches limit the volumes of runoff from smaller storm events that are normally the major contributor of receiving water contaminants. Potential contamination of groundwater should be considered when examining runoff quality directed to the infiltration trench.

7. Design Considerations

A surface infiltration trench and a subsurface infiltration trench are shown in Figures 5.13 and 5.14, respectively. Infiltration trenches require groundwater levels and bedrock layers to be at least 1 m below the bottom of the infiltration trench. Soils must have a percolation rate of more that 15 mm/hr. A suitable filter fabric should be used to protect the stone storage media from clogging.

Careful consideration should be given to the volume of stormwater directed to the infiltration trench. Only sufficient volumes should be directed to the trench to allow, at a maximum, a 48-hour draw down period.

In a subsurface trench, a series of perforated pipes carries stormwater to the trench. A bypass pipe or flow path should be provided for flows in excess of the design capacity of the trench.

5.3.5.5 Infiltration Basins

1. Purpose

The purpose of an infiltration basin is to collect and provide temporary storage of surface runoff for a specific design frequency storm and to promote subsequent infiltration.

2. Description

Infiltration basins are aboveground pond impoundment systems that promote recharge. Water percolating through an infiltration basin either recharges the groundwater system or is collected by an underground-perforated pipe system and discharged at a downstream outlet. The appearance of an infiltration basin is similar to that of a wet or dry pond.

3. Applicability

Infiltration basins are generally considered for drainage areas less than 5 ha that have permeable soils. As with wet or dry ponds, an infiltration basin can be designed as a multi-stage facility to achieve various stormwater management objectives. Infiltration basins should be used in residential areas only. Runoff from industrial or commercial land areas is generally of poor quality and could contaminate groundwater.

4. Effectiveness

Infiltration basins have a very high rate of failure. Most failures can be attributed to poor site selection, poor design, poor construction techniques, large drainage area, and lack of maintenance. One of the main problems inherent in infiltration basins is that large volumes of water from a large catchment area are expected to infiltrate over a very small surface area. This leads to numerous problems and general failure of these basins.

5. Water Quantity

Infiltration basins are generally ineffective for water quantity control. They only infiltrate limited volumes of water from generally large catchment areas and must be provided with an overflow structure to discharge excess flow. As such, the application of infiltration basins is likely only appropriate as a secondary facility where the maintenance of groundwater recharge is a concern.

6. Water Quality

The application of pre-treatment to reduce sediment loadings and a bypass to restrict flows during certain periods (road sanding / salting, local excavation works, facility maintenance) is recommended to improve long-term infiltration basin performance.

7. Design Considerations

A typical infiltration basin is illustrated in Figure 5.15. Infiltration basin design considerations must include provision for construction at the end of the development construction. Also, compaction of the basin and smearing of the basin native material must be avoided. The basin must be constructed with a maximum water storage depth of 0.6 m to avoid compaction, and the groundwater table should be a minimum of 1.0 m below the infiltration layer. Any area bedrock should also be a minimum of 1.0 m below the infiltration layer. Planting in the basin should include grasses and legumes to maintain or enhance the pore spaces in the soil.

5.3.5.6 Filter Strips

1. Purpose

Filter strips are engineered conveyance systems that are designed to remove pollutants from overland runoff. By reducing overland flow velocities, the time of concentration and infiltration are increased, thereby slightly reducing the volume of runoff and minimally controlling discharge rates.

2. Description

There are two general types of filter strips: grass and forested. Both consist of a level spreader, which ensures level flows, and abundant vegetative plantings. The vegetative plantings promote pollutant filtration and infiltration of stormwater. Filter strips are generally best implemented adjacent to a buffer strip, watercourse, or drainage swale, as discharge from a filter strips will be a sheet flow and thus difficult to convey in a traditional stormwater conveyance system.

3. Applicability

Filter strips are best applied as one of a combination of BMPs as the maintenance of sheet flow through the vegetation, and thus consistent water quality benefits, has been difficult to maintain in practice.

4. Effectiveness

Limited filter strip performance data are available in the literature although it is generally thought that properly designed filter strips are capable of removing a high percentage of stormwater particulates.

5. Water Quantity

Filter strips may slightly reduce the volume of runoff by inducing infiltration.

6. Water Quality

Although filter strips have been shown to be somewhat effective in removing sediment and pollutant loads in urban stormwater runoff, the ability to maintain sheet flow through the vegetation over the long term has been questioned.

7. Design Considerations

A schematic of a grassed and wooded filter strip is shown in Figure 5.16. The filter strip requires a level spreader with available upstream storage to regulate the discharge rate and depth of flow through the filter strip. The ideal slope for a filter strip is less than 5.0 percent over a distance of 10 to 20 m in the direction of flow.

5.3.5.7 Sand Filters

1. Purpose

Sand filters are above or below ground end-of-pipe treatment devices that promote pollutant removal from overland runoff or storm sewer systems. Sand filters do not provide a recharge benefit as filtered stormwater is discharged to the storm sewer or receiving water.

2. Description

Sand filters can be constructed either above or below ground as an end-of-pipe BMP. They are most commonly constructed with impermeable liners to guard against native material clogging pore spaces and to prevent filtered water from entering the groundwater system. Water that infiltrates through the filer is collected by a pervious pipe system and conveyed to a downstream outlet. Some designs incorporate a layer of peat to enhance pollutant removal capabilities of the sand filter, thus making discharge to an infiltration trench a possibility.

3. Applicability

Sand filters can be constructed either above or below ground as an end-of-pipe BMP and are generally only appropriate for relatively small drainage areas (< 5 ha). Also, very little is known in regard to sand filter performance and cold-climate operation and maintenance.

4. Effectiveness

This method of water quality enhancement should not be generally applied without a detailed feasibility assessment.

5. Water Quantity

Sand filters are not suitable for water quantity control as they should not be designed to handle large influent flows.

6. Water Quality

Sand filters have been found to be effective in removing pollutants, however, little is know about their performance in winter or freshet conditions.

7. Design Considerations

A sand filter application is illustrated in Figure 5.17. Sand filters can be constructed as surface filters or subsurface filters as part of the stormwater conveyance system. Surface filters are normally covered by a grass layer. Filters are lined with impermeable membranes to restrict clogging of the filter material by native material.

5.3.5.8 Oil / Grit Separators

1. Purpose

Oil / grit separators are a variation of traditional settling tanks. They are designed to capture sediment and trap hydrocarbons suspended in runoff from impervious surfaces as the runoff is conveyed through a storm sewer network.

2. Description

An Oil / grit separator is a belowground, pre-cast concrete structure that takes the place of a conventional manhole in a storm drain system. The separator implements the use of permanent pool storage in the removal of hydrocarbons and sediment from stormwater runoff before discharging into receiving waters or storm sewer systems.

3. Applicability

Oil / grit separators are typically applied to urban-based drainage areas (<5 ha) where ponds or wetlands are not feasible or cost effective. Separators are best applied in areas of high impervious cover where there is a potential for hydrocarbon spills and polluted sediment discharges. Typical applications include parking lots, commercial and industrial sites, petroleum service stations, airports, and residential developments (pre-treatment of ponds / wetlands or as part of a treatment train).

4. Effectiveness

Oil / grit separators can be effective for treatment of stormwater pollution at its source. Source control is favourable for water quality control since the dilution of pollutants in stormwater becomes problematic in terms of effective treatment as the drainage area increases. Depending on land use, drainage area, site conditions, and hydrology, some oil / grit separators may be effective in reducing TSS. See Table 5.2 for oil / grit separator design types and characteristics.

5. Water Quantity

Oil / grit separators implement the use of permanent pool storage for removal of stormwater pollution. However, they are not designed to provide extended detention storage, and thus provide little flow attenuation.

6. Water Quality

Oil / grit separators vary in design and performance. Separators that do not incorporate a high flow bypass have been found to be generally ineffective in removing / containing hydrocarbon and sediment pollutants, because of a continuous process of re-suspension and settling of solids.

7. Design Considerations

Three chambered oil / grit separators operate most effectively when constructed offline. A flow splitter should be used to direct excess flow back to the conveyance system or to some other control practice. Only low flows should be directed to the separator.

Bypass separators are installed online, and high flows do not affect the performance of the unit.

See Figures 5.18 and 5.19 for illustrations of the two types of oil / grit separators.

5.3.6 BMP Screening and Selection

5.3.6.1 Initial Screening

There are a range of stormwater BMP options available for most applications. The selection of an appropriate BMP or group of BMPs depends first on the objectives for stormwater management defined for a particular catchment area, as well as the constraints placed on the feasibility of particular BMPs by physical site factors.

Once the objectives for stormwater management are well defined and the site constraints are understood individual BMPs can be evaluated in terms of their overall effectiveness as a stormwater control facilities. The evaluation of overall effectiveness must include both water quantity and water quality objectives.

Also, each stormwater management BMP has associated with it certain advantages and disadvantages that may allow the viable options for stormwater management to be reduced for a particular development area.

Table 5.2 summarizes the advantages and disadvantages of a number of BMPs.

TABLE 5.2
BMP ADVANTAGES AND DISADVANTAGES

BMP	Advantages	Disadvantages
Wet pond	· Capable of removing soluble as well as solid pollutants · Provides erosion control · Habitat, aesthetic, and recreation opportunities provided · Relatively less frequent maintenance schedule	· More costly than dry ponds · Permanent pool storage requires larger land area · Could have negative downstream temperature impacts · Could be constrained by topography or land designations · Sediment removal relatively costly when required
Dry pond	· Batch mode has comparable effectiveness to wet ponds · Not constrained by land area required by wet ponds · Can provide recreational benefits	· Potential re-suspension of contaminants · More expensive O&M costs than wet ponds (batch mode)
Wetlands	· Pollutant-removal capability similar to wet ponds · Offers enhanced nutrient-removal capability · Potential ancillary benefits, including aviary, terrestrial, and aquatic habitat	· Requires more land area than wet ponds · Could have negative downstream temperature impacts · Could be constrained by topography or land designations · Potential for some nuisance problems
Infiltration trenches	· Potentially effective in promoting recharge and maintaining low flows in small areas · May be appropriate as secondary facility where maintenance of groundwater recharge is a concern · No thermal impact · No public safety concern	· Appropriate only to small drainage areas (<2 ha) and residential land uses · Constrained by native soil permeability's · Usually requires pre-treatment device · Potential contamination of groundwater must be investigated · Generally ineffective for water quantity control · High rate of failure due to improper siting and design, pollutant loading, and lack of maintenance
Infiltration basins	· Potentially effective in promoting recharge and maintaining low flows in small areas · May be appropriate as secondary facility where maintenance of groundwater recharge is a concern · No thermal impact · No public safety concern	· Appropriate only to relatively small drainage areas (<5 ha) and residential land uses · Constrained by native soil permeability's · Pre-treatment is recommended · Potential contamination of groundwater must be investigated · Generally ineffective for water quantity control · High rate of failure due to improper siting and design, pollutant loading, and lack of maintenance

Table 5.2 continued

Filter strips	· Water quality benefits may be realized if part of overall SUM plan (i.e., as secondary facility) · Effective in filtering out suspended solids and intercepting precipitation · May reduce runoff by reducing overland flow velocities, increasing time of concentration, and increasing infiltration · Can create wildlife habitat · No thermal impact	· Limited to small drainage areas (<2 ha) with little topographic relief · Uniform sheet flow through vegetation difficult to maintain · Effectiveness in freeze / thaw conditions questionable
Sand filters	· Generally effective in removing pollutants, are resistant to clogging and are easier / less expensive to retrofit compared to infiltration trenches	· Not suitable for water quantity control · Generally applicable to only small drainage areas (<5 ha) · Do not generally recharge groundwater system · May cause aesthetic / odour problems · O&M costs generally higher than other end-of-pipe facilities
Oil / Grit Separators (3-Chamber Separator)	· Offline, 3-chamber (oil, grit, discharge) separators may be appropriate for commercial, industrial, large parking, or transportation-related areas less than 2 ha	· Scour and resuspension of trapped pollutants in heavy rainfall events · Difficult to maintain · Relatively high O&M costs · Online design of 3-chamber separators has resulted in poor pollutant removal performance
Oil / Grit Separators (Bypass Separator)	· Bypass prevents the scouring and resuspension of trapped pollutants in heavy rainfall events · Effective in removing sediment load when properly applied as a source control for small areas · Effective in trapping oil / grease from run off.	· Relatively high capital costs compared to manholes · Applicable for drainage areas less than 5 ha.

5.3.6.2 Physical Constraints

Site characteristics may be the factor that will ultimately determine the applicability of individual or combinations of BMPs. Physical factors that need to be assessed in evaluating the suitability of BMPs include:

- topography
- soils stratification
- depth to bedrock
- depth to seasonably high water table
- drainage area.

Table 5.3 summarizes physical constraints associated with various BMP types.

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

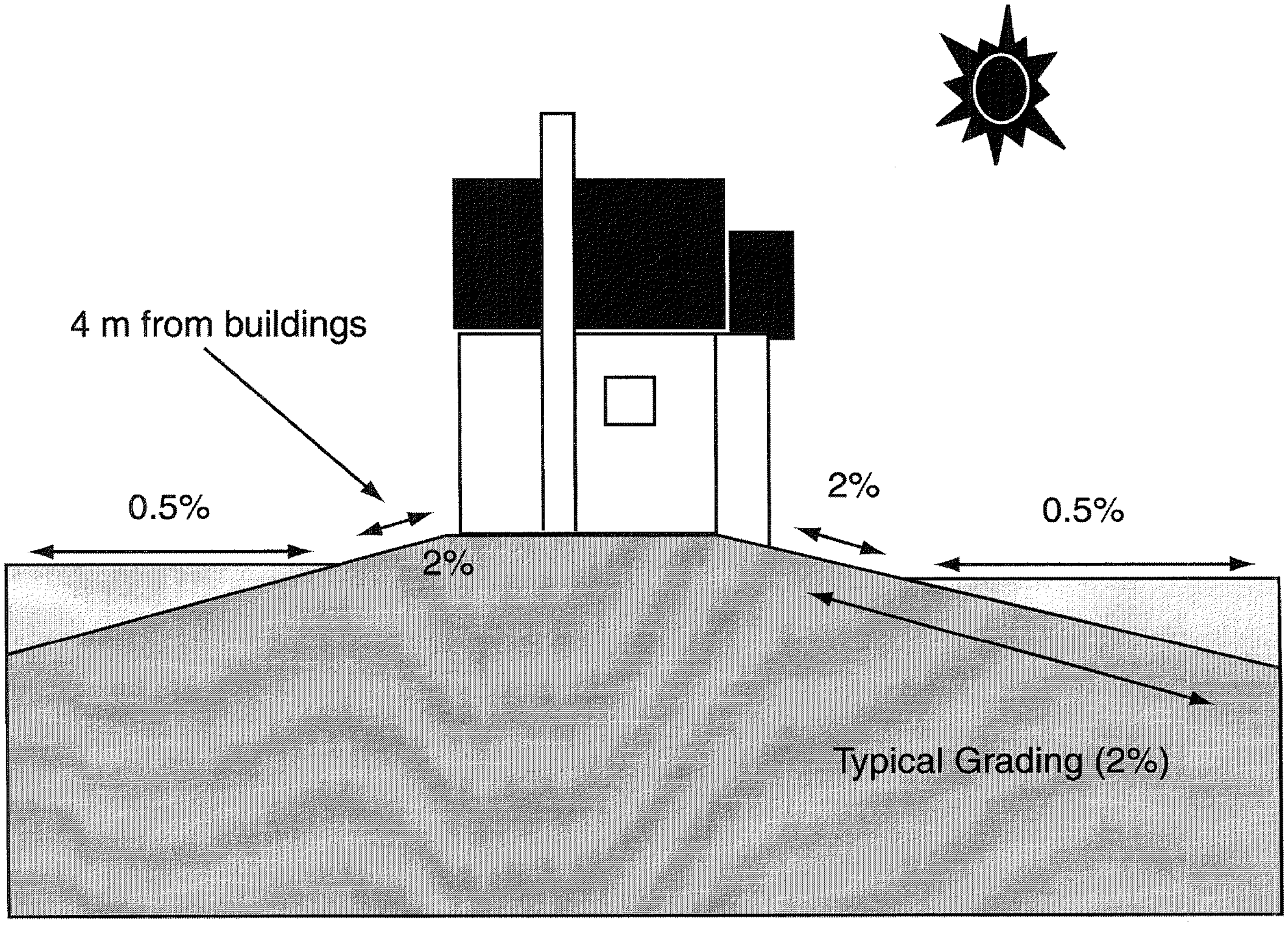


Figure 5.1
Lot Grading Guidelines

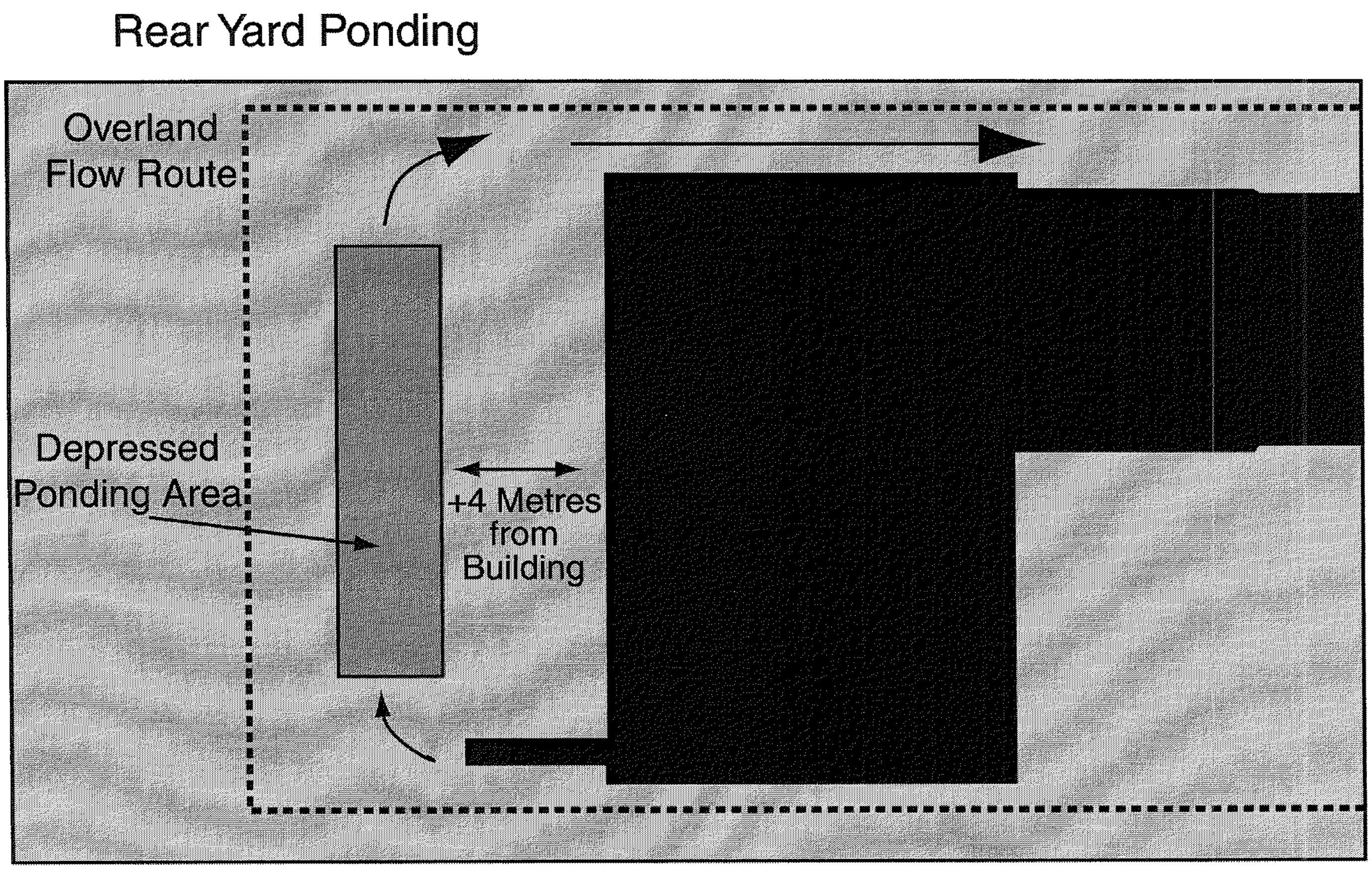


Figure 5.2
Rear Lot Ponding Guidelines

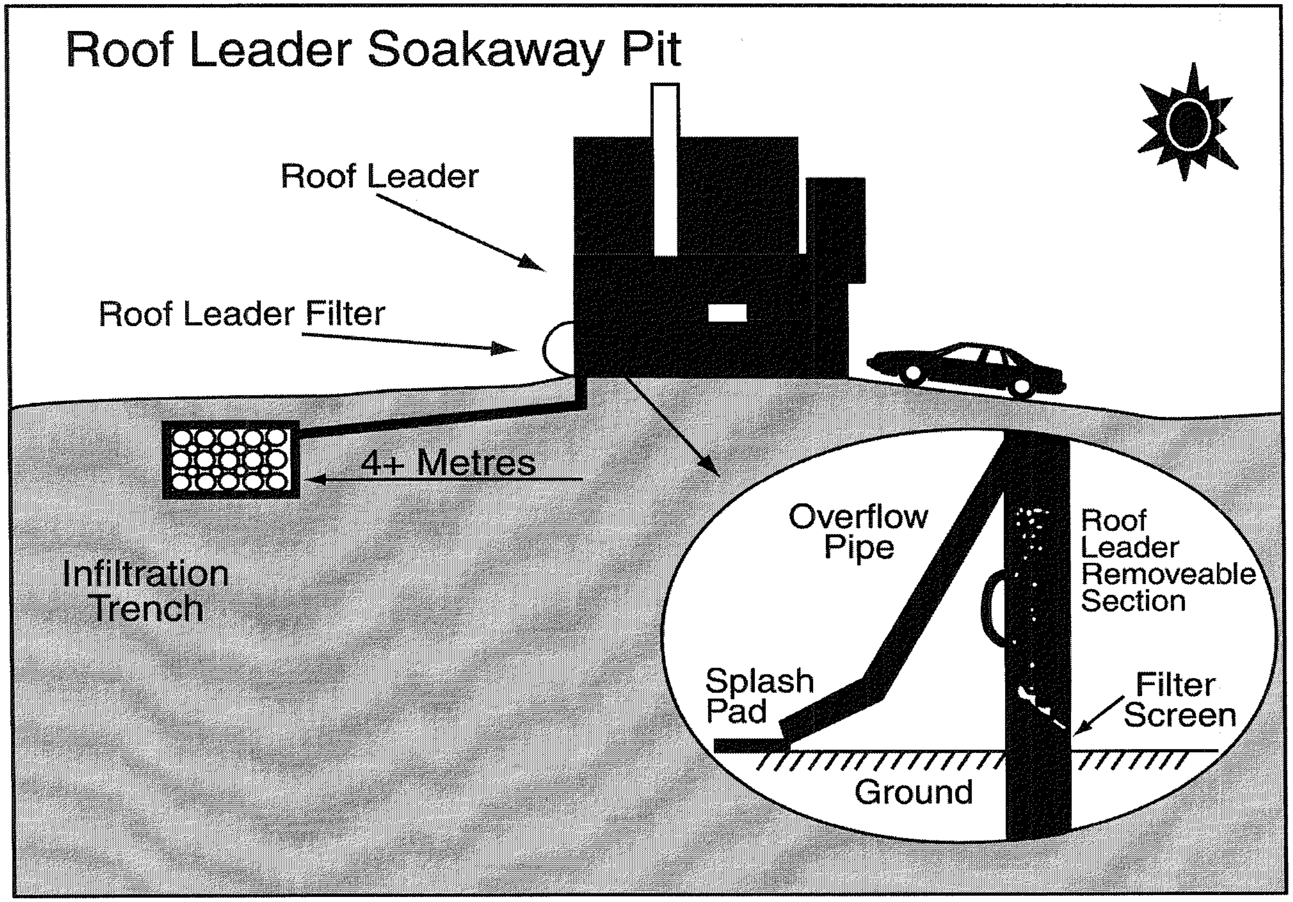


Figure 5.3
Infiltration System with Roof Leader Filter

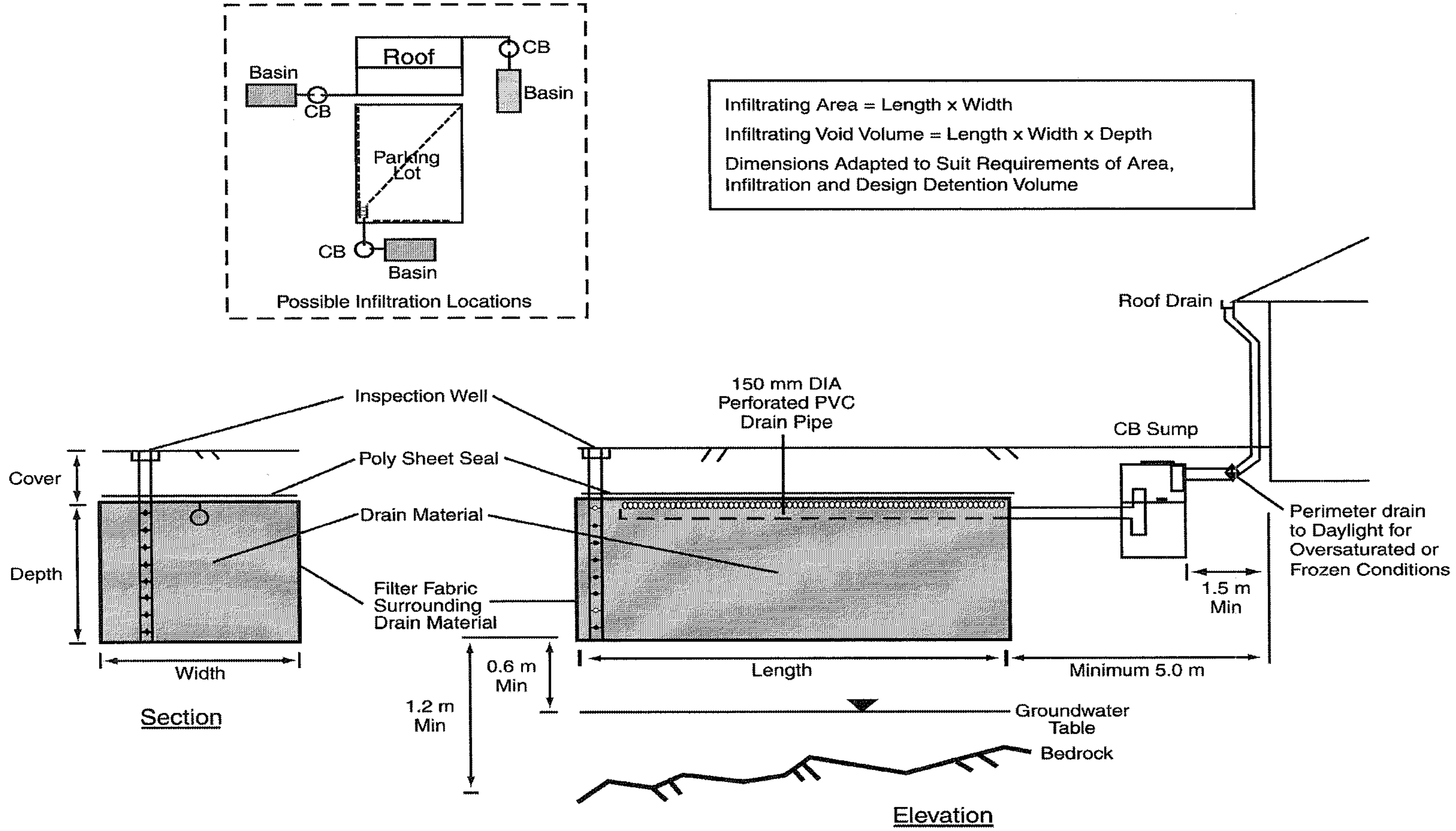


Figure 5.4
Infiltration System with Pretreatment Sump

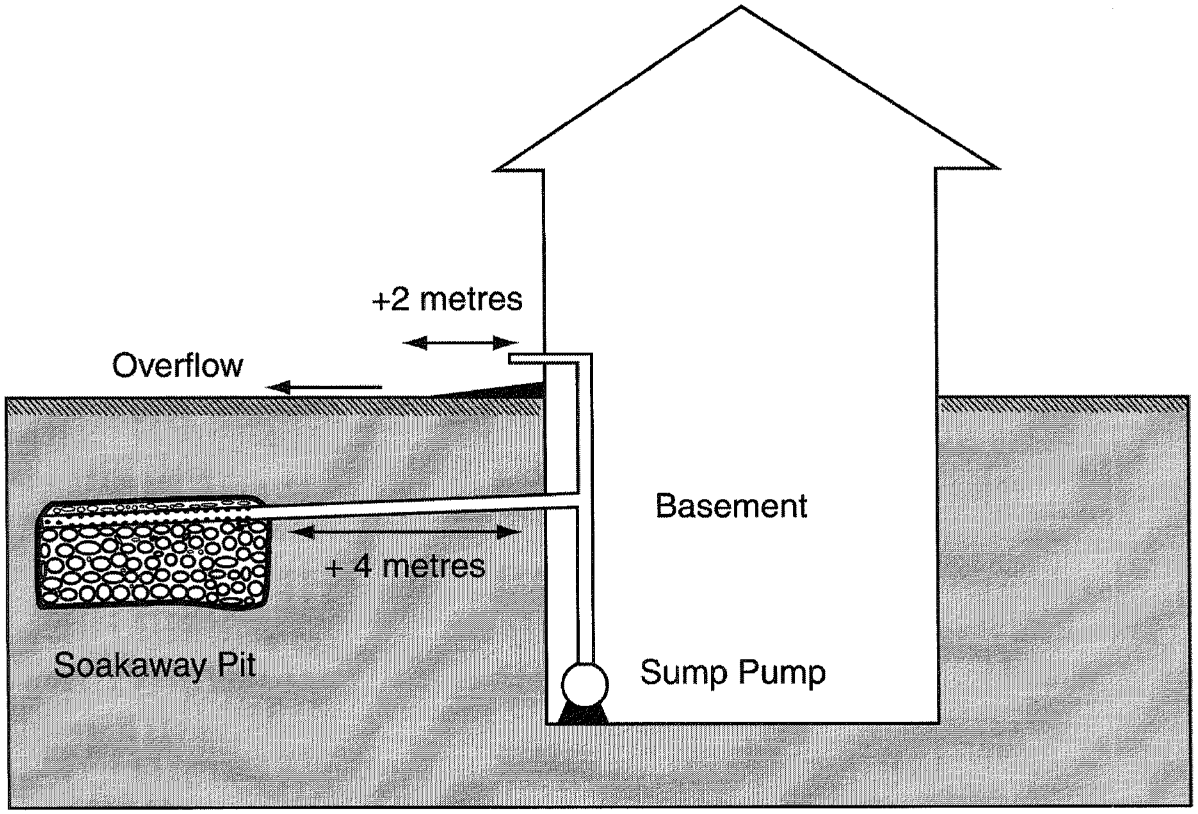


Figure 5.5
Sump Pump Foundation Drainage

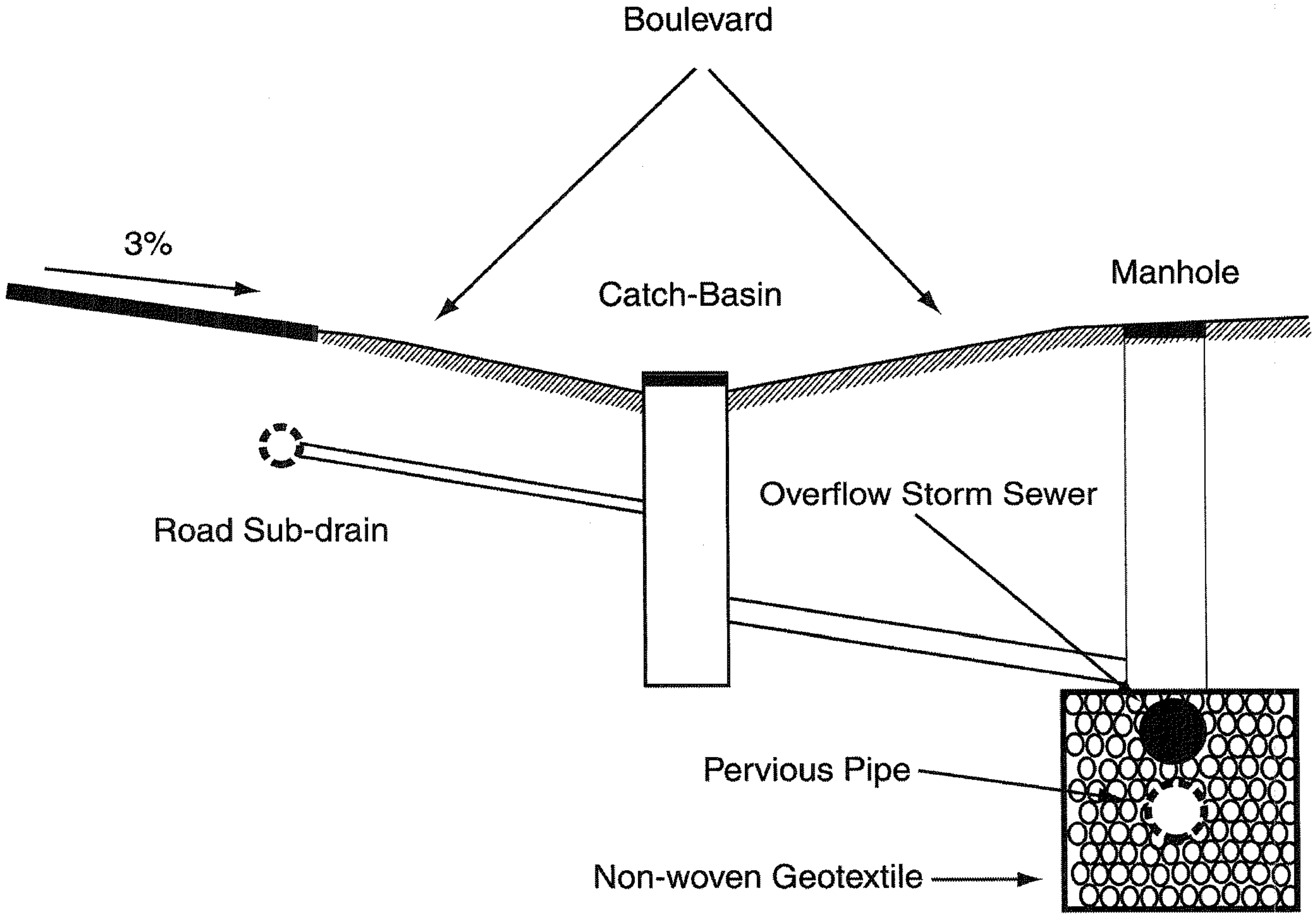


Figure 5.6
Pervious Pipe System

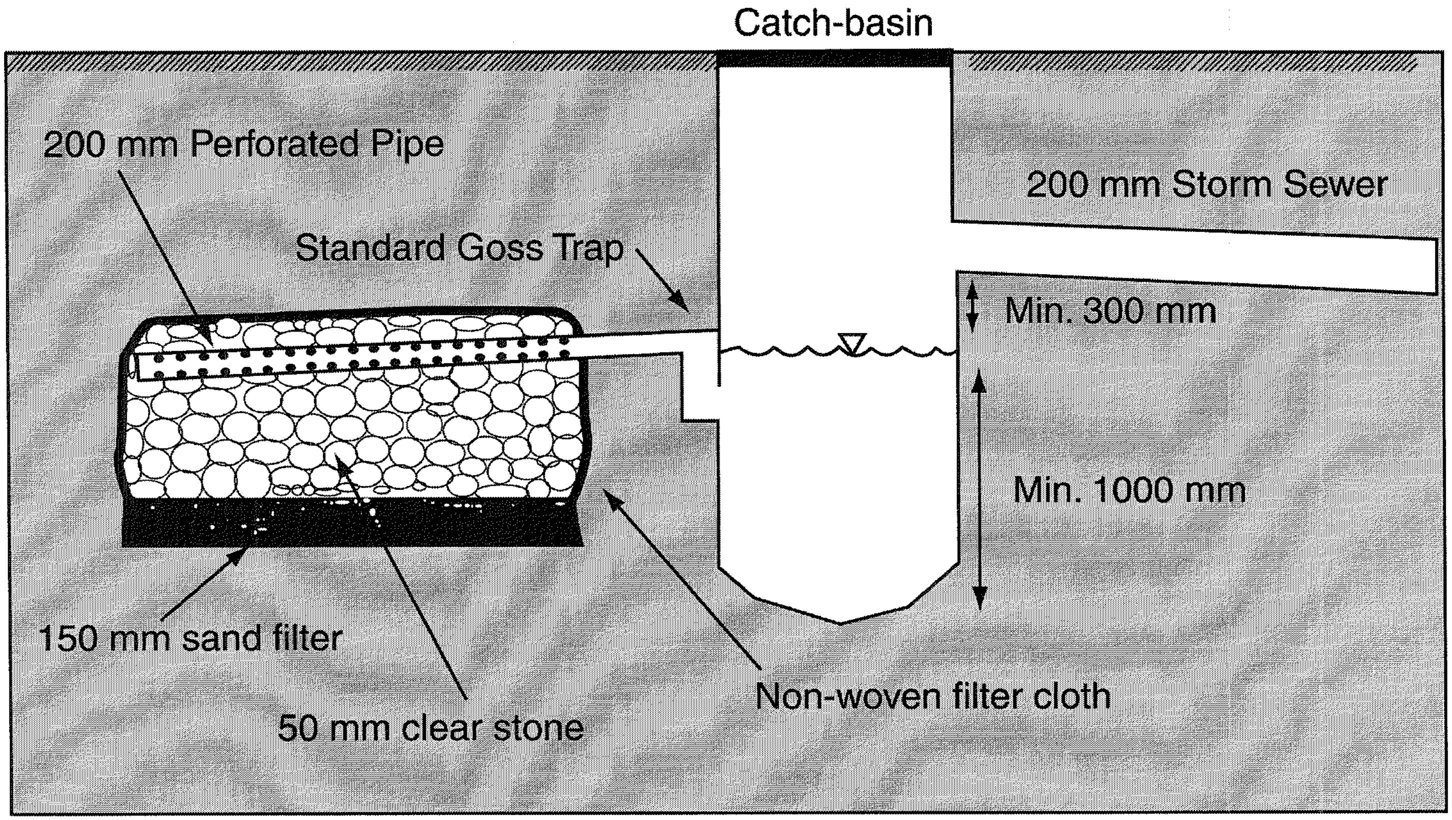
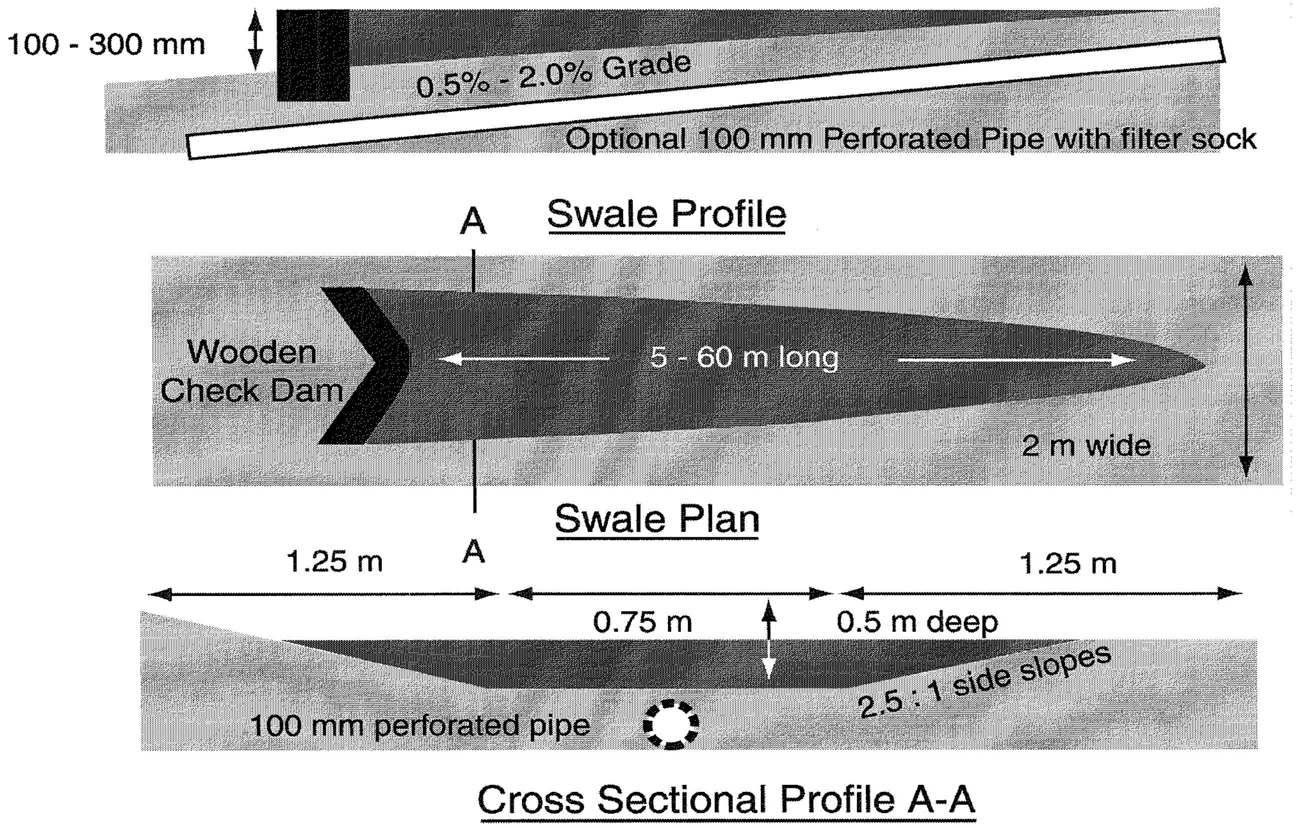


Figure 5.7
Pervious Catch-Basin



Swale Profile

Swale Plan

Cross Sectional Profile A-A

Figure 5.8
Grass Swale Design

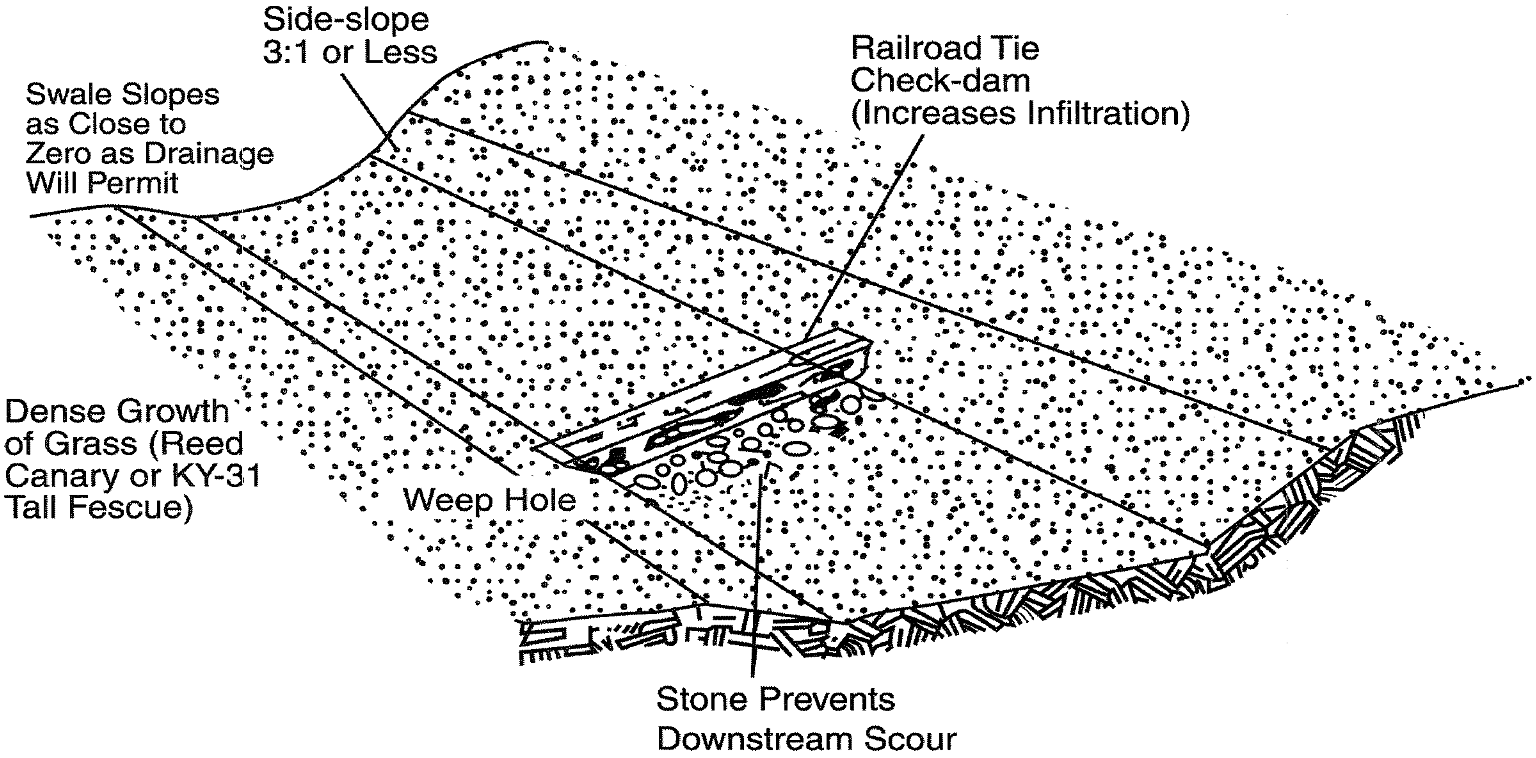


Figure 5.9
Grass Swale with Check Dam

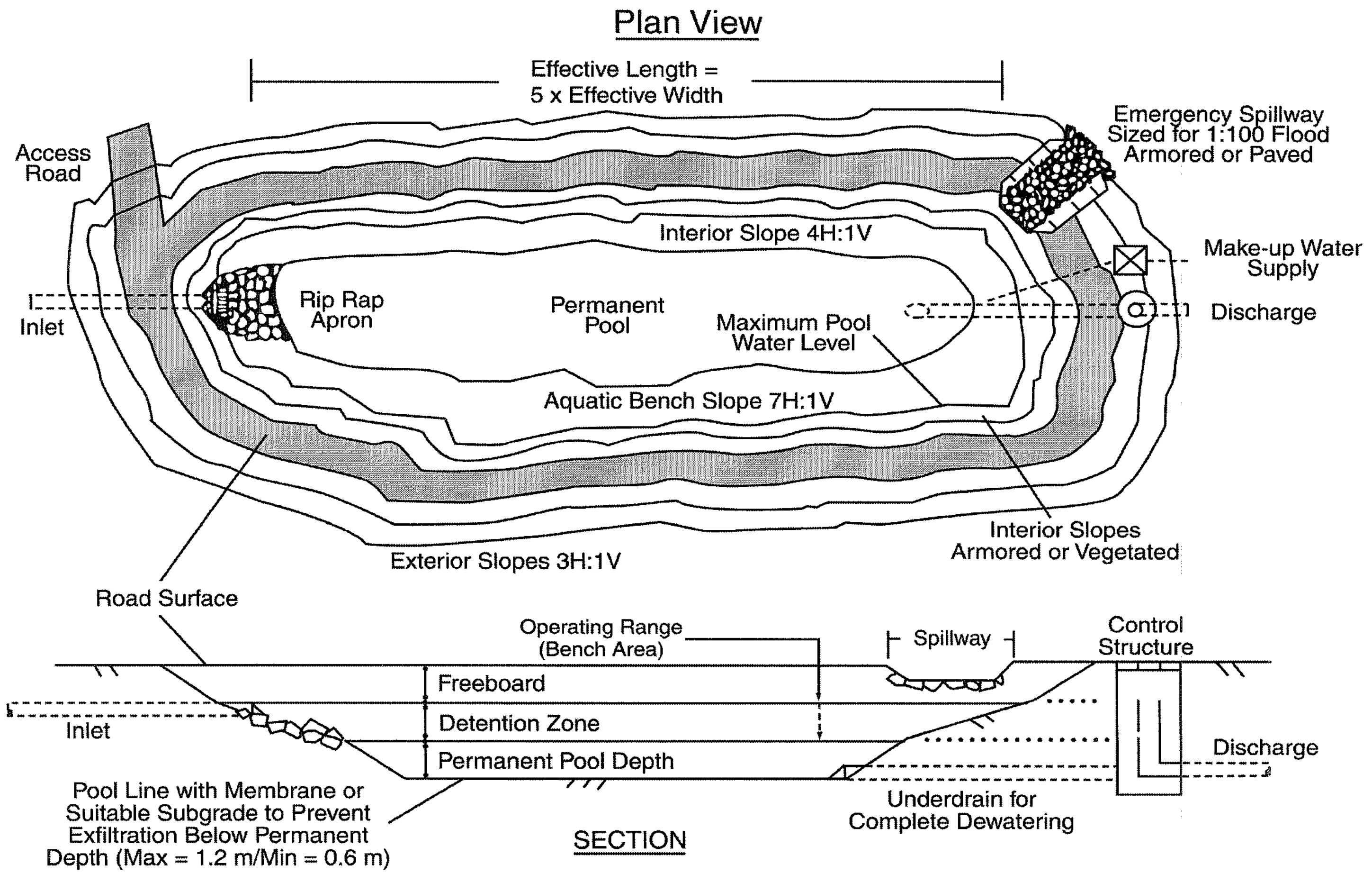


Figure 5.10
Wet Detention Pond Plan and Sections

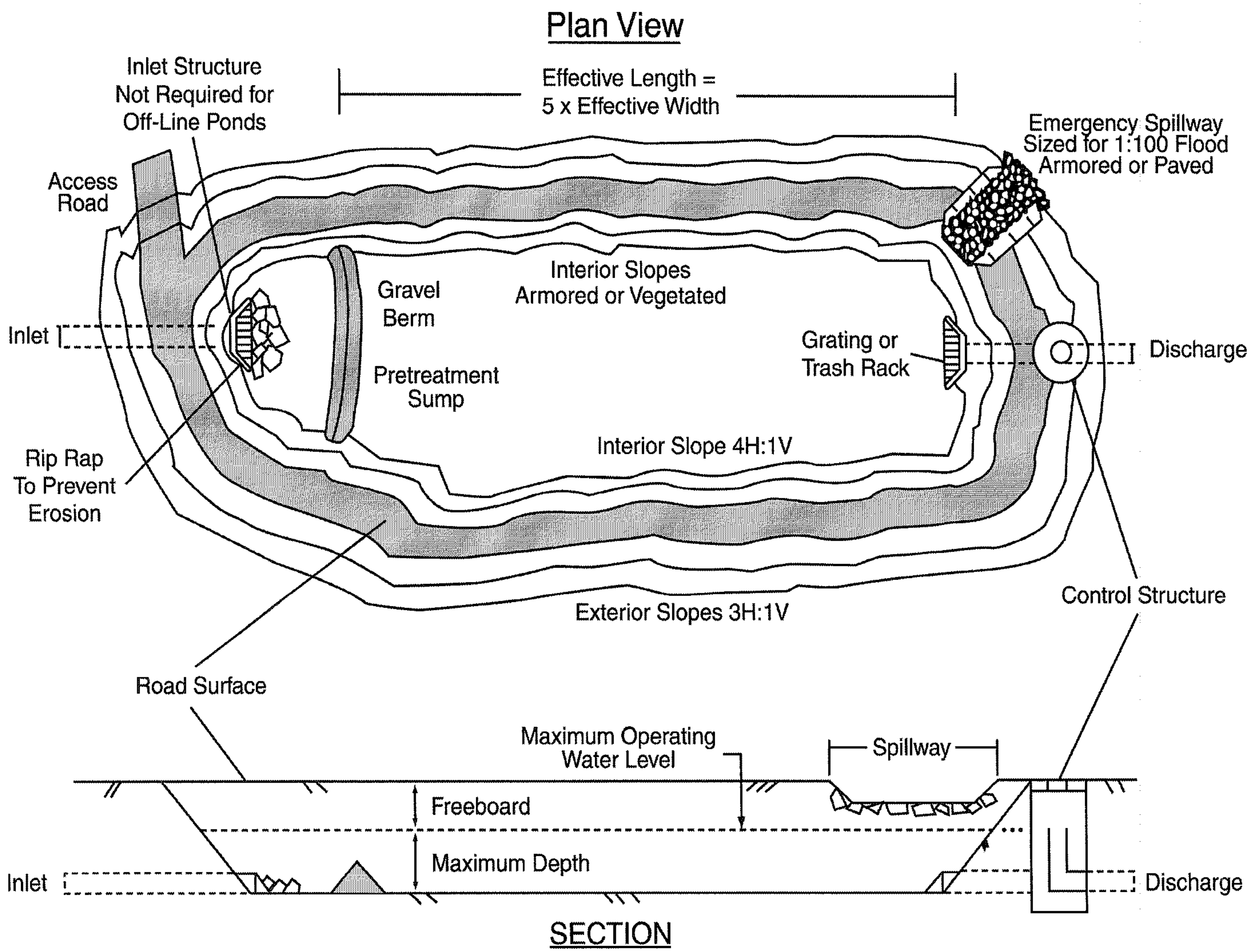
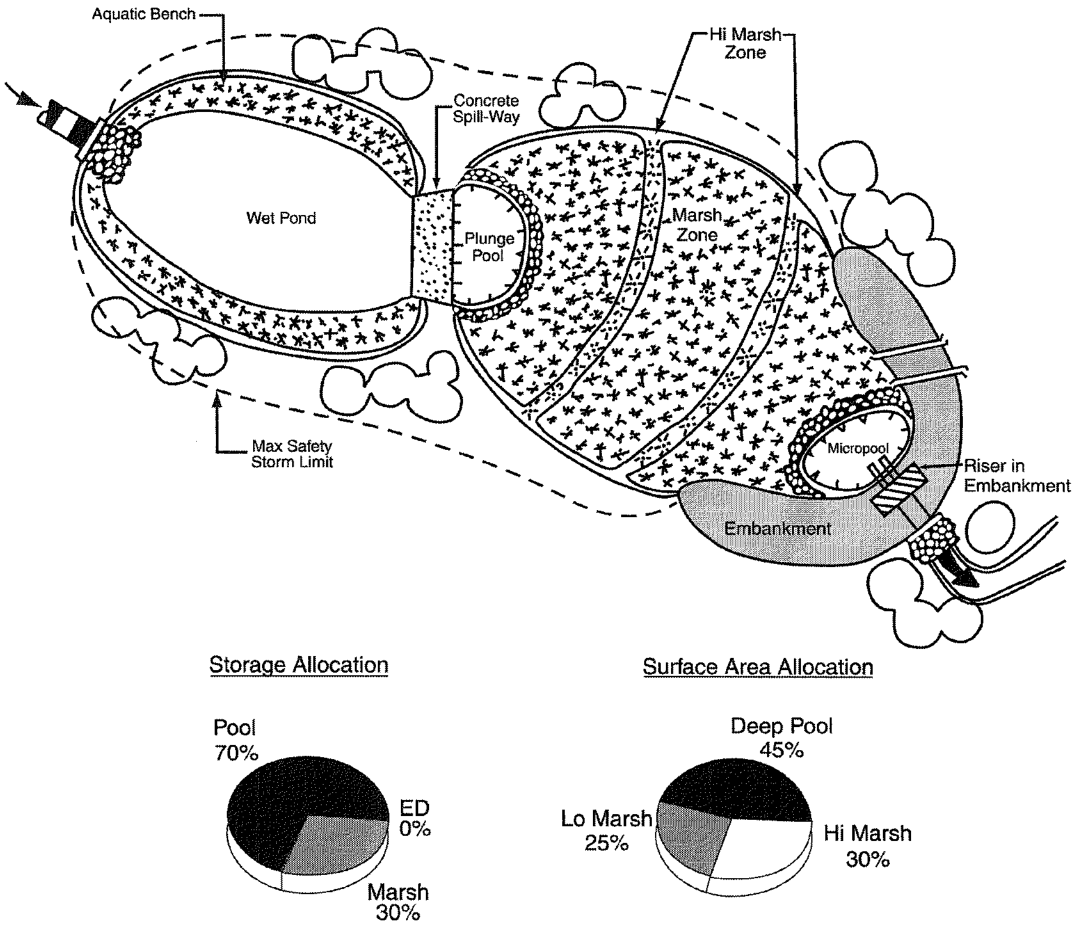


Figure 5.11
Dry Detention Pond Plan and Sections



The pond/wetland system consists of two separate cells - a deep pond leading to a shallow wetland. The pond removes pollutants, and reduces the space required for the system.

Figure 5.12
Stormwater Wetland

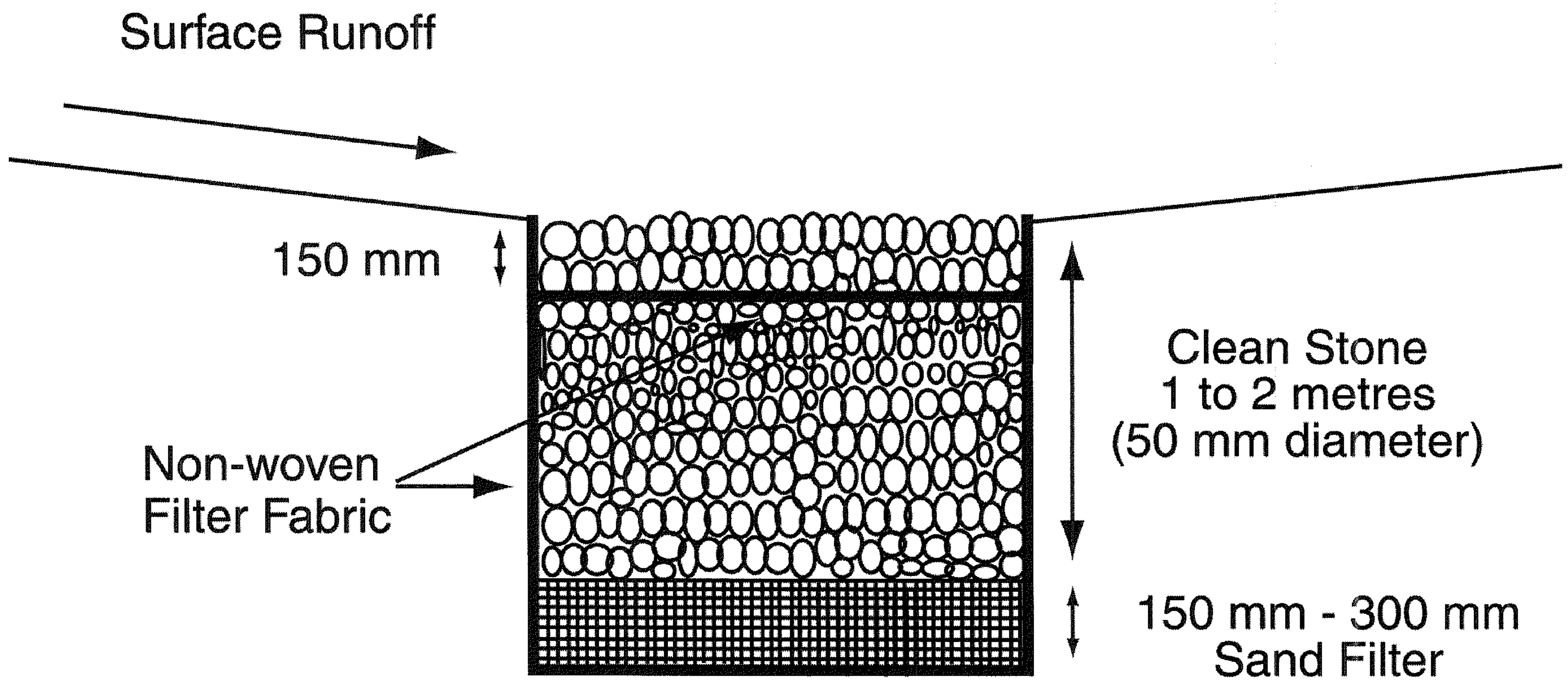


Figure 5.13
Surface Infiltration Trench

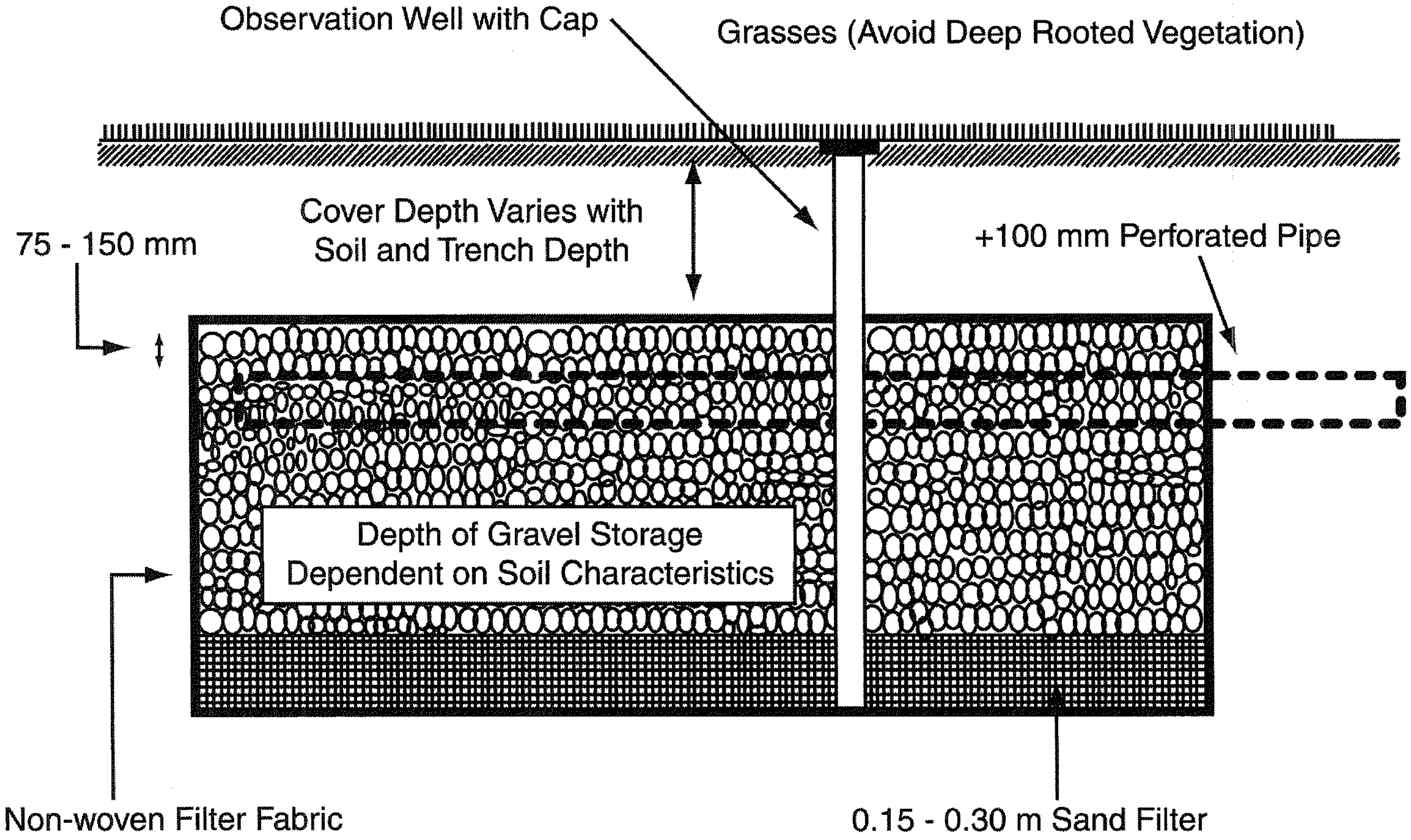


Figure 5.14
Subsurface Infiltration Trench

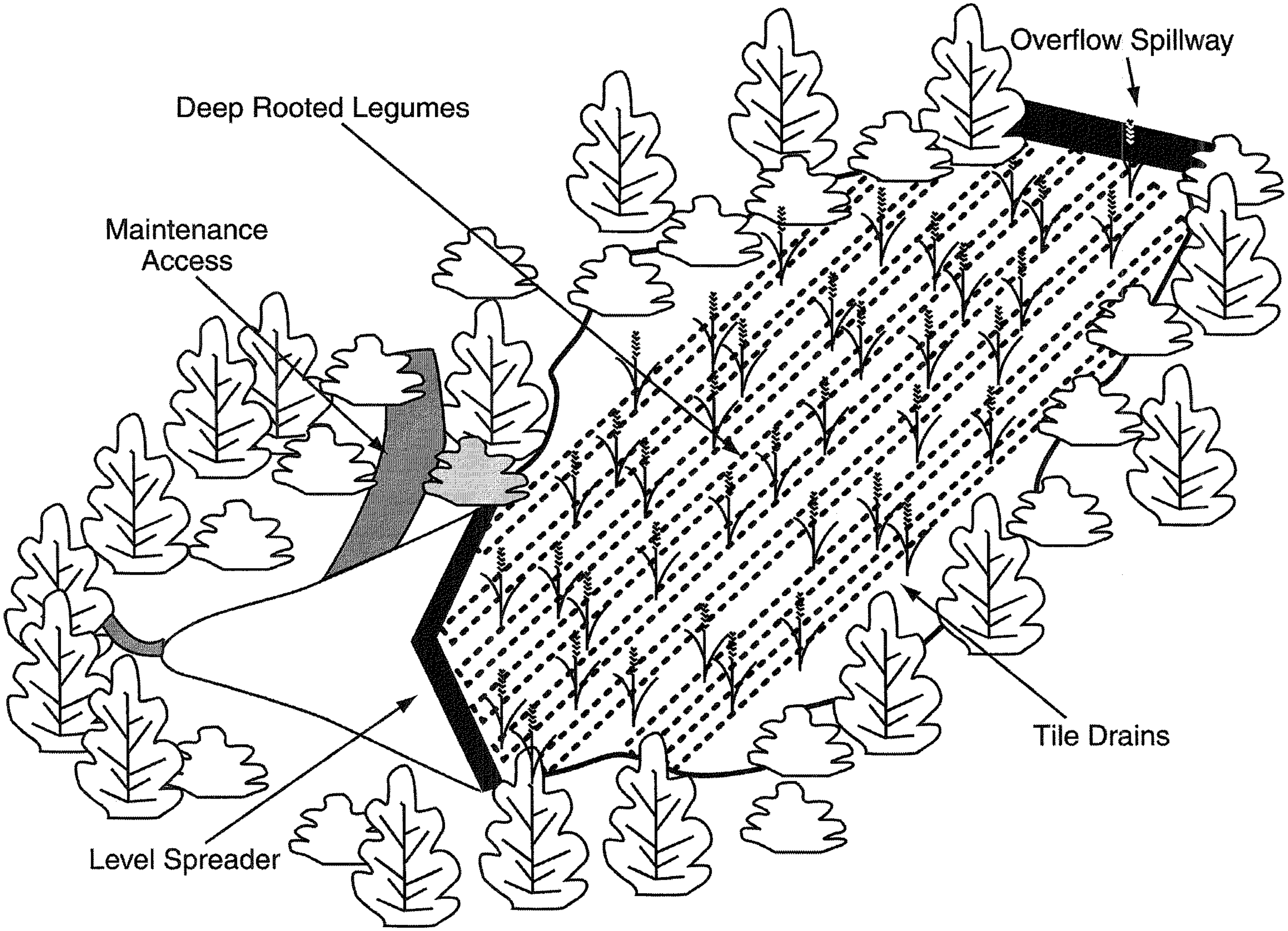


Figure 5.15
Infiltration Basin

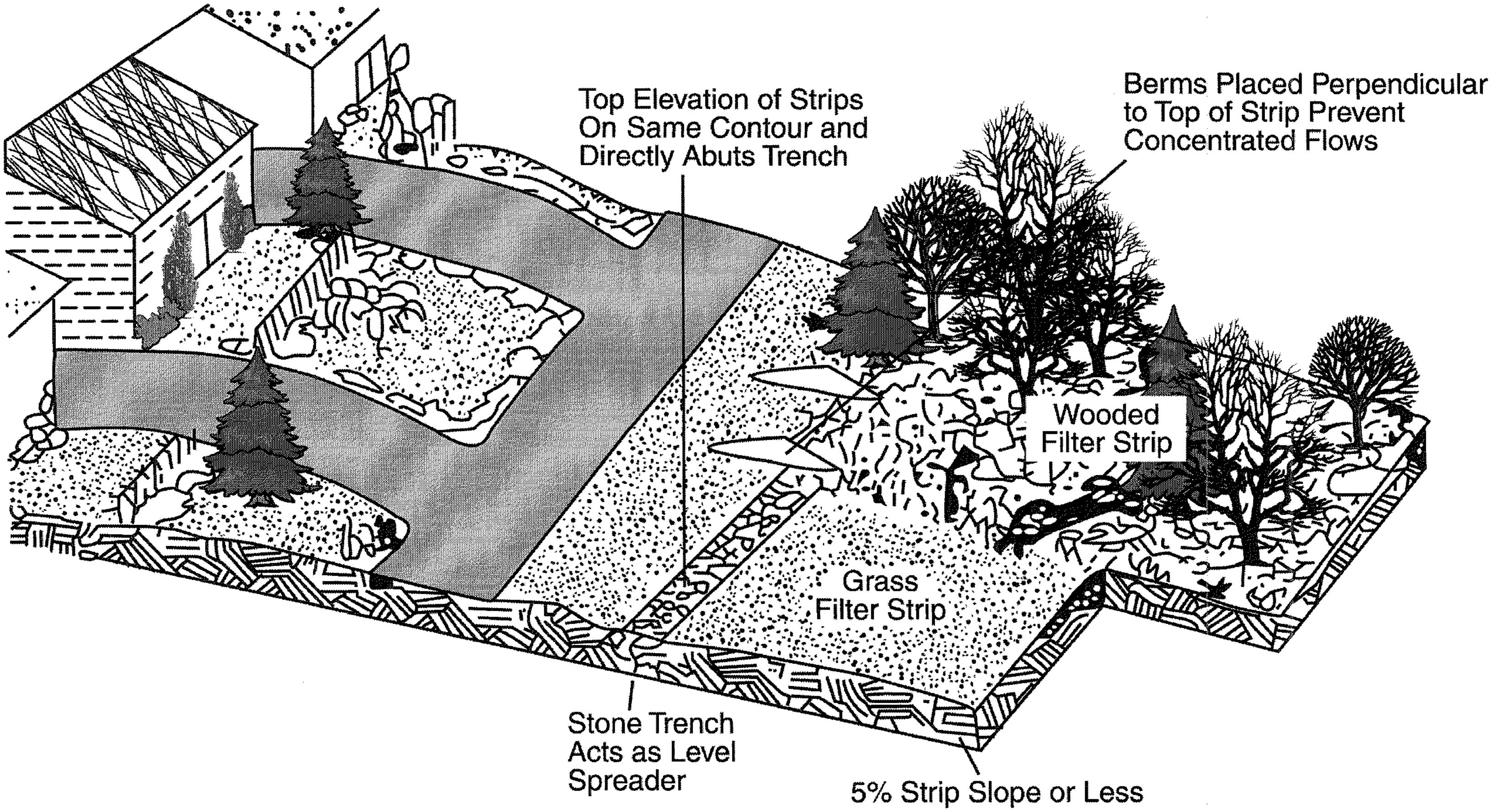


Figure 5.16
Schematic of Grassed and Wooded Filter Strip

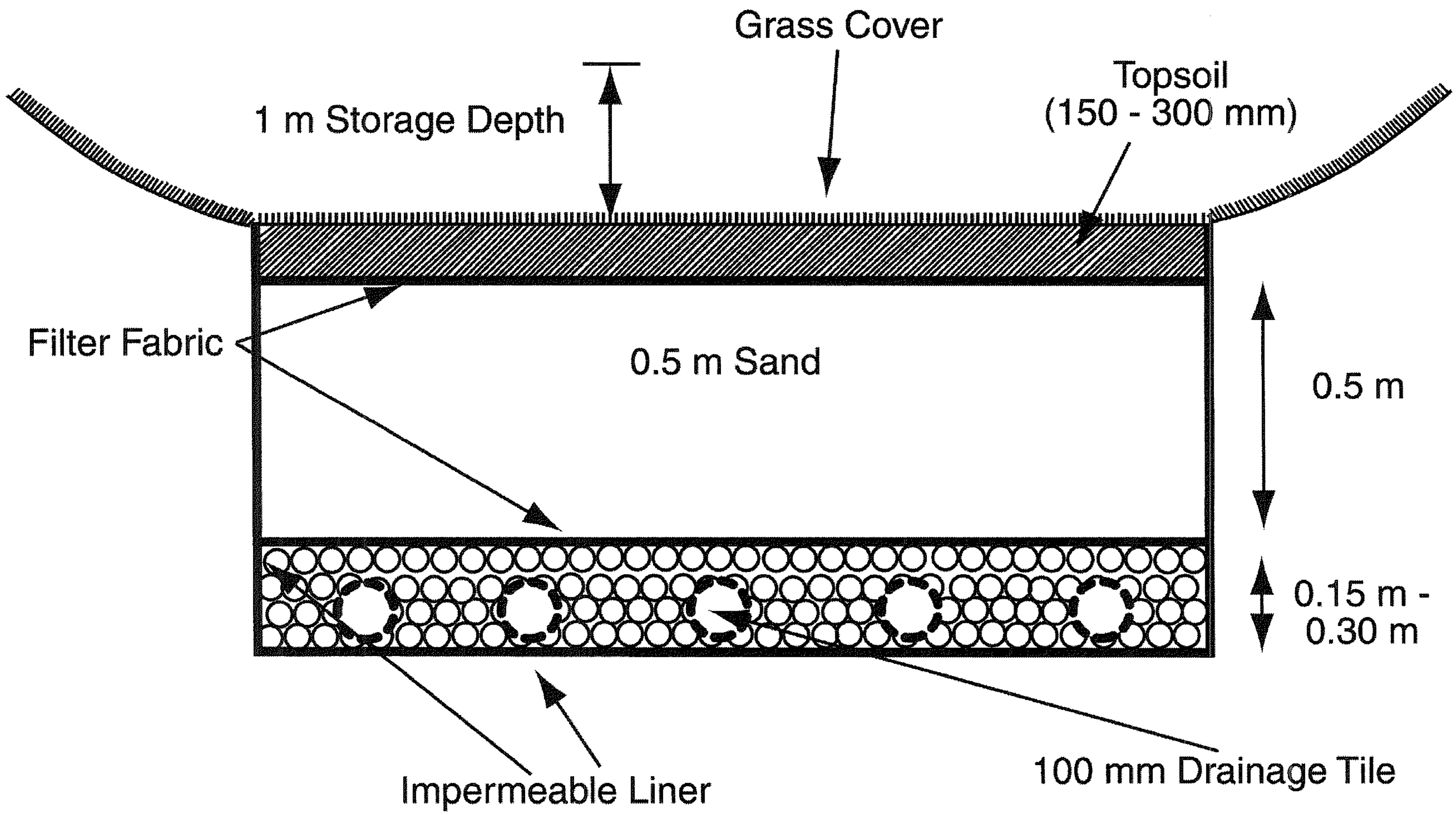


Figure 5.17
Sand Filter Cross Section Profile

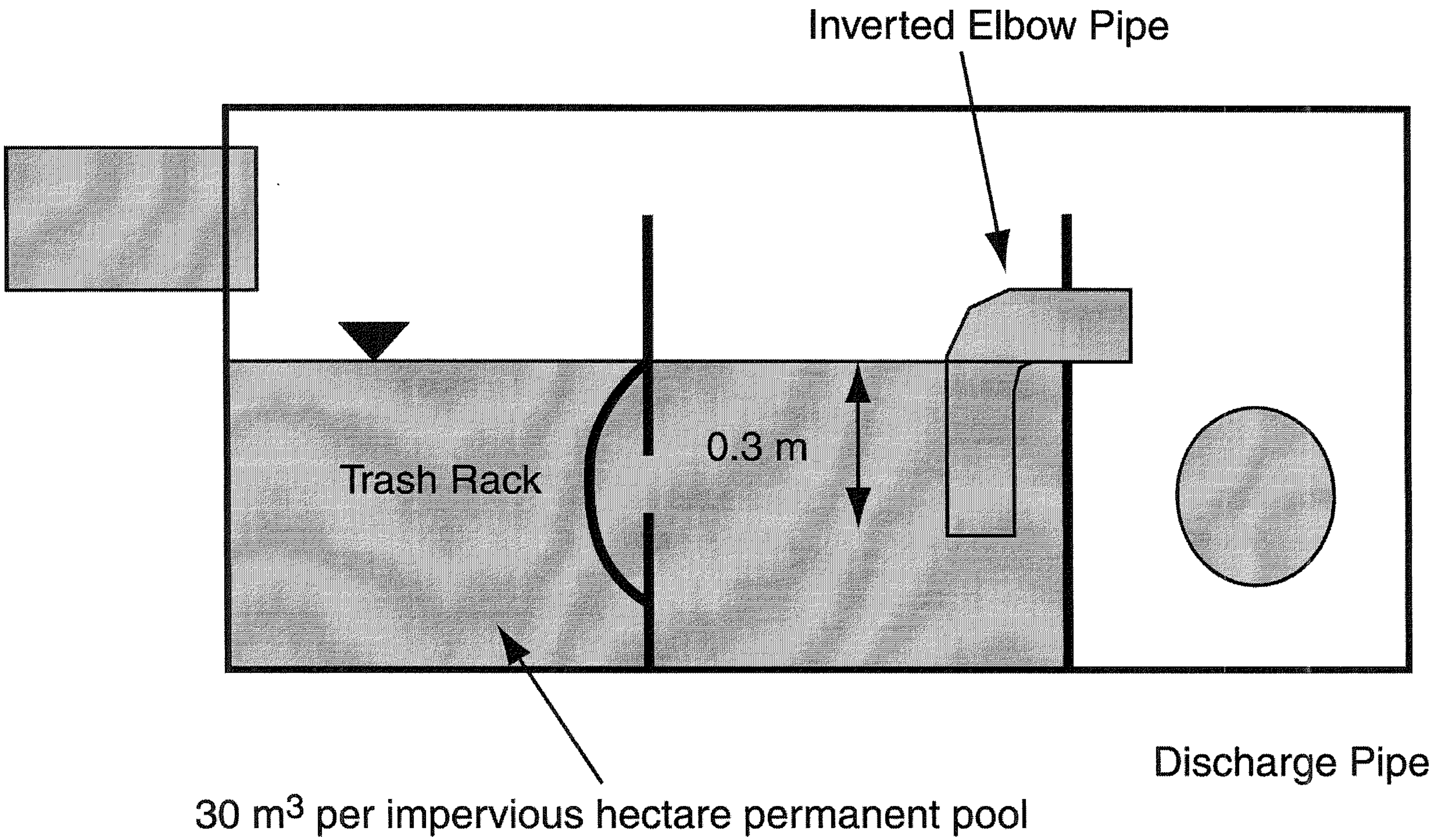


Figure 5.18
Standard 3 Chamber Oil / Grit Separator

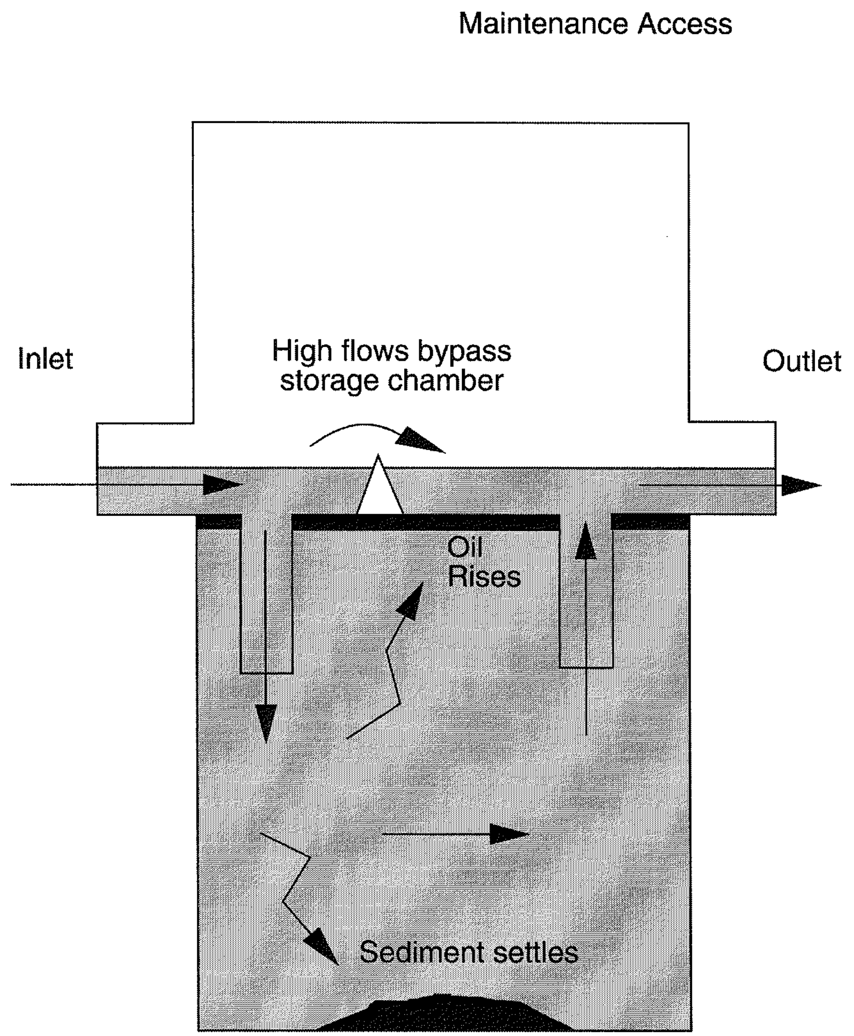
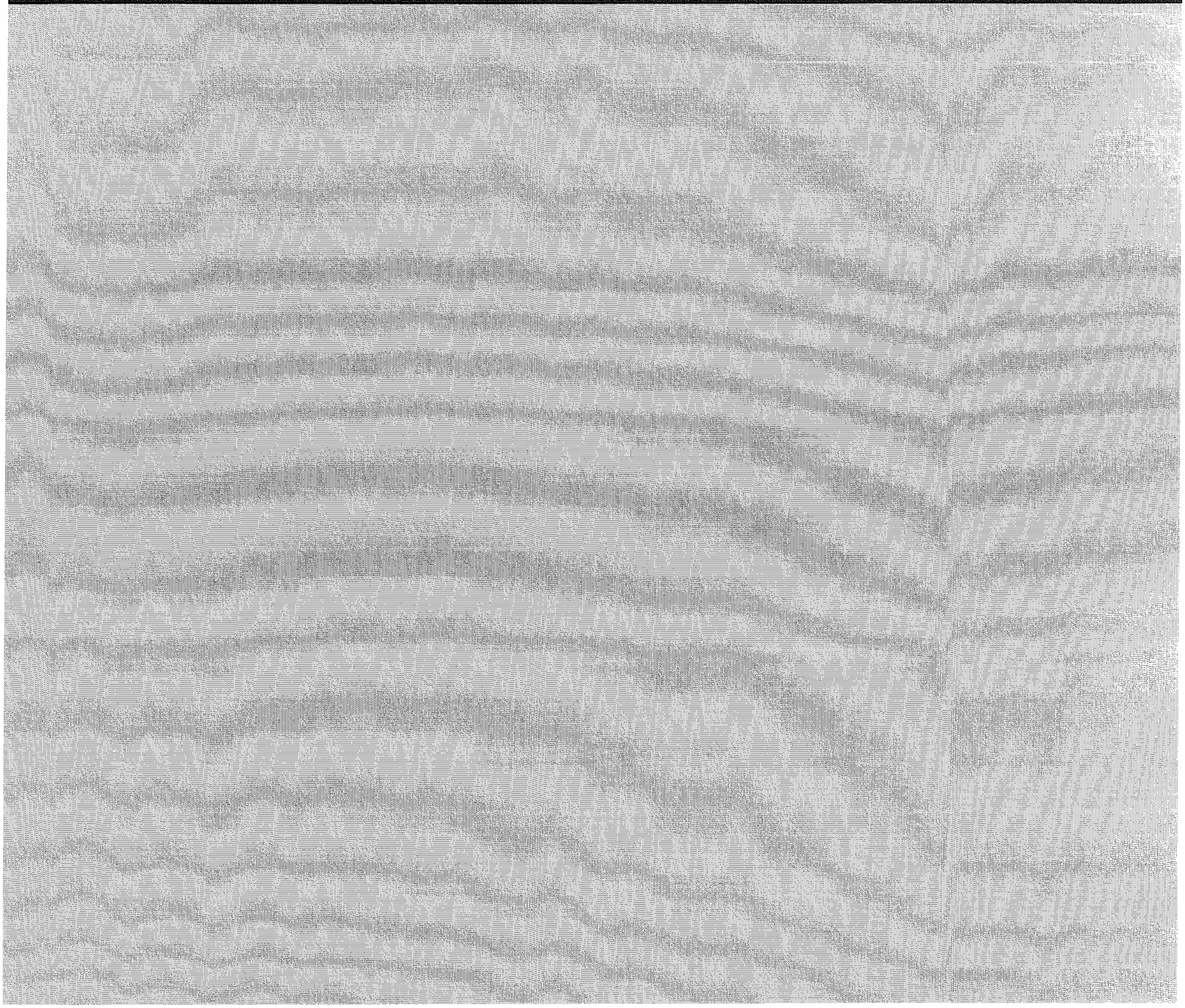


Figure 5.19
Bypass Separator



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

CHAPTER 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 X B) / 100]

R = 60 + 50 – [(60 X 50) /100] = 110 - 30 = 80% 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.

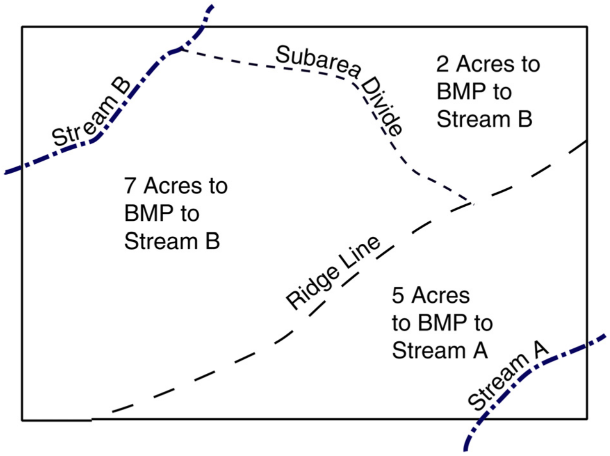
Example 4-2: TSS Removal Rates at Sites with Multiple Discharge Points and Subareas

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 H
CREDIT VALLEY CONSERVATION – LOW IMPACT DEVELOPMENT GUIDANCE DOCUMENTS

1.0 INTRODUCTION

1.1 About This Document

The *Low Impact Development Stormwater Management Planning and Design Guide* (*LID SWM Guide*) has been developed by Credit Valley Conservation (CVC) and Toronto and Region Conservation Authority (TRCA) as a tool to help developers, consultants, municipalities and landowners understand and implement more sustainable stormwater management planning and design practices in their watersheds. Many jurisdictions have defined the term low impact development. For this document, the following definition, adapted from the United States Environmental Protection Agency (U.S. EPA, 2007) will be used:

> Low impact development (LID) is a stormwater management strategy that seeks to mitigate the impacts of increased runoff and stormwater pollution by managing runoff as close to its source as possible. LID comprises a set of site design strategies that minimize runoff and distributed, small scale structural practices that mimic natural or predevelopment hydrology through the processes of infiltration, evapotranspiration, harvesting, filtration and detention of stormwater. These practices can effectively remove nutrients, pathogens and metals from runoff, and they reduce the volume and intensity of stormwater flows.

The *LID SWM Guide* provides information and direction to assist engineers, ecologists and planners with landscape-based stormwater management planning and the selection, design, construction and monitoring of sustainable stormwater management practices. The focus of this guide is on guidance regarding the planning and design of structural low impact development practices for stormwater management.

The practice of managing stormwater is continuing to evolve as the science of watershed management and understanding of our watersheds grow. Effective management of stormwater is critical to the continued health of our streams, rivers, lakes, fisheries and terrestrial habitats. CVC and TRCA believe that an improved understanding of the municipal and environmental planning process and the requirements for stormwater management will lead to improvements in management practices and an increasingly standardized and streamlined approach to addressing stormwater throughout the CVC and TRCA watersheds.

The *LID SWM Guide* is intended to augment the Ontario Ministry of the Environment (OMOE) Stormwater Management Planning and Design Manual (2003). The OMOE manual provides design criteria for “conventional” end-of-pipe stormwater management practices such as wet ponds and constructed wetlands but provides only limited information about lot level and conveyance controls. The OMOE manual does, however, emphasize the use of a “treatment train” approach to reduce the impacts of stormwater runoff. A treatment train approach – a combination of lot level, conveyance, and end-of-pipe stormwater management practices – is usually required to meet the multiple objectives of stormwater management, which include maintaining the hydrologic cycle, protecting water quality, and preventing increased erosion and flooding.

This *LID SWM Guide* focuses on a number of lot level and conveyance stormwater management practices that have been used extensively in Europe, the United States, British Columbia and at demonstration sites in Ontario. These practices have only recently been considered for broad application in Ontario as part of the treatment train approach. These low impact development practices include green roofs, bioretention, permeable pavement, soakaways, perforated pipe systems, enhanced grass swales, dry swales and rainwater harvesting. The *LID SWM Guide* recommends and supports the use of the treatment train approach for stormwater management. Accordingly, the reader is urged to refer to the OMOE manual (OMOE, 2003), as a guide for incorporating more traditional practices such as wet ponds and wetlands into the overall stormwater management planning and design process.

The *LID SWM Guide* is not intended to limit innovation or restrict the use of creative solutions for stormwater management. Indeed, the OMOE, CVC, TRCA and partner municipalities encourage the development of innovative designs and technologies.

1.2 History and Context

In 1993, the Ontario Ministry of the Environment and Energy and Ontario Ministry of Natural Resources released three policy documents that focused on integrating water resources management and urban planning:

- Water Management on a Watershed Basis: Implementing an Ecosystems Approach;
- Subwatershed Planning; and
- Integrating Water Management Objectives into Municipal Planning Documents.

These documents heralded a new approach to water management in Ontario. They emphasized the need for an increased focus on protecting the natural environment and the need to expand stormwater management practices to pay more attention to water quality and environmental concerns, in addition to addressing traditional water quantity concerns.

In 1994, the Ontario Ministry of Environment and Energy (OMOEE) released two practitioners’ guides to stormwater management planning:

- Stormwater Quality Best Management Practices; and
- Stormwater Management Practices Planning and Design (SMPPD) Manual.

The OMOEE SMPPD manual was intended to introduce practitioners to a broad range of stormwater management facilities that were designed to not only offset the effects of hydrologic changes of urban development on streams and rivers, but also address water quality and erosion impacts. The SMPPD manual also provided detailed guidance on how to design and build multi-purpose facilities and included sections on operations and maintenance, as well as environmental monitoring requirements.

In 2003, OMOE released a new Stormwater Management Planning and Design Manual, which significantly updated and expanded on the 1994 version. The 2003 manual:

- provided an overview of the impacts of urbanization on the hydrologic cycle and stream ecosystems;
- addressed the evolution of the watershed planning process and implications for the design process;
- incorporated water quantity, erosion control, water quality protection, and water balance principles into the selection and design of stormwater management practices (SWMPs);
- documented the performance of SWMPs that have been monitored;
- incorporated design considerations for SWMPs in cold climates;
- provided information on new “state of the art” SWMPs;
- addressed infill projects;
- updated operations and maintenance requirements;
- provided design examples for SWMPs;
- updated material related to planting strategies and the function of plant materials in SWMP design;
- provided examples of retrofitting SWMPs; and
- outlined integrated planning for stormwater management.

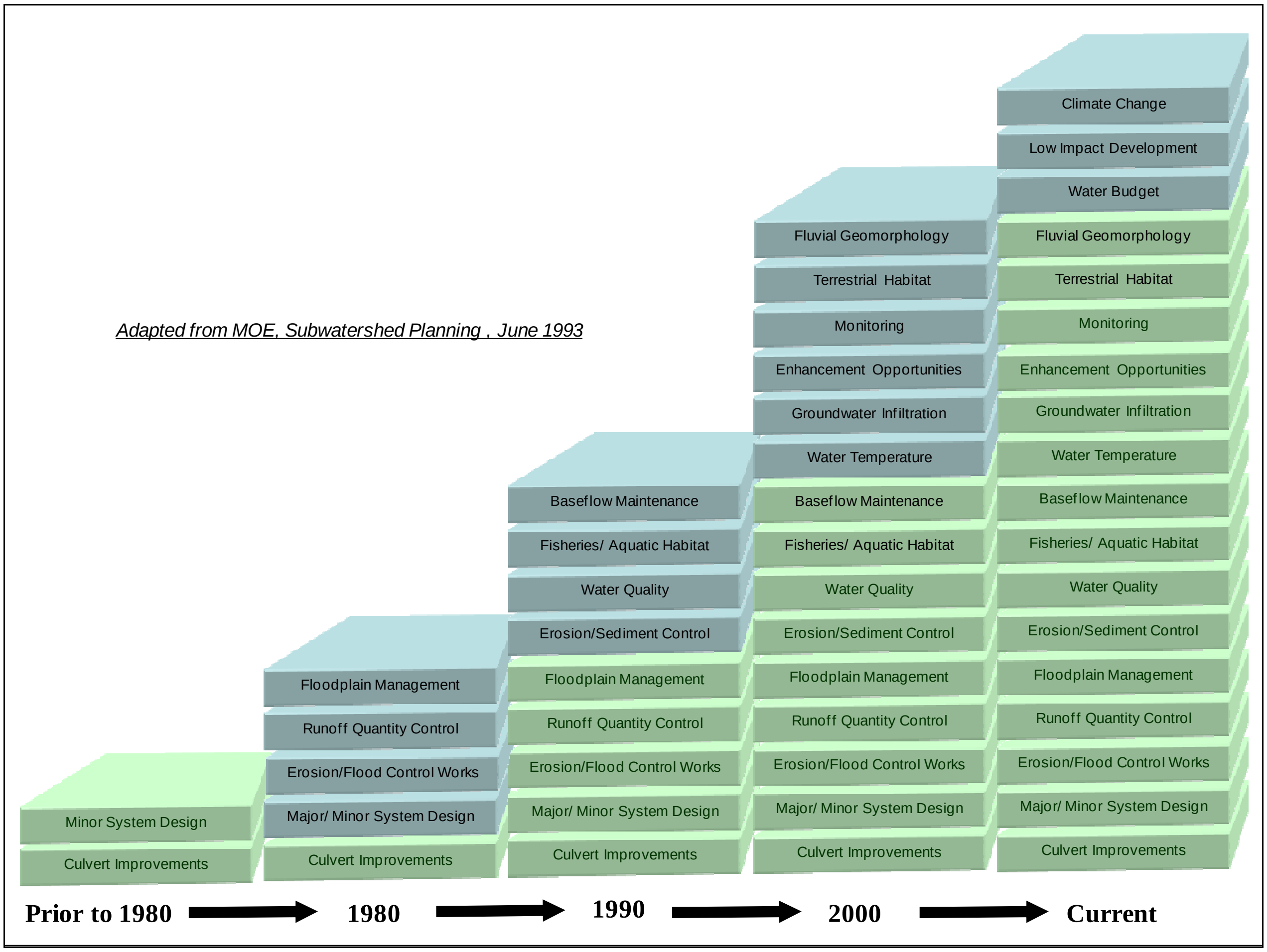
1.3 The Evolution of Stormwater Management

During the past three decades, the practice of stormwater management has evolved. In the mid 1970s, attempts to control runoff flow rates from urban developments were initiated. By the late 1980s, water quality became an additional focus and in the late 1990s, approaches to mitigate accelerated stream channel erosion were introduced. Lot level stormwater management approaches have been advocated in Ontario since 1995 (OMMAH, 1995), but widespread application has yet to occur. Today, with improvements in our understanding of watershed systems and the potential impacts urbanization can have on aquatic ecosystems, stormwater management addresses a broad suite of issues including fluvial geomorphology (stream channel forming processes), groundwater resources and the protection of aquatic and terrestrial habitats (Figure 1.2.1).

Municipalities, with the support of conservation authorities, review stormwater management facilities and plans designed to address this multitude of concerns. This has led to an increasing complexity in stormwater management planning and design including:

- increasingly complex stormwater management facilities and best management practices;
- the need to involve more inter-disciplinary expertise in studies to define environmental opportunities and constraints;
- expanding requirements for multi-purpose stormwater management facilities; and,
- increased emphasis on the treatment train approach and use of multiple types of controls to address environmental issues.

Figure 1.2.1 Evolution of stormwater management practice in Ontario



Adapted from MOE, Subwatershed Planning , June 1993

CVC and TRCA have been extensively involved in integrated watershed-wide environmental monitoring for many years. The results of this monitoring have shown that the environmental health of many watersheds continue to decline as urbanization increases. This environmental deterioration has taken place despite widespread compliance with provincial and conservation authority requirements for stormwater management planning and facility design. Conventional stormwater management, which focuses on controlling peak flow rate and the concentration of suspended solids, has failed to address the widespread and cumulative hydrologic modifications in watersheds that increase the volume of stormwater, increase the runoff rate, and cause excessive erosion and degradation of stream channels. Conventional stormwater management also fails to adequately treat other pollutants of concern, such as nutrients, pathogens and metals.[1]

CVC's recent Credit River Water Management Strategy Update concludes that continued use of what are currently considered "state of the art" stormwater management practices will lead to continued degradation of the watershed, jeopardizing the health of the Credit's world class fishery and other valued environmental resources (CVC, 2007b). To protect the health of the Credit River watershed, the updated water management strategy calls for an immediate shift to more proactive and innovative stormwater management systems that include low impact development practices. TRCA's Rouge River Watershed Plan (TRCA, 2007c), Humber River Watershed Plan (TRCA, 2008a) and Don River Watershed Plan (TRCA, 2009a) reach similar conclusions about the inability of conventional stormwater management practices to protect the health of rivers and the need for low impact development approaches. In addition, the Rouge River Watershed Plan concludes that widespread implementation of LID practices in new and existing developments could increase the resiliency of the watershed system to some anticipated impacts of climate change on baseflow and channel erosion (TRCA, 2007d).

Recent research (Aquafor Beech Ltd., 2006) has suggested that current practices to offset the hydrologic effects of urbanization are insufficient to prevent increased channel erosion and deterioration of aquatic habitats. In many cases, even small incremental changes in watershed hydrology commensurate with an increase in impermeable surfaces of 4%, can result in changes to stream channel characteristics and aquatic communities. To offset these impacts, an increased emphasis on maintaining natural water balance and replicating the predevelopment hydrologic cycle is required (Aquafor Beech Ltd., 2006).

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Finally the 2003 OMOE Stormwater Management Planning and Design Manual, though reflective of current technology is rapidly becoming dated, since much of the material it reviewed dates from 1999. In the last five years, over 30 state-of-the-science stormwater management manuals and guidelines have been released in locations such as Maryland, Washington State, British Columbia, Minnesota, Pennsylvania and Oregon. The objective of maintaining predevelopment water balance, use of the treatment train approach and application of low impact development practices are all becoming common practice in these jurisdictions.

Two recent documents, one prepared by the City of Toronto and the other prepared by the Greater Vancouver Regional District summarize how the approach to stormwater management needs to change.

> Rainwater should be treated as a resource to nourish and enhance the City's environment. Management should begin where precipitation hits the ground according to the priority of source, conveyance, end-of-pipe and finally, stream restoration measures (City of Toronto, 2006).
>
> There is a need for a change in the philosophy of treating runoff from one of stormwater management to rainwater management (GVRD, 2005).

This is why CVC and TRCA commissioned the development of a stormwater management guide to provide guidance on the kind of cutting edge practices that are needed to protect the health of the CVC and TRCA watersheds. The *LID SWM Guide* draws on published research, literature and local studies to provide planning and design guidance that reflects regional policies, practices and climate. It provides information and guidance on the following:

- how to integrate stormwater management into the urban planning process;
- how to design, construct and maintain a range of LID stormwater management practices; and
- the kinds of environmental and performance monitoring that should be carried out.

Acknowledging that it will not always be possible to maintain the predevelopment water budget of a site, predicted increases in runoff from land development that cannot be mitigated through stormwater infiltration practices should be minimized through practices that either evapotranspire (*e.g.,* green roofs, bioretention), or harvest runoff for non-potable uses (*i.e.*, rainwater harvesting). In areas where development has already taken place, LID can be used as a retrofit practice to reduce runoff volumes, pollutant loadings, and the overall impacts of existing developments on receiving waters. LID practices can include:

- conservation site design strategies (*i.e.*, non-structural LID practices);

- infiltration practices;
- rainwater harvesting;
- runoff storage and evapotranspiration;
- runoff conveyance;
- filtration practices; and
- landscaping.

Studies show that implementing LID practices can have multiple positive environmental effects including:

- protection of downstream resources;
- abatement of pollution;
- recharge of groundwater;
- improvement of water quality;
- improvement of habitat;
- reduced downstream flooding and erosion;
- conservation of water and energy; and
- improved aesthetics in streams and rivers.

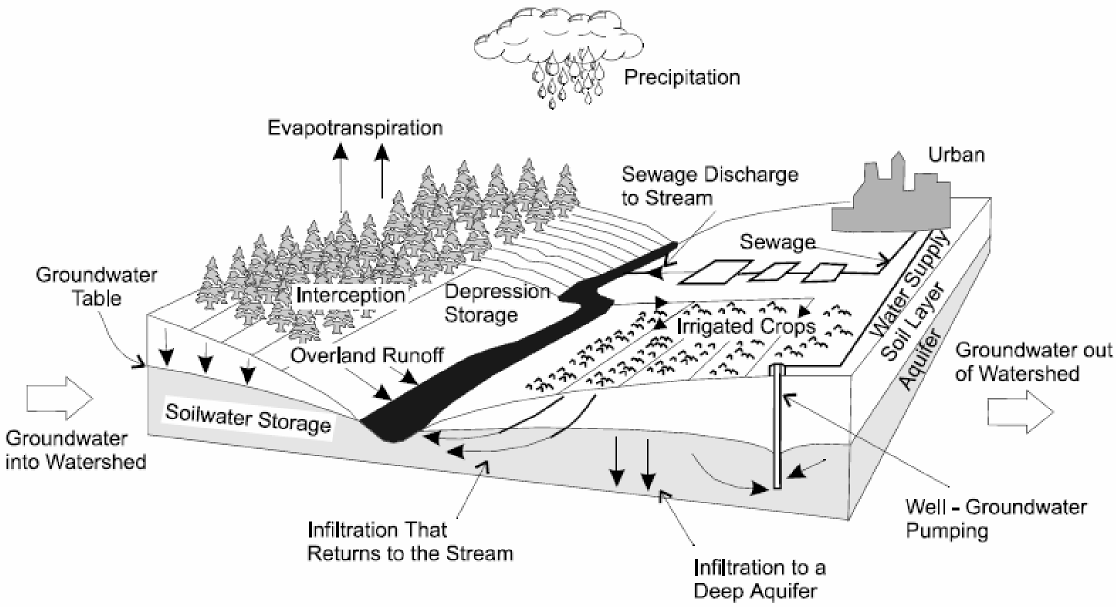
These combined benefits help to mitigate potential negative impacts of climate change on groundwater levels, risk of flooding and stream channel erosion.

1.4 The Impact of Urbanization

As indicated previously, early stormwater management plans developed in the 1980s focused on controlling water quantity, with the intent of ensuring that runoff from newly developed urban areas did not increase the potential for flooding downstream.

Figure 1.4.1 provides an illustration of the hydrologic cycle. When lands are urbanized, there are significant changes in the proportion of precipitation that infiltrates into the ground, evaporates back into the atmosphere and enters drainage features as surface runoff primarily as a result of clearing of vegetation and paving of the ground surface.

Figure 1.4.1; The hydrologic cycle



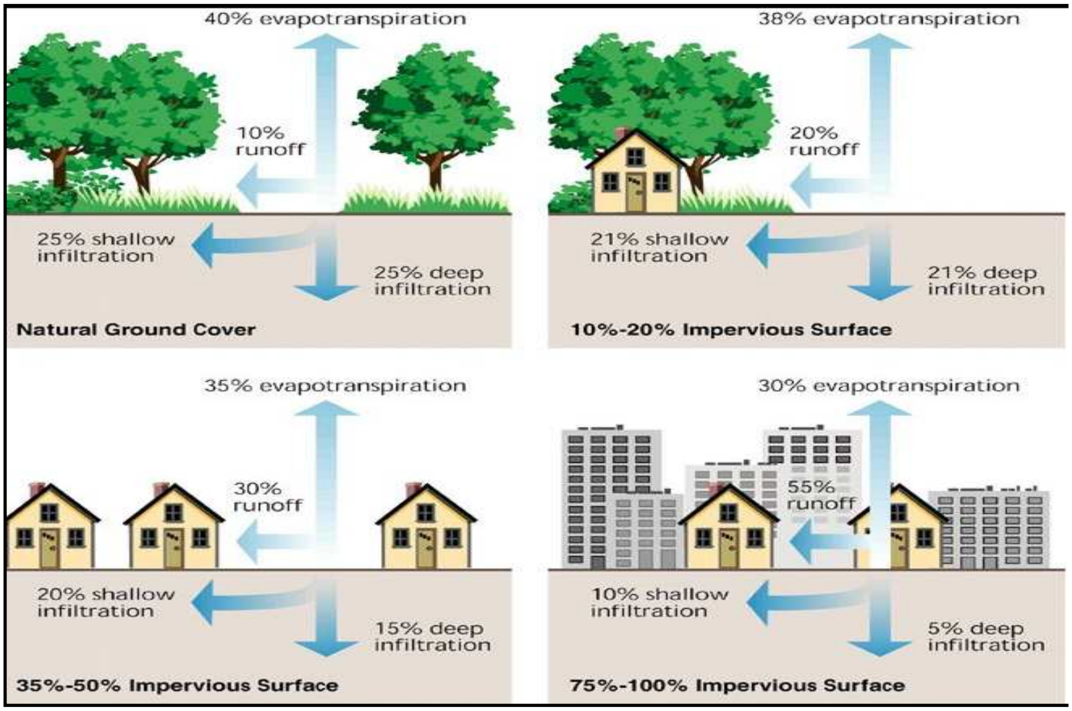
Source : After, M. L. Davis, D. A. Cornwell. **Introduction to Environmental Engineering**, 1991.

Definitions:
Overland runoff – water that travels over the ground surface to a channel
Streamflow – movement of water via channels
Groundwater flow – movement of water through the subsurface
Infiltration – penetration of water through the ground surface
Groundwater recharge – water that reaches saturated zone

Figure 1.4.2 illustrates the dramatic changes in the proportion of precipitation entering different flow pathways when land use changes from native vegetation to an urban landscape. In particular, there can be a 3 to 5 fold increase in the amount of runoff reaching streams, with a corresponding reduction in infiltration of water into the ground.

Not only is there a change in the total volume of stormwater runoff from urban areas, but the characteristics of the runoff change as shown in the Figure 1.4.3. For a given event, both the peak discharge (the peak rate of runoff) and the duration (the amount of time) that this higher peak flow occurs is increased in urban versus rural or forested watersheds (Figure 1.4.4).

Figure 1.4.2 The impact of conventional urbanization on the hydrologic cycle



Source: U.S. EPA, 2007

Figure 1.4.3 Flood hydrographs for urbanized and natural drainage basins

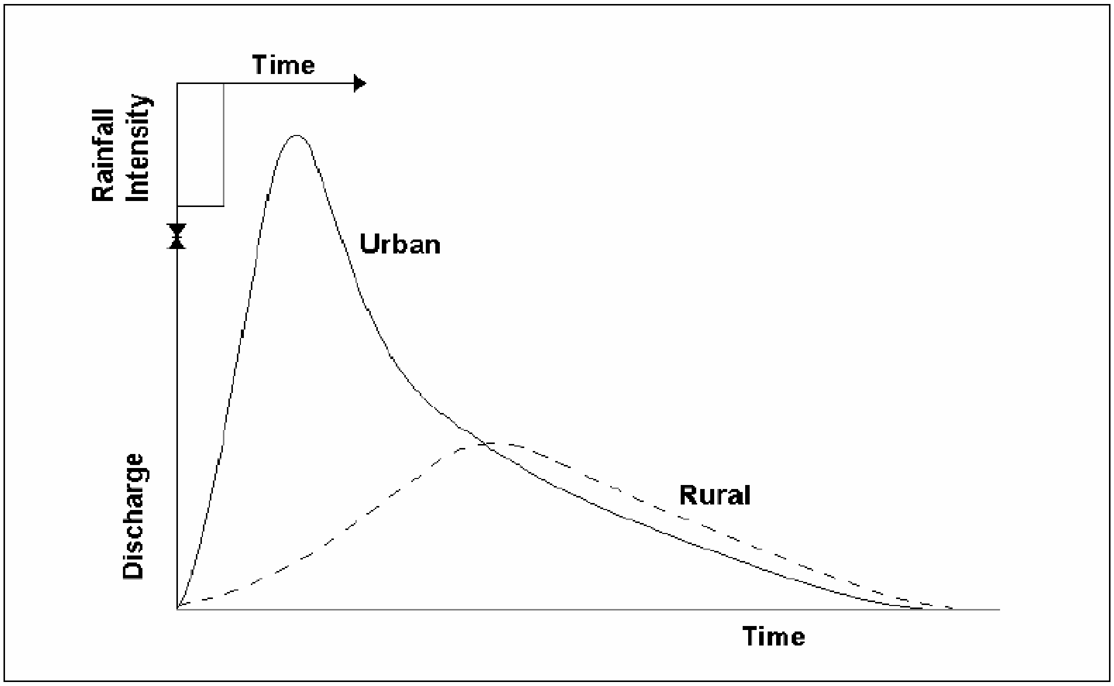
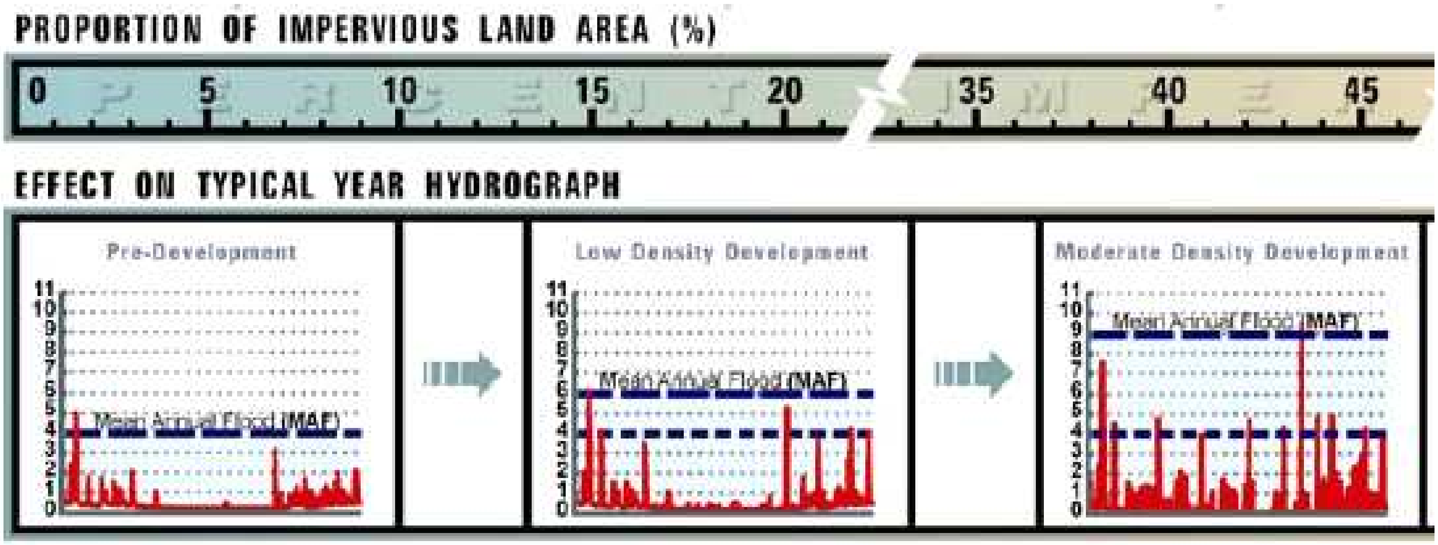


Figure 1.4.4 Changes in magnitude and frequency of peak flows as urbanization increases



Source: BC MWLAP, 2002

This means that not only is there an increase in potential for flooding downstream, but the hydrologic changes associated with increased imperviousness can cause other problems such as:

- alteration of stream flows;
- alteration of stream channels and associated aquatic habitat;
- increased erosion and sedimentation; and
- degraded water quality.

If effective stormwater management controls are not in place, increased imperviousness leads to a cascade of effects as shown in Table 1.4.1. Rivers in highly urbanized areas are sometimes referred to as “peaky” because they have too little flow under dry conditions, and too much flow (high volumes and high peak flows) when it rains. This leads to problems with flooding, erosion, water quality and alterations to stream channels and aquatic habitat.

Flooding and Stream Flows

While stormwater management ponds were originally used primarily to control the increase in peak flows from urbanization to address flooding concerns, it soon became apparent that both the peak flow and its duration needed to be controlled to address problems of erosion, sedimentation and habitat alteration. Since urban stormwater also carries a significant load of suspended sediments, nutrients and other contaminants, the amount of these materials entering a waterbody can be reduced simply by reducing the volume of stormwater reaching the waterbody. Thus controlling runoff volumes is part of the solution to addressing water quality impacts from urbanization.

Table 1.4.1 Ecosystem responses to urbanization

Results of Increased Imperviousness	**Resulting Impacts**					
	Flooding and Altered Stream Flows	**Habitat Loss**	**Erosion and Sedimentation**	**Channel Widening**	**Streambed Alteration**	**Water Quality**
Increased Flow Volume	✓	✓	✓	✓	✓	✓
Increased Peak Flow	✓	✓	✓	✓	✓	✓
Increased Peak Duration	✓	✓	✓	✓	✓	✓
Increased Stream Temperature		✓				✓
Decreased Base Flow	✓	✓				✓
Sediment Loading Changes	✓	✓	✓	✓	✓	✓

CVC's Credit River Water Management Strategy Update study showed that conventional stormwater best management practices have only limited benefits in restoring predevelopment runoff rates and represent only a small improvement over uncontrolled urban growth (Table 1.4.2; Figure 1.4.5). Only by implementing state of the science, treatment-train stormwater management technologies, did a significant reduction in runoff occur.

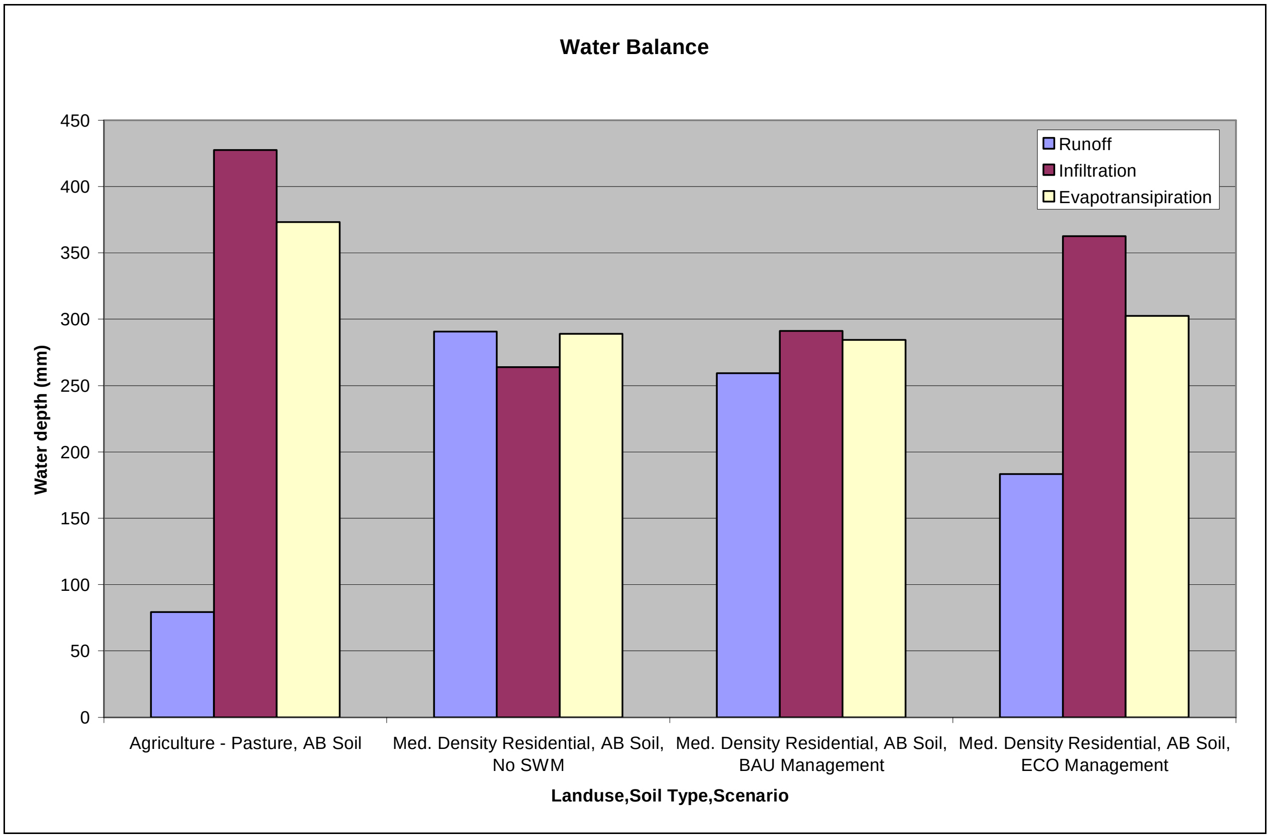
Table 1.4.2 Summary of water balance characteristics for different land uses, soil types and stormwater management strategies

Land Use	**Soil Type**	**Scenario**	**Annual (mm)**			
			Rainfall	**Runoff**	**Infiltration**	**Evapo-transpiration**
Agriculture - Pasture	Sandy Soils	Existing conditions	804	77	418	365
Medium Density Residential	Sandy Soils	No SWM*	804	291	264	289
Medium Density Residential	Sandy Soils	Business-as-usual management approach**	804	259	291	284
Medium Density Residential	Sandy Soils	"Ecotopia" management approach***	804	183	363	303

*SWM – Stormwater management;
** Business-as-usual (BAU) management approach assumes implementation of traditional stormwater management practices, such as detention ponds;
*** "Ecotopia" (ECO) management approach assumes implementation of a full treatment train of stormwater management practices, including lot level and conveyance controls and wetland treatment systems.

Source: CVC, 2007b

Figure 1.4.5 Comparison of runoff, infiltration and evapotranspiration rates for different stormwater management strategies



Source: CVC, 2007b

Erosion and Sedimentation

The changes in the water budget that accompany the urbanization of a watershed have a direct bearing on the morphology, stability and character of the receiving streams. These effects include:

- *Stream widening and bank erosion:* Stream channels enlarge to accommodate higher stormwater volumes and peak flows.
- *Streambed changes due to sedimentation:* Channel erosion and sediment loading from urban construction lead to deposition of fine material in streams covering coarser materials with mud, silt and sand.
- *Stream downcutting:* Another adjustment that occurs in response to flow increases is downcutting of the stream channel, which leads to a steepening of the stream profile or gradient, thus accelerating the erosion process.
- *Loss of riparian tree canopy:* The continued undercutting and failure of stream banks exposes tree roots that normally protect stream banks from erosion, leading to uprooting of trees that causes further weakening of the structural integrity of the stream banks

Many of these erosion and sedimentation effects are delayed until some time after the process of urbanization occurs. Stream channels can continue to enlarge and erode for decades after development occurs before they reach a new stable regime.

Water Quality

Urban stormwater is a source of a variety of pollutants including nutrients, contaminants, bacteria, and suspended sediment. Typical concentrations of these pollutants are shown in Table 1.4.3. Typical sources are listed in the Table 1.4.4.

In a recent review of the effectiveness of stormwater management practices, it was noted that one of the most effective ways of minimizing the potential for channel erosion, reduction in water quality loadings and degradation of aquatic habitat in the receiving channel downstream of an urban development is to minimize changes to runoff volume and discharge rate (Aquafor Beech Ltd., 2006). An equally important corollary to this statement is that a significant reduction in the delivery of pollutants from urban areas into receiving waters requires that sources of “clean” runoff are not contaminated or combined with polluted runoff.

Table 1.4.3 Comparison of urban stormwater runoff concentrations with provincial water quality objectives (PWQO)

Parameter	Units	PWQO	Observed Concentrations
Escherichia coli	CFU/100 mL	-	10,000 to 16 x 10^6
Total Suspended Solids (TSS)	mg/L	-	87 – 188
Total Phosphorus (TP)	mg/L	0.03 (interim)	0.3 – 0.7
Total Kjeldahl Nitrogen (TKN)	mg/L	-	1.9 – 3.0
Phenols	mg/L	0.001	0.014 – 0.019
Aluminum (Al)	mg/L	-	1.2 – 2.5
Iron (Fe)	mg/L	-	2.7 – 7.2
Lead (Pb)	mg/L	0.005 (interim)	0.038 – 0.055
Silver (Ag)	mg/L	0.0001	0.002 – 0.005
Copper (Cu)	mg/L	0.005	0.045 – 0.46
Nickel (Ni)	mg/L	0.025	0.009 – 0.016
Zinc (Zn)	mg/L	0.020 (interim)	0.14 – 0.26
Cadmium (Cd)	mg/L	0.0002	0.001 – 0.024

Source: Adapted from OMOE, 2003

Table 1.4.3 Major sources of common stormwater pollutants

Common Constituents	Major Sources Related to Urban Land Use
Sediment and Particulates	Construction, winter road sanding, vehicle emissions, pavement wear
Hydrocarbons (PAH's)	Spills, leaks, dumping, vehicle emissions, asphalt breakdown, wood preservatives
Pathogens (Bacteria, Viruses)	Illicit connection of septic systems to storm sewers, poor housekeeping (animal feces, bird feces from rooftops)
Chloride, Sodium, Calcium	De-icing salt applications
Cyanide	Anti-caking agent in de-icing salts and sand / salt mixtures
Nutrients (N, P)	Illicit connection of septic systems to storm sewers, detergents (car washing), lawn fertilizers
Cadmium	Tire wear, insecticides, wood preservatives
Zinc	Galvanized building materials, tire wear, motor oil, grease
Lead	Motor oil, lubricants, batteries, bearing wear, paint, vehicle exhaust
Copper	Wear of moving engine parts, metal plating, fungicides and insecticides
Manganese	Wear of moving engine parts
Nickel	Vehicle exhaust, lubricants, metal plating, wear of moving parts
Chromium	Metal plating, wear of moving parts
Iron	Steel structures, rusting automobile bodies
PCBs	Leaks from electrical transformers, spraying of highway right of ways, catalyst in tire construction

Source: Adapted from Burton and Pitt, 2002

Aquatic Habitats

Along with the alterations in hydrology, morphology and water quality that typically take place in a watershed as urbanization progresses, there can be a continued deterioration in the quality and quantity of aquatic habitat for fish and other forms of aquatic life. The impacts on habitat consist include:

- *Increased water temperature:* The combination of warmer runoff from impervious areas and SWM ponds, loss of riparian cover from erosion and reduction in groundwater infiltration can produce severely elevated temperatures in the receiving streams, which can contribute to reductions in dissolved oxygen and create conditions outside of the thermal tolerance limits for desirable fish species and other aquatic life.

- *Reduced groundwater levels and base flow conditions:* The loss of infiltration of rain adversely affects available groundwater resources, ultimately leading to a decline in stream baseflows, which can adversely affect instream habitat during periods when fish are most vulnerable to low flow conditions.

- *Degradation of habitat structure:* The negative effects on the quantity of aquatic habitats take several forms. Increased peak flows and velocities of flow can render some habitats unsuitable for fish; erosion and sedimentation can significantly alter valuable habitats and smother eggs.

- *Loss of channel structure:* As stream morphology degrades, the stream channel becomes straightened and the alternating sequence of pools and riffles is lost, reducing the diversity of habitats for fish.

- *Reduction in biodiversity*: Collectively the above effects will degrade the quality and reduce that variability of aquatic habitats leading to a corresponding reduction in the ability of the habitat to support the variety and abundance of aquatic life it once supported.

1.5 Legislative Framework

Conservation authorities (CAs) are directed by the *Conservation Authorities Act* to carry out a number of critical functions related to watershed planning and management. This includes preventing, eliminating, or reducing loss of life and property from flooding and erosion, and encouraging the protection and regeneration of natural systems. Under the *Conservation Authorities Act*, the powers of a CA include:

- to study and investigate the watershed and to determine a program whereby the natural resources of the watershed may be conserved, restored, developed and managed; and, to cause research to be done (Section 21); and
- to make regulations applicable in the area under its jurisdiction (Section 28).

Both TRCA and CVC administer their own individual regulations, which permit them to:

(a) prohibit, regulate or require the permission of the authority for straightening, changing, diverting or interfering in any way with the existing channel of a river, creek, stream or watercourse, or for changing or interfering in any way with a wetland;
(b) prohibit, regulate or require the permission of the authority for development, if in the opinion of the authority, the control of flooding, erosion, dynamic beaches or pollution or the conservation of land may be affected by the development.

Permit applications made under these regulations are assessed to determine if proposed works will affect the control of flooding, erosion, dynamic beaches, pollution or the conservation of land in accordance with the *Conservation Authorities Act*, and as guided by the two CAs' programs and policies. Both CAs have policies which implement their respective regulations and facilitate their role as commenting agencies under the *Planning Act* and the *Environmental Assessment Act* as described below.

Under the *Planning Act*, CAs are a prescribed agency, meaning they have the opportunity to comment on *Planning Act* applications circulated to them by their municipal partners. Municipalities are the approval authority for *Planning Act* applications and their decisions must be consistent with the provincial interest in planning expressed in the Ontario Ministry of Municipal Affairs and Housing (OMMAH) 2005 Provincial Policy Statement (PPS). Section 2.1 of the PPS provides direction for protecting natural heritage; Section 2.2 deals with water management; and Section 3.1 addresses the management of natural hazards and the need to direct development outside of hazardous areas. Because municipalities tend to have limited expertise with respect to Section 3.1, the Province entered into a memorandum of agreement (MOU) with Conservation Ontario, the umbrella organization that represents Ontario's 36 CAs, to delegate the responsibility of upholding the natural hazards section of the PPS to CAs. In this delegated role, CAs are responsible for representing the "Provincial Interest" on natural hazard matters where the Province is not involved.

Just as the Province recognized the expertise of conservation authorities, municipalities commonly rely on them for advice on natural heritage and water management. For regional municipalities, this relationship has been formalized through a series of MOUs with CVC and TRCA, while a mix of formal and informal agreements exist with local municipalities. Generally, these MOUs and agreements stipulate that the protection, restoration, and enhancement of the natural environment, and the safety of persons and property, is carried out in part through the review of, and preparation of comments on development applications, and that it is a shared responsibility of the municipality and the CA. Parameters for plan review and technical clearance are also established along with protocols for streamlining the planning process. Specific responsibilities typically include establishing requirements and conditions to determine the need for, and adequacy of, studies that assess impacts and propose mitigation measures related to surface and groundwater, natural features and functions.

As part of the overall planning process, CVC and TRCA are expected to review and comment on all environmental assessments (EAs) within their respective jurisdictions. Often, at the detailed design stage of infrastructure projects undergoing an EA process, a permit under a CA regulation is required.

In both their commenting roles under these two Acts, CVC and TRCA must also be aware of impacts to fish habitat, as both CAs have agreements with Fisheries and Oceans Canada to implement section 35(2) of the federal *Fisheries Act*, which states that no person shall carry on work that would cause the harmful alteration, destruction, or disruption of fish habitat.

The complexity of the planning and development process is apparent, so many of CVC's and TRCA's MOUs with their municipal partners recognize and secure the CA's expertise in water management, in order to help them "be consistent" with the water policies in Section 2.2 of the PPS. Section 2.2.1 states:

> Planning authorities shall protect, improve or restore the quality and quantity of water by: a) using the watershed as the ecologically meaningful scale for planning; b) minimizing potential negative impacts, including cross-jurisdictional and cross-watershed impacts; c) identifying surface water features, ground water features, hydrologic functions and

> natural heritage features and areas which are necessary for the ecological and hydrological integrity of the watershed; d) maintaining linkages and related functions among surface water features, ground water features, hydrologic functions and natural heritage features and areas; g) ensuring stormwater management practices minimize stormwater volumes and contaminant loads, and maintain or increase the extent of vegetative and pervious surfaces (OMMAH, 2005).

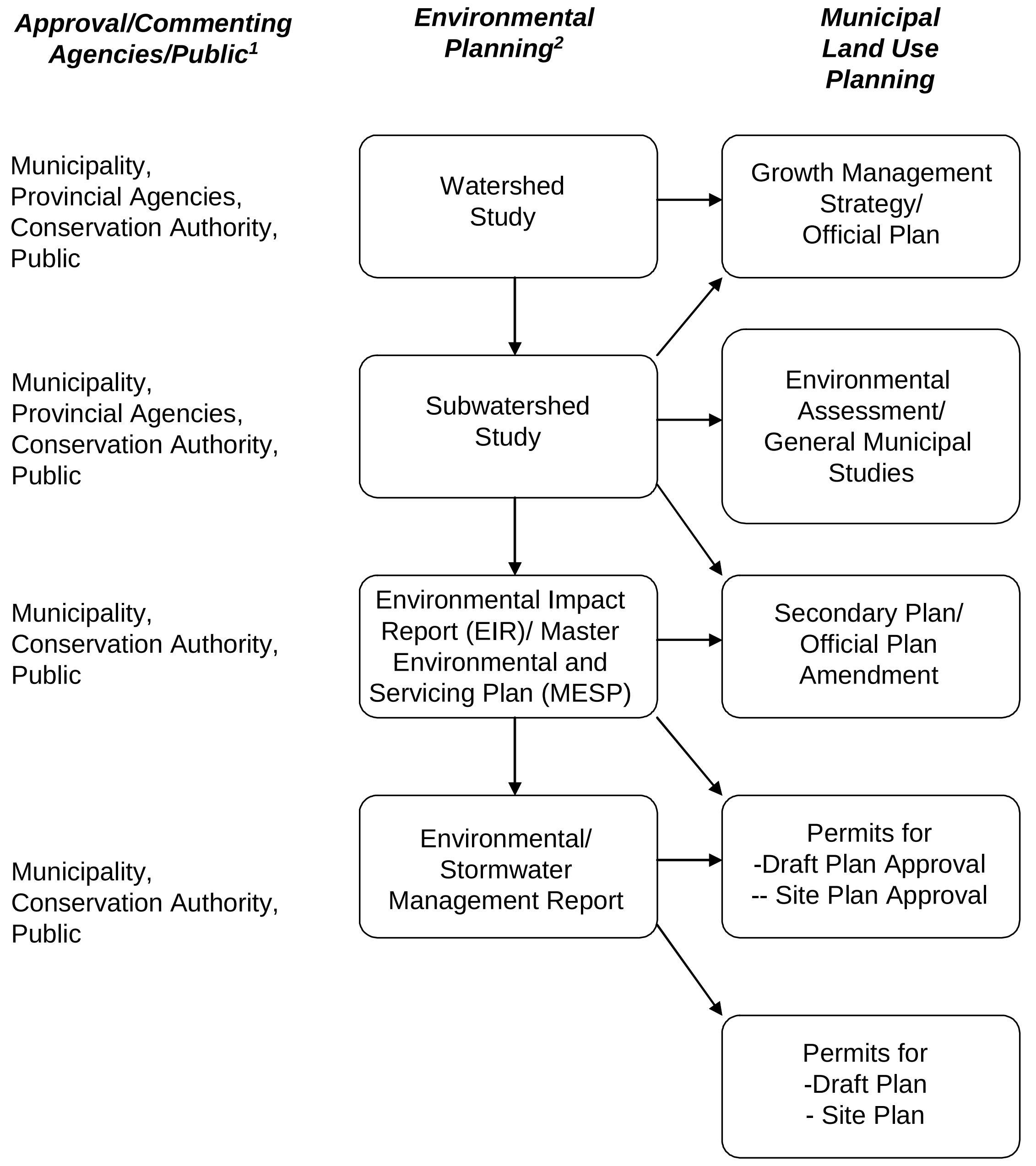
In CVC's and TRCA's role as advisors to our municipal partners on planning matters, and as ingrained in each agency's watershed management plans, the importance of achieving a post-development water balance that matches, as closely as possible, the pre-development water balance condition is emphasized. On sites that have been designed with conventional stormwater management, examination of post-development conditions has shown that natural features are not being sustained and natural hazards are being exacerbated. Therefore, the implementation of innovative stormwater management techniques is required to complement more traditional methods; these can include source and conveyance controls that infiltrate, re-use, or evapotranspirate run-off. This *Low Impact Development Stormwater Management Planning and Design Guide* outlines a host of these best management practices, collectively termed low impact development, which can be used to manage stormwater volume and protect the water resources and natural heritage systems over the long term. Accordingly, Section 2.2.2 of the PPS states that, "mitigative measures and/or alternative development approaches may be required in order to protect, improve or restore sensitive surface water features, sensitive ground water features, and their hydrologic functions" (OMMAH, 2005).

Innovative, non-traditional stormwater management needs to take place in not only areas of new development, but also in areas undergoing redevelopment. While development standards and practices have improved greatly since the earlier decades of urbanization, older developed areas have already taken their toll on watershed conditions. Impervious surfaces cover considerable portions of CVC and TRCA watersheds and a large proportion of these areas lack comprehensive stormwater control.

Therefore, in both development and redevelopment scenarios, a comprehensive outlook is necessary to effectively manage stormwater from a landscape perspective. This can be achieved by considering stormwater and LID as early in the planning process as possible, as further described in Chapter 2.

The general inter-relationship between the traditional municipal land use planning process and environmental (*i.e.*, watershed) planning is depicted in Figure 1.5.1. Ideally, this provides a hierarchy of plans that integrate environmental and municipal planning, and a process in which all relevant agencies provide input under their respective legislative mandates.

Figure 1.5.1 Relationship between municipal land use planning and environmental (watershed) planning processes



1. Approval/commenting agency/public involvement will vary from jurisdiction to jurisdiction
2. For a given jurisdictional area, one Environmental Planning component would generally be associated with one Municipal Land Use Planning component. Multiple arrows leading from the Environmental Planning component to the Municipal Land Use Planning component signify different approaches which are used in different jurisdictions.

Adapted from OMOE, 2003

1.6 Report Outline

Chapter 1 provides an overview of why the guide has been developed. It reviews the environmental impacts of urbanization and the current planning framework for stormwater management in Ontario.

Chapter 2 discusses how stormwater management facility planning and design can be better integrated into the development planning process, in particular, illustrating how better site design and identification of environmental opportunities and constraints early on in the process can lead to more effective stormwater management. The chapter also highlights the importance of planners, engineers, biologist, hydrogeologists and landscape architects working together to develop an overall plan.

Chapter 3 provides an introduction to low impact development, an overview of the LID design process and information to help practitioners select practices suitable to site specific conditions and stormwater source areas.

Chapter 4 describes ten structural low impact development practices for stormwater management. Guidance regarding site suitability, design, operation and maintenance is provided for each general type of practice.

Chapter 5 describes compliance, performance and environmental effects monitoring programs, as they relate to stormwater management systems.

Chapter 6 provides a master list of documents that have been referred to in this guide.

APPENDIX I
EROSION AND SEDIMENT MINIMALIZATION PLAN

EROSION AND SEDIMENT MINIMIZATION PLAN

CONSTRUCTION SCHEDULE

Environmental Concern

The probability for erosion and sedimentation on construction sites is highest during precipitation events. According to 30 years records at Shearwater Airport, the greatest amounts of precipitation occur during winter and spring months.

This area is predominantly overburden with native surficial soils consisting of sandy silt and silty sandy clay. The characteristic permeability of these soils is considered moderate. Though these soils are only moderately erodable the construction on the site must proceed with caution to ensure that the environmental protection measures are adhered to and enforced.

CLEARING AND GRUBBING

Environmental Concern

Clearing activities in the vicinity of a watercourse will cause disturbance of the protective vegetative buffer or riparian zone adjacent to the watercourse and could subsequently lead to erosion of the approach slopes and sedimentation into and the obstruction of the watercourse. For construction projects, there are three categories of erosion and sediment control: runoff controls, erosion protection, and sediment interception.

Runoff controls limit or contain soil movement from the construction site, minimizing raindrop impact on the soil and reducing runoff volume and runoff velocities. Generic controls considered for this Project are discussed below.

Erosion protection measures are used to reduce or eliminate the detachment of soil particles by falling raindrops or to resist sheet or channel flow. These measures are placed on, or applied to, the soil surface and are often used in conjunction with runoff control and sediment interception measures. Erosion protection measures to be used as appropriate in pipeline construction include:

- gravel sheeting;
- mulches;
- tackifiers;
- erosion control blankets; and
- revegetation.

Re-vegetation is generally used only for permanent protection and often requires another form of temporary protection measure to be successfully established.

The key to managing runoff and stormwater flows is to minimize erosion and sedimentation. Methods for managing stormwater flows include:

- wet and dry pond for stormwater detention;
- infiltration systems;
- engineered stormwater systems;
- onsite detention facilities; and
- constructed wetlands.

Best Management Practice

- Before any clearing or grubbing commences. clearing limits, easements, setbacks, sensitive/critical areas and their buffers, trees and drainage courses will be delineated with flagging tape. This practice ensures workers can clearly recognize areas to be protected.

- No clearing or construction will occur within the protective green/belts/protected sensitive areas as identified on the development plans.

- To reduce the velocity of runoff, crop residues, plants, and rough soil surfaces are applied to help spread the flow of water over a greater area and into a thin layer.

- Diversion berms are commonly used on slopes to intercept sheet flow on exposed surfaces and to reroute flow into undisturbed areas. Erosion protection is required at the berm outlets.

- Check dams are a temporary measure constructed in ditches, swales, or chutes to reduce hydraulic gradient and flow velocity, thus minimizing the potential for erosion of the channel.

- Sediment traps and swales or dikes (diversion channels) will be installed around each lot before construction begins to control excavation water and where required to intercept runoff \from sheet flow from entering the disturbed house pad area. Necessary erosion control measures such as interception ditches will be completed prior to clearing of each work site.

- The work site will not be cleared nor will topsoil be removed prior to commencement of construction

- Cleared and graded areas will be limited to minimize the area of exposed soil

- Minimal amount of natural vegetation and topsoil will be removed at each construction site

- Home sites will be cleared and grubbed and will be stabilized immediately following the completed excavation.

- Mulches consisting of wood chips, stone or commercial anti-erosion mats will be used to limit erosion on land, which is cleared of vegetation.

- All non-mercantile timber will be chipped on site and used as temporary protective cover over exposed and disturbed areas.

- Grubbed material, which is not used for fill, will be disposed offsite in accordance with Nova Scotia Department of Environment legislation and Halifax Regional Municipal Bylaws.

- The contractor and developer will maintain a stockpile of erosion control material onsite.

GRADING

Environmental Concern

Grading requirements near watercourses can be extensive in housing developments to accommodate lot and street development. Accordingly, slopes may be contoured to allow for the site development. Disturbance of the slopes may cause instability, which could result in erosion and subsequent sedimentation of watercourse.

Soil loss from slopes may occur even with erosion and runoff control measures. If this soil can enter a waterbody, mitigative measures will be required to intercept it. Methods used to trap sediment include vegetated buffer strips, silt fences, filter berms, and sediment traps.

Best Management Practices

- Construction along the access roads will be sequenced such that each section is to be completed and stabilized before proceeding to the next section unless overlapping work is approved by the project engineer.

- Work along the streets will not exceed 500 metres. The contractor will work continuously until the streets are completed. If work is halted for 5 days, temporary stabilization structures and material will be installed.

- A crushed rock construction entrance will be established to prevent tracking of mud offsite and through the new and adjacent subdivisions.

- Lot grading will entail completion of each lot driveway first and vehicular travel on the lot will be restricted to the driveway. Access to each lot will be restricted to one driveway.

- The driveway will consist of clear stone or gravel to a thickness of three to six inches. If necessary, filter fabric will be laid under the stone if fines are encountered. This surface will be maintained during construction.

- Once the house pad is graded, the exposed pad unless prepared from from rock fill will be graveled with clear stone. All exposed soil or unworked home sites will be stabilized no more than 5 days upon completion of the construction.

- No mud, debris or other excavation material will be placed on the street. Fill material will not be stored next to the curb. Fill will be piled within the perimeter of the cleared lot (no more than 3 metres around the house pad) until needed for cut lots or landscaping.

- Imported fill material will be assessed to ensure that material is not composed of high percentage of fines.

- All stockpiled fill material will be covered with tarps or other material, which are secure, to protect it from rainfall.

- Diversions will be constructed at the top of each fill slope at the end of each work day, as needed. Diversions will be located at least 0.6 m uphill from the tope edge of each fill. The outlet of diversions, if free of sediment, will be located on undisturbed or stabilized areas when possible. Otherwise, sediment laden runoff must be diverted to a sediment retention structure.

- Sediment traps, smaller than sediment basins, are more easily installed and moved as grading progresses, will be incorporated into the drainage pattern around each house lot. Sediment traps will serve areas less than 2 ha (5 acres). These structures will be placed downslope of the home lots to intercept runoff on relatively level areas or natural depressions.

- Sediment barriers will be used to treat small areas and include enviro-fencing, straw bales, filter fabric, gravel and earth berms. Barriers will be placed below disturbed areas subject to erosion including along the contour of exposed slopes; at the base of a slope; along a street or sidewalk; and at storm drain inlets. Barriers will not be placed in a drainage way with high volume or high velocity.

- All water pumped from ditches, swales or sumps should be discharged away from the watercourse and filtered through a sediment trap, 2 m3 (3 yd3) of class B gravel, filter bag, or undisturbed vegetation to filter out solid material before the water enters the watercourse.

- Silt accumulation along silt fences and swales will be removed regularly.

- Long and steep slopes on the construction site will be minimized to prevent erosional velocities from developing. If long slopes are present, they will be benched to interrupt the flow of water and minimize erosion.

CULVERT INSTALLATION

- A buffer zone will be established along the watercourse by placing geotextile silt fences on both sides of the channel. Work must be completed in the dry, therefore water will be diverted around the construction site.

- Diversion channels can consist of a ditch lined with polyethylene liners that are properly placed and secured. Sandbags or an impermeable dam will be installed at the inlet to divert the flow. Inlet and outlet protection to prevent erosion and scouring at the ends will be installed.

- Unlimited fording of watercourses by construction equipment will not be permitted.

- Culverts will be properly designed to handle the increased flows as a result of development and comply with NSDOEL regulations with respect to the Watercourse Alteration Permit.

- Side banks of the channel will be stabilized and revegetated subsequent to completion of the culvert installation.

INSPECTION AND ENFORCEMENT

Environmental Concern

Thorough maintenance of all temporary and permanent erosion and sediment control measures will ensure the integrity of the aquatic resources they protect. Monitoring of the site following major rainstorms will determine that runoff control devices are effective and allow for the removal of accumulated sediment.

Best Management Practices

- With respect to sediment control, all work is to be completed to the satisfaction of the project engineer and HRM.

- On-site inspection will be an active part of any development and management program. The effectiveness of control measures will be inspected and monitored during rain events and maintained and upgraded as necessary or as directed by the Project Engineer or Environmental Inspectors.

- The Contractor and Project Engineer will incorporate a routine end-of-day check to ensure the integrity of the protection measures.

- Monitoring of meteorological conditions and forecasts as a proactive means will be conducted to minimize the potential for erosion.

RESTORATION AND PERMANENT PROTECTION MEASURES

The final restoration phase is critical for mitigation long-term impacts to watercourses. Clayton Developments will incorporate all appropriate mitigative measures to ensure proper restoration of the sites adjacent to watercourses and channel of each watercourse.

Environmental Concern

Proper restoration of the watercourses and adjacent areas will minimize post-construction impacts to these areas. Implementation of permanent protection measures such as a stormwater management plan will minimize the volume of stormwater constituents into water courses.

Best Management Practices

- The sites will be reclaimed immediately to limit sustained erosion.

- Wood chips, vegetative growth or rock facing (riprap) on steep slopes will be restored in all denuded areas.

- Prompt re-establishment of vegetation will reduce the need for costly remedial measures caused by erosion damage to slopes.

- The targets to minimize and reduce contaminant input into the Kearney Lake / Papermill Lake system will be met through implementation of control devices that have proven to reduce contaminant inputs. The strategy recommended for this site is to provide an integrated approach to stormwater management that is premised on controlling surface runoff and pollution at the source. Therefore, a hierarchy, or train, of stormwater management practices may include:

- stormwater lot level controls, which will be achieved using an overflow catchbasin piping arrangement, storage upon the roof and parking lot, CDS Stormwater oil/water separation units; and

- end-of-pipe stormwater management facilities which will consist of CDS Stormwater units (or approved equal), and velocity breaks prior to storm water entering the natural water courses.

- Stormwater lot level controls involve measures to store and treat stormwater before it reaches the street conveyance system.

- End-of-pipe stormwater management facilities found to be most suitable for the proposed commercial development for treatment of the stormwater is the CDS Stormwater Unit (or approved equal) system for the following reasons:
  - performance does not depend upon soil characteristics;
  - no additional disturbance to the natural areas to create retention ponds or artificial wetlands;
  - the performance is definable and measurable; and
  - maintenance is simple and the HRM has the equipment required.

HAZARDOUS MATERIAL STORAGE AND HANDLING OF FUELS AND HAZARDOUS MATERIALS

Environmental Concern

Accidental spills of fuels, lubricants or other chemicals may enter watercourse and eventually reach the Kearney Run/ Papermill Lake Watershed. Proper storage and handling of these materials should prevent the probability of accidents.

Best Management Practice

- Machinery maintenance will not be performed in or near a watercourse, ditch or storm sewer. Some examples of maintenance include washing out cement mixers, changing oil, greasing, spray painting, cleaning of spraying equipment or painting equipment, etc.

- Any hazardous liquid including fuel and lubricants will be stored in a designated area surrounded by an impervious berm, which would contain a spill of the volume of all stored liquid.

- Solid hazardous materials including cement, lime and sulphur should not be stored within 25 m of a watercourse.

- Any spillage of a hazardous material into any watercourse will be reported to the Nova Scotia Department of Environments Environmental Emergencies 24 Hour Service (424-5620).

CONTINGENCY PLANNING

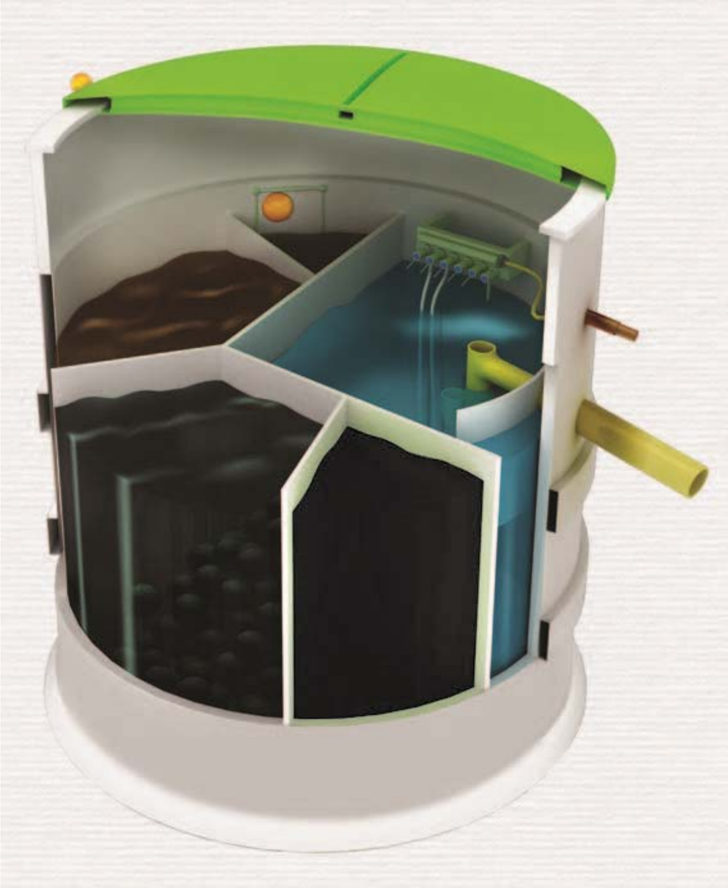
Extreme Storm Events

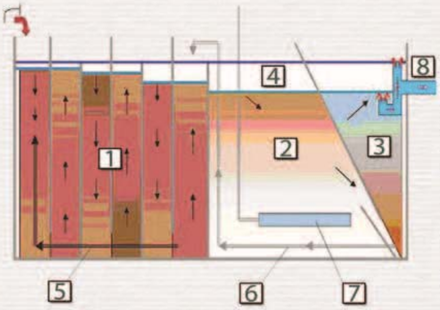
Extreme storm events (usually subtropical storms) can result in extensive erosion due to heavy rainfall impact and the associated stormwater runoff. Erosion of approach slopes adjacent to watercourses is to be expected during these events. Watercourse flows can be expected to increase suddenly, possibly exceeding the capacity of ditches, swales and sediment traps. Throughout the course of construction, the Environmental Inspectors must be aware of current meteorological predictions and the potential ramifications. Subject to a review of the construction activities planned for the day and the locations of these activities, the prediction of storm events will result in the suspension in the vicinity of watercourses and wetlands.

Excessive runoff can be mitigated or controlled by the use of additional diversion berms, straw bale check dams, sediment fences and/or sandbag barriers. Additional sediment interception measures such as sediment traps can also be constructed quickly. The CONTRACTOR will ensure that equipment, personnel and required materials will be available for application as required.

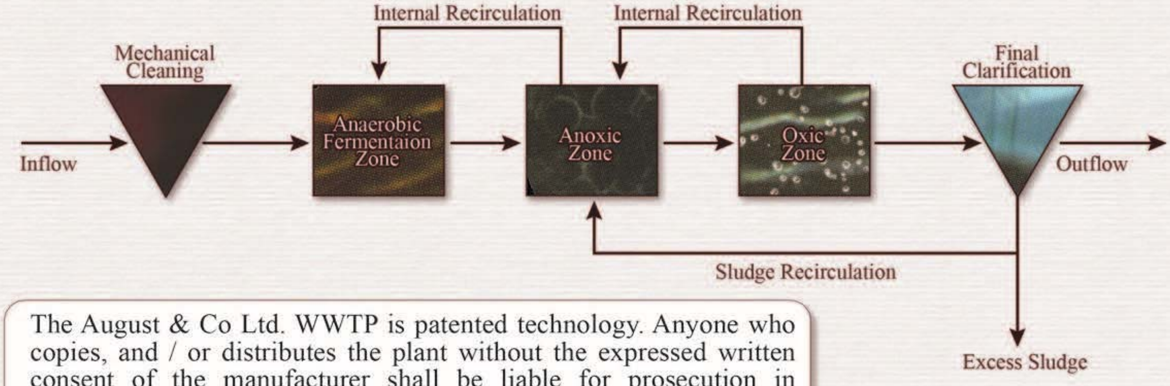
Following extreme storm events, Environmental Inspectors, will conduct environmental monitoring in those area deemed at risk. Recommendations regarding erosion control will be made by the Environmental Inspectors as required.

APPENDIX J
AUGUST BIOPRO BIOLOGICAL WASTEWATER TREATMENT BROCHURE





1. Anoxic chamber
2. Oxic chamber
3. Final clarification chamber
4. Integrated Retention area
5. Internal Recirculation
6. Recirculation of the sludge
7. Fine-bubble aeration
8. Flow control device



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APPENDIX K
DETAILED CALCULATION OF TRANSVERSE DISPERSION PLUME

The width of the transverse dispersion of the plume is calculated in the following steps:

1. Calculate Darcy velocity (m/s):

$$v_x = \left(\frac{K_s}{n}\right)\left(\frac{dh}{dx}\right)$$

Where:

$K_s = saturated\ hydraulic\ conductivity\ (m/s)$

$n = effective\ porosity$

$dh/dx = slope\ of\ subsurface\ soil$

---

2. Calculate Longitudinal Dynamic Dispersivity (m):

$$\alpha_L = 0.83\left(log_{10}L_{path}\right)^{2.414}$$

Where:

$L_{path} = the\ length\ of\ subsurface\ profile\ path\ from\ the\ OSSDS\ field\ to$
$the\ surface\ water\ feature\ (m)$

---

3. Calculate Longitudinal Dispersivity (m²/s):

$$D_L = v_x \alpha_L$$

Where:

$v_x = Darcy\ velocity\ (m/s)$

$\alpha_L = Longitudinal\ Dynamic\ Dispersivity\ (m^2/s)$

---

4. Calculate Hydrodynamic Dispersion Coefficient (m²/s):

$$D_T = 0.1 D_L$$

Where:

$D_L = Longitudinal\ Dispersivity\ (m^2/s)$

---

5. Calculate Transverse Dispersion (m):

$$\sigma_T = \sqrt{2D_T * \frac{L_{path}}{v_x}}$$

Where:

$D_T = Hydrodynamic\ Dispersion\ Coefficient\ (m^2/s)$

$L_{path} = the\ length\ of\ subsurface\ profile\ path\ from\ the\ OSSDS\ field\ to$
$the\ surface\ water\ feature\ (m)$

$v_x = Darcy\ velocity\ (m/s)$

APPENDIX L

WATER QUALITY MODEL RESULTS - OSSDSS

Step 1: Calculate P Loading in OSS

1a) Analyze typical OSS

1b) Analyze special P treatment

Step 2: Calculate P Loading in Subsurface Soil

Step 3: Calculate mass of P removed by sorption and precipitation

Step 1: Calculate P Loading in OSS

$$OSSDS\ P\ Load = \frac{(1 - RED_{OSSDS,P}) * C_{SEPTIC} * Q_{SEPTIC}}{10^6}$$

Where:

OSSDS P Load = P load leaving OSSDS (kg P)

$RED_{OSS,P}$ = OSS P reduction rate(-)

C_{SEPTIC} = P concentration of effluent (mg/L)

Q_{SEPTIC} = effluent daily flow rate (L/day)

Block	$RED_{OSS,P}$	C_{SEPTIC} (mg/L)	Q_{SEPTIC} (L/day)
A	0.756	14.4	12,750
B			15,250
C			12,750
D			12,750
E			19,000
F			32,000
G			35,000

Step 1a: Calculate P Loading in typical OSS

$RED_{OSS,P}$ = 0.2

Block	P Load (kg/day)	P Load (kg/year)
A	0.147	53.611
B	0.176	64.123
C	0.147	53.611
D	0.147	53.611
E	0.219	79.891
F	0.369	134.554
G	0.403	147.168

Step 1b: Calculate P Loading in special P treatment OSS

$RED_{OSS,P}$ = 0.756

Block	P Load (kg/day)	P Load (kg/year)
A	0.045	16.351
B	0.054	19.558
C	0.045	16.351
D	0.045	16.351
E	0.067	24.367
F	0.112	41.039
G	0.123	44.886

Calculate OSS P Loads

Calculate daily generation of phosphorus load (Influent)

Block	P Load (kg/day)
A	0.184
B	0.220
C	0.184
D	0.184
E	0.274
F	0.461
G	0.504

$$OSSDS\ P\ Generation = \frac{C_{SEPTIC} * Q_{SEPTIC}}{10^6}$$

Where:

OSSDS P Generation = P load generated by dev. (kg P)

RED $_{OSS,P}$ = OSS P reduction rate(-)

C $_{SEPTIC}$ = P concentration of effluent (mg/L)

Q $_{SEPTIC}$ = effluent daily flow rate (L/day)

Timelines (years)
10
20
30
40
50

Calculate cumulative P load (generated from domestic wastewater) (Influent)

Block	P Load (kg) (daily)	P Load (kg) (10 Year)	P Load (kg) (20 Year)	P Load (kg) (30 Year)	P Load (kg) (40 Year)	P Load (kg) (50 Year)
A	0.184	670.14	1340.28	2010.42	2680.56	3350.70
B	0.220	801.54	1603.08	2404.62	3206.16	4007.70
C	0.184	670.14	1340.28	2010.42	2680.56	3350.70
D	0.184	670.14	1340.28	2010.42	2680.56	3350.70
E	0.274	998.64	1997.28	2995.92	3994.56	4993.20
F	0.461	1681.92	3363.84	5045.76	6727.68	8409.60
G	0.504	1839.60	3679.20	5518.80	7358.40	9198.00

Calculate cumulative P load from OSS Step 1a & 1b (typical OSS vs. special P treatment)

Typical OSS Treatment

Block	P Load (kg) (daily)	P Load (kg) (10 Year)	P Load (kg) (20 Year)	P Load (kg) (30 Year)	P Load (kg) (40 Year)	P Load (kg) (50 Year)
A	0.147	536.11	1072.22	1608.34	2144.45	2680.56
B	0.176	641.23	1282.46	1923.70	2564.93	3206.16
C	0.147	536.11	1072.22	1608.34	2144.45	2680.56
D	0.147	536.11	1072.22	1608.34	2144.45	2680.56
E	0.219	798.91	1597.82	2396.74	3195.65	3994.56
F	0.369	1345.54	2691.07	4036.61	5382.14	6727.68
G	0.403	1471.68	2943.36	4415.04	5886.72	7358.40

Special P Treatment

Block	P Load (kg) (daily)	P Load (kg) (10 Year)	P Load (kg) (20 Year)	P Load (kg) (30 Year)	P Load (kg) (40 Year)	P Load (kg) (50 Year)
A	0.045	163.51	327.03	490.54	654.06	817.57
B	0.054	195.58	391.15	586.73	782.30	977.88
C	0.045	163.51	327.03	490.54	654.06	817.57
D	0.045	163.51	327.03	490.54	654.06	817.57
E	0.067	243.67	487.34	731.00	974.67	1218.34
F	0.112	410.39	820.78	1231.17	1641.55	2051.94
G	0.123	448.86	897.72	1346.59	1795.45	2244.31

Calculate Subsurface soil P Loads

$$M_{SSP} = E_{SSP} * \rho_b * D * \left\{\left[\left(W_{sys} * L_{path}\right) + \frac{\sigma_T * L_{path}}{2}\right] + L_{sys} * W_{sys}\right\}$$

Where:

M_{SSP} = the mass of soil involved in P

E_{SSP} = effective volume of plume

ρ_b = soil bulk density (kg/m ³)

D = saturation depth of effluent below the discharging from disposal field (m)

W_{sys} = Width of OSS disposal field perpendicular to drainage path to surface water feature (m)

L_{sys} = Length of OSS disposal field (m)

L_{path} = Length of subsurface soil profile path from OSS disposal field to surface water feature (m)

σ_T = Standard deviation of plume width (m)

$$\sigma_T = \sqrt{2D_T * \frac{L_{path}}{v_x}}$$

Where:

v_x = Darcy velocity (m/s)

D_T = hydrodynamic dispersion coefficient perpendicular to the principal direction of flow (transverse) (m ²/s)

$$D_T = 0.1D_L$$

Where:

D_L = longitudinal dispersivity

$$D_L = v_x * \alpha_L$$

Where:

α_L = longitudinal dynamic dispersivity (m)

$$\alpha_L = 0.83(log_{10}L_{path})^{2.414}$$

$$v_x = \left(\frac{K_s}{n}\right)\left(\frac{dh}{dx}\right)$$

Where:

K_S = saturated hydraulic conductivity (m/s)

n = effective porosity

dh/dx = slope of soil subsurface

Calculate Subsurface soil P Loads

Block	Parameters								
	K_s	n	p_b	D	W_{sys}	L_{sys}	E_{ssp}	L_{path}	dh/dx
	(m/s)		*(kg/m ³)*	*m*	*m*	*m*		*m*	
A	1.85E-07	0.28	2202.4	0.3	63	6	0.75	33	0.121
B					68	6		36	0.213
C					90	6		35	0.057
D					64	6		19	0.079
E					74	8.2		72	0.078
F					109	14.7		72	0.104
G					186	17.5		74	0.068

Block	v_x (m/s)	α_L (m)	D_L (m²/s)	D_T (m²/s)	σ_T (m)
A	8.01E-08	2.28	1.82E-07	1.82E-08	3.88
B	1.41E-07	2.41	3.40E-07	3.40E-08	4.17
C	3.77E-08	2.37	8.94E-08	8.94E-09	4.07
D	5.21E-08	1.50	7.83E-08	7.83E-09	2.39
E	5.14E-08	3.70	1.90E-07	1.90E-08	7.30
F	6.88E-08	3.70	2.55E-07	2.55E-08	7.30
G	4.46E-08	3.76	1.68E-07	1.68E-08	7.46

Calculate the mass of soil involved in P treatment

Block	M_{ssp} (kg)
A	1,249,226.23
B	1,452,451.20
C	1,863,854.84
D	804,113.28
E	3,071,142.89
F	4,813,213.76
G	8,570,320.20

$$M_{SSP} = E_{SSP} * \rho_b * D * \left\{ \left[\left(W_{sys} * L_{path} \right) + \frac{\sigma_T * L_{path}}{2} \right] + L_{sys} * W_{sys} \right\}$$

Calculate Subsurface soil P Loads

Calculate the P load per unit soil (mg P/kg soil)

$$Soil\ P\ Load_{ssp} = \frac{OSS\ P\ Load\ (mg)}{M_{ssp}(kg)}$$

Typical OSS Treatment

Block	P Load (mg/kg) (daily)	P Load (mg/kg) (10 Year)	P Load (mg/kg) (20 Year)	P Load (mg/kg) (30 Year)	P Load (mg/kg) (40 Year)	P Load (mg/kg) (50 Year)
A	0.12	429.16	858.31	1287.47	1716.62	2145.78
B	0.12	441.48	882.97	1324.45	1765.93	2207.41
C	0.08	287.64	575.27	862.91	1150.54	1438.18
D	0.18	666.71	1333.42	2000.14	2666.85	3333.56
E	0.07	260.14	520.27	780.41	1040.54	1300.68
F	0.08	279.55	559.10	838.65	1118.20	1397.75
G	0.05	171.72	343.44	515.15	686.87	858.59

Special P Treatment

Block	P Load (mg/kg) (daily)	P Load (mg/kg) (10 Year)	P Load (mg/kg) (20 Year)	P Load (mg/kg) (30 Year)	P Load (mg/kg) (40 Year)	P Load (mg/kg) (50 Year)
A	0.04	130.89	261.78	392.68	523.57	654.46
B	0.04	134.65	269.30	403.96	538.61	673.26
C	0.02	87.73	175.46	263.19	350.92	438.65
D	0.06	203.35	406.69	610.04	813.39	1016.74
E	0.02	79.34	158.68	238.02	317.36	396.71
F	0.02	85.26	170.53	255.79	341.05	426.31
G	0.01	52.37	104.75	157.12	209.50	261.87

Calculate the P load sorbed & precipated (mg P/kg soil)

Typical OSS Treatment

Block	P Load (mg/kg) (10 Year)	P Load (mg/kg) (20 Year)	P Load (mg/kg) (30 Year)	P Load (mg/kg) (40 Year)	P Load (mg/kg) (50 Year)
A	281.46	405.91	530.37	654.82	779.28
B	285.03	413.06	541.09	669.12	797.15
C	240.41	323.83	407.24	490.66	574.07
D	350.35	543.69	737.04	930.39	1123.73
E	223.72	307.88	383.32	458.76	534.20
F	238.07	319.14	400.21	481.28	562.35
G	147.68	256.60	306.39	356.19	405.99

Special P Treatment

Block	P Load (mg/kg) (10 Year)	P Load (mg/kg) (20 Year)	P Load (mg/kg) (30 Year)	P Load (mg/kg) (40 Year)	P Load (mg/kg) (50 Year)
A	112.57	225.13	270.88	308.84	346.79
B	115.80	231.60	274.15	313.20	352.25
C	75.45	150.89	226.34	258.77	284.21
D	174.88	274.94	333.91	392.88	451.85
E	68.23	136.47	204.70	249.04	272.04
F	73.33	146.65	219.98	255.90	280.63
G	45.04	90.08	135.13	180.17	225.21

$$\frac{P_{removed}}{M_{SSP}} = \begin{cases} \frac{P_{filter}}{M_{SSP}} * m_1 + b_1, & when\ \frac{P_{filter}}{M_{ssp}} < S_{max,filter}\ (I) \\ \frac{P_{filter}}{M_{SSP}} * m_2 + b_2, & when\ \frac{P_{filter}}{M_{SSP}} \geq S_{max,filter} (II) \end{cases}$$

Calculate Subsurface soil P Loads

Calculate the P load to watercourse (mg P/kg soil)

Typical OSS Treatment

Block	P Load (mg/kg) (10 Year)	P Load (mg/kg) (20 Year)	P Load (mg/kg) (30 Year)	P Load (mg/kg) (40 Year)	P Load (mg/kg) (50 Year)
A	147.70	452.40	757.10	1061.80	1366.50
B	156.45	469.91	783.36	1096.81	1410.26
C	47.22	251.44	455.66	659.89	864.11
D	316.37	789.73	1263.10	1736.46	2209.83
E	36.42	212.39	397.09	581.78	766.48
F	41.48	239.96	438.44	636.92	835.40
G	24.04	86.84	208.76	330.68	452.60

Special P Treatment

Block	P Load (mg/kg) (10 Year)	P Load (mg/kg) (20 Year)	P Load (mg/kg) (30 Year)	P Load (mg/kg) (40 Year)	P Load (mg/kg) (50 Year)
A	18.32	36.65	121.80	214.73	307.67
B	18.85	37.70	129.81	225.41	321.02
C	12.28	24.56	36.85	92.15	154.44
D	28.47	131.75	276.13	420.51	564.88
E	11.11	22.22	33.32	68.33	124.66
F	11.94	23.87	35.81	85.15	145.68
G	7.33	14.66	22.00	29.33	36.66

Calculate the P load to watercourse (kg P)

Typical OSS Treatment

Block	P Load (kg) (10 Year)	P Load (kg) (20 Year)	P Load (kg) (30 Year)	P Load (kg) (40 Year)	P Load (kg) (50 Year)
A	184.51	565.15	945.79	1326.43	1707.07
B	227.24	682.51	1137.79	1593.06	2048.34
C	88.01	468.65	849.29	1229.93	1610.57
D	254.39	635.03	1015.67	1396.31	1776.95
E	111.85	652.29	1219.51	1786.74	2353.97
F	199.66	1154.99	2110.32	3065.65	4020.98
G	206.04	744.25	1789.14	2834.03	3878.92

Special P Treatment

Block	P Load (kg) (10 Year)	P Load (kg) (20 Year)	P Load (kg) (30 Year)	P Load (kg) (40 Year)	P Load (kg) (50 Year)
A	22.9	45.8	152.2	268.3	384.3
B	27.4	54.8	188.5	327.4	466.3
C	22.9	45.8	68.7	171.8	287.9
D	22.9	105.9	222.0	338.1	454.2
E	34.1	68.2	102.3	209.8	382.9
F	57.5	114.9	172.4	409.8	701.2
G	62.8	125.7	188.5	251.4	314.2

Calculate the % removal of P at watercourse (%)

Typical OSS Treatment

Block	P Load Removal (10 Year)	P Load Removal (20 Year)	P Load Removal (30 Year)	P Load Removal (40 Year)	P Load Removal (50 Year)
A	72%	58%	53%	51%	49%
B	72%	57%	53%	50%	49%
C	87%	65%	58%	54%	52%
D	62%	53%	49%	48%	47%
E	89%	67%	59%	55%	53%
F	88%	66%	58%	54%	52%
G	89%	80%	68%	61%	58%

Special P Treatment

Block	P Load Removal (10 Year)	P Load Removal (20 Year)	P Load Removal (30 Year)	P Load Removal (40 Year)	P Load Removal (50 Year)
A	97%	97%	92%	90%	89%
B	97%	97%	92%	90%	88%
C	97%	97%	97%	94%	91%
D	97%	92%	89%	87%	86%
E	97%	97%	97%	95%	92%
F	97%	97%	97%	94%	92%
G	97%	97%	97%	97%	97%

APPENDIX M
WATER QUALITY MODEL RESULTS – STORMWATER

19-6784 - Charleswood Subdivision Development - Water Quality Model (Pre-Development)

July 8, 2019

Pre-Development Conditions - Total Disturbed Area

Return Period	Land Use	Area m^2	Area-ha	Precipitation (m)	Runoff C	Total Runoff (m^3)	TSS - mg/L	TSS - kg	TP-mg/L	TP-kg
1 in 2	Upland Forest	202,162	20.22	0.083	0.27	4530.45	19.7	89.25	0.2	0.91
1 in 5	Upland Forest	202,162	20.22	0.107	0.27	5840.46	19.7	115.06	0.2	1.17
1 in 10	Upland Forest	202,162	20.22	0.125	0.27	6822.97	19.7	134.41	0.2	1.36
1 in 25	Upland Forest	202,162	20.22	0.146	0.27	7969.23	19.7	156.99	0.2	1.59
1 in 100	Upland Forest	202,162	20.22	0.176	0.45	16011.23	19.7	315.42	0.2	3.20

Post-Development Conditions With No BMPs - Total Disturbed Area

Return Period	Land Use	Area m^2	Area-ha	Precipitation (m)	Runoff C	Total Runoff (m^3)	TSS - mg/L	TSS - kg	TP-mg/L	TP-kg
1 in 2	Medium-Density Residential	171,846	17.18	0.083	0.40	5742.00	30.5	175.13	0.20	1.15
	Paved Public Road	30,316	3.03	0.083	0.53	1321.03	57.8	76.36	0.47	0.62
	Total	**202,162**	**20.22**			**7063.03**		**251.49**		**1.77**
1 in 5	Medium-Density Residential	171,846	17.18	0.107	0.40	7402.34	30.5	225.77	0.20	1.48
	Paved Public Road	30,316	3.03	0.107	0.53	1703.01	57.8	98.43	0.47	0.80
	Total	**202,162**	**20.22**			**9105.35**		**324.21**		**2.28**
1 in 10	Medium-Density Residential	171,846	17.18	0.125	0.40	8647.60	30.5	263.75	0.20	1.73
	Paved Public Road	30,316	3.03	0.125	0.53	1989.50	57.8	114.99	0.47	0.93
	Total	**202,162**	**20.22**			**10637.09**		**378.74**		**2.66**
1 in 25	Medium-Density Residential	171,846	17.18	0.146	0.40	10100.39	30.5	308.06	0.20	2.02
	Paved Public Road	30,316	3.03	0.146	0.53	2323.73	57.8	134.31	0.47	1.09
	Total	**202,162**	**20.22**			**12424.12**		**442.37**		**3.11**
1 in 100	Medium-Density Residential	171,846	17.18	0.176	0.65	19659.17	30.5	599.60	0.20	3.93
	Paved Public Road	30,316	3.03	0.176	0.85	4535.29	57.8	262.14	0.47	2.12
	Total	**202,162**	**20.22**			**24194.46**		**861.74**		**6.05**

Effect of urbanization with no control

	Existing Land Use	Future Land Use	Net Change
1 in 2 TP Loading (kg)	0.91	1.77	Increase
1 in 5 TP Loading (kg)	1.17	2.28	Increase
1 in 10 TP Loading (kg)	1.36	2.66	Increase
1 in 25 TP Loading (kg)	1.59	3.11	Increase
1 in 100 TP Loading (kg)	3.20	6.05	Increase

	Existing Land Use	Future Land Use	Net Change
1 in 2 TSS Loading (kg)	89.2	251.5	Increase
1 in 5 TSS Loading (kg)	115.1	324.2	Increase
1 in 10 TSS Loading (kg)	134.4	378.7	Increase
1 in 25 TSS Loading (kg)	157.0	442.4	Increase
1 in 100 TSS Loading (kg)	315.4	861.7	Increase

Post-development Runoff Coefficients

Land Type	% Land	Runoff C
Residential Impervious	31%	0.85
Residential Pervious	69%	0.2
Weighted Residential Runoff C	**0.40**	
Weighted 100yr Runoff C	**0.65**	

19-6784 - Charleswood Subdivision Development - Water Quality Model (Post-Development)

July 8, 2019

Block A - Post-Development Conditions With BMPs

Return Period	Land Use	Area m^2	Area-ha	Runoff C	Precipitation (m)	Total Runoff (m^3)	TP-mg/L	TP-kg	TSS - mg/L	TSS - kg
1 in 2	Medium-Density Residential	11,915	1.19	0.42	0.083	417.04	0.2	0.08	30.5	12.72
1 in 5		11,915	1.19	0.42	0.107	537.63	0.2	0.11	30.5	16.40
1 in 10		11,915	1.19	0.42	0.125	628.08	0.2	0.13	30.5	19.16
1 in 25		11,915	1.19	0.42	0.146	733.60	0.2	0.15	30.5	22.37
1 in 100		11,915	1.19	0.65	0.176	1363.09	0.2	0.27	30.5	41.57

				Uncontrolled		End of Treatment Train	
	Land Use	TP - mg/L	TSS - mg/L	TP - kg	TSS-kg	TP - kg	TSS - kg
1 in 2	Medium-Density Residential	0.2	30.5	0.08	12.72	0.046	2.046
1 in 5		0.2	30.5	0.11	16.40	0.059	2.638
1 in 10		0.2	30.5	0.13	19.16	0.069	3.082
1 in 25		0.2	30.5	0.15	22.37	0.080	3.600
1 in 100		0.2	30.5	0.27	41.57	0.149	6.688

Treatment Train Summary	
BMP #1	Vegetated Filter Strip
BMP #2	Enhanced Grass Swale
TP Weighted Removal Effeciency	45.4%
TSS Weighted Removal Effeciency	83.9%

Block B - Post-Development Conditions With BMPs

Return Period	Land Use	Area m^2	Area-ha	Runoff C	Precipitation (m)	Total Runoff (m^3)	TP-mg/L	TP-kg	TSS - mg/L	TSS - kg
1 in 2	Medium-Density Residential	15,742	1.57	0.42	0.083	545.10	0.2	0.11	30.5	16.63
1 in 5		15,742	1.57	0.42	0.107	702.72	0.2	0.14	30.5	21.43
1 in 10		15,742	1.57	0.42	0.125	820.94	0.2	0.16	30.5	25.04
1 in 25		15,742	1.57	0.42	0.146	958.85	0.2	0.19	30.5	29.25
1 in 100		15,742	1.57	0.65	0.176	1800.94	0.2	0.36	30.5	54.93

				Uncontrolled		End of Treatment Train	
	Land Use	TP - mg/L	TSS - mg/L	TP - kg	TSS-kg	TP - kg	TSS - kg
1 in 2	Medium-Density Residential	0.2	30.5	0.11	16.63	0.048	2.108
1 in 5		0.2	30.5	0.14	21.43	0.061	2.718
1 in 10		0.2	30.5	0.16	25.04	0.072	3.175
1 in 25		0.2	30.5	0.19	29.25	0.084	3.709
1 in 100		0.2	30.5	0.36	54.93	0.157	6.966

Treatment Train Summary	
BMP #1	None
BMP #2	Enhanced Grass Swale
TP Weighted Removal Effeciency	56.4%
TSS Weighted Removal Effeciency	87.3%

Block C - Post-Development Conditions With BMPs

Return Period	Land Use	Area m^2	Area-ha	Runoff C	Precipitation (m)	Total Runoff (m^3)	TP-mg/L	TP-kg	TSS - mg/L	TSS - kg
1 in 2	Medium-Density Residential	11,682	1.17	0.42	0.083	405.19	0.2	0.08	30.5	12.36
1 in 5		11,682	1.17	0.42	0.107	522.35	0.2	0.10	30.5	15.93
1 in 10		11,682	1.17	0.42	0.125	610.22	0.2	0.12	30.5	18.61
1 in 25		11,682	1.17	0.42	0.146	712.74	0.2	0.14	30.5	21.74
1 in 100		11,682	1.17	0.65	0.176	1336.42	0.2	0.27	30.5	40.76

				Uncontrolled		End of Treatment Train	
	Land Use	TP - mg/L	TSS - mg/L	TP - kg	TSS-kg	TP - kg	TSS - kg
1 in 2	Medium-Density Residential	0.2	30.5	0.08	12.36	0.058	4.594
1 in 5		0.2	30.5	0.10	15.93	0.075	5.923
1 in 10		0.2	30.5	0.12	18.61	0.088	6.919
1 in 25		0.2	30.5	0.14	21.74	0.102	8.081
1 in 100		0.2	30.5	0.27	40.76	0.192	15.153

Treatment Train Summary	
BMP #1	Vegetated Filter Strip
BMP #2	Enhanced Grass Swale
TP Weighted Removal Effeciency	28.3%
TSS Weighted Removal Effeciency	62.8%

Block D - Post-Development Conditions With BMPs

Return Period	Land Use	Area m^2	Area-ha	Runoff C	Precipitation (m)	Total Runoff (m^3)	TP-mg/L	TP-kg	TSS - mg/L	TSS - kg
1 in 2	Medium-Density Residential	11,980	1.20	0.42	0.083	416.24	0.2	0.08	30.5	12.70
1 in 5		11,980	1.20	0.42	0.107	536.60	0.2	0.11	30.5	16.37
1 in 10		11,980	1.20	0.42	0.125	626.87	0.2	0.13	30.5	19.12
1 in 25		11,980	1.20	0.42	0.146	732.18	0.2	0.15	30.5	22.33
1 in 100		11,980	1.20	0.65	0.176	1370.57	0.2	0.27	30.5	41.80

				Uncontrolled		End of Treatment Train	
	Land Use	TP - mg/L	TSS - mg/L	TP - kg	TSS-kg	TP - kg	TSS - kg
1 in 2	Medium-Density Residential	0.2	30.5	0.08	12.70	0.049	5.111
1 in 5		0.2	30.5	0.11	16.37	0.063	6.588
1 in 10		0.2	30.5	0.13	19.12	0.073	7.697
1 in 25		0.2	30.5	0.15	22.33	0.086	8.990
1 in 100		0.2	30.5	0.27	41.80	0.160	16.828

Treatment Train Summary	
BMP #1	Vegetated Filter Strip
BMP #2	Enhanced Grass Swale
TP Weighted Removal Effeciency	41.5%
TSS Weighted Removal Effeciency	59.7%

Block E - Post-Development Conditions With BMPs

Return Period	Land Use	Area m^2	Area-ha	Runoff C	Precipitation (m)	Total Runoff (m^3)	TP-mg/L	TP-kg	TSS - mg/L	TSS - kg
1 in 2	Medium-Density Residential	26,542	2.65	0.39	0.083	867.07	0.2	0.17	30.5	26.45
1 in 5		26,542	2.65	0.39	0.107	1117.79	0.2	0.22	30.5	34.09
1 in 10		26,542	2.65	0.39	0.125	1305.82	0.2	0.26	30.5	39.83
1 in 25		26,542	2.65	0.39	0.146	1525.20	0.2	0.31	30.5	46.52
1 in 100		26,542	2.65	0.65	0.176	3036.37	0.2	0.61	30.5	92.61

				Uncontrolled		End of Treatment Train	
	Land Use	TP - mg/L	TSS - mg/L	TP - kg	TSS-kg	TP - kg	TSS - kg
1 in 2	Medium-Density Residential	0.2	30.5	0.17	26.45	0.088	3.693
1 in 5		0.2	30.5	0.22	34.09	0.113	4.761
1 in 10		0.2	30.5	0.26	39.83	0.132	5.562
1 in 25		0.2	30.5	0.31	46.52	0.155	6.497
1 in 100		0.2	30.5	0.61	92.61	0.308	12.934

Treatment Train Summary	
BMP #1	None
BMP #2	Enhanced Grass Swale
TP Weighted Removal Effeciency	49.3%
TSS Weighted Removal Effeciency	86.0%

Cumberland Roadway - Post-Development Conditions With BMPs

Return Period	Land Use	Area m^2	Area-ha	Runoff C	Precipitation (m)	Total Runoff (m^3)	TP-mg/L	TP-kg	TSS - mg/L	TSS - kg
1 in 2	Paved Public Road	13,503	1.35	0.53	0.083	588.40	0.47	0.28	57.8	34.01
1 in 5		13,503	1.35	0.53	0.107	758.54	0.47	0.35	57.8	43.84
1 in 10		13,503	1.35	0.53	0.125	886.14	0.47	0.41	57.8	51.22
1 in 25		13,503	1.35	0.53	0.146	1035.01	0.47	0.48	57.8	59.82
1 in 100		13,503	1.35	0.85	0.176	2020.07	0.47	0.94	57.8	116.76

				Uncontrolled		End of Treatment Train	
	Land Use	TP - mg/L	TSS - mg/L	TP - kg	TSS-kg	TP - kg	TSS - kg
1 in 2	Paved Public Road	0.4675	57.8	0.28	34.01	0.099	0.765
1 in 5		0.4675	57.8	0.35	43.84	0.128	0.986
1 in 10		0.4675	57.8	0.41	51.22	0.149	1.152
1 in 25		0.4675	57.8	0.48	59.82	0.174	1.346
1 in 100		0.4675	57.8	0.94	116.76	0.340	2.627

Treatment Train Summary	
BMP #1	None
BMP #2	Enhanced Grass Swale
TP Weighted Removal Effeciency	64.0%
TSS Weighted Removal Effeciency	97.8%

Effect of urbanization with BMPs (Sum of Block A to E & Cumberland)

	Existing Land Use	Future Land Use	Net Change
1 in 2 TP Loading (kg)	0.41	0.39	Decrease
1 in 5 TP Loading (kg)	0.53	0.50	Decrease
1 in 10 TP Loading (kg)	0.62	0.58	Decrease
1 in 25 TP Loading (kg)	0.72	0.68	Decrease
1 in 100 TP Loading (kg)	1.45	1.31	Decrease

	Existing Land Use	Future Land Use	Net Change
1 in 2 TSS Loading (kg)	40.34	18.32	Decrease
1 in 5 TSS Loading (kg)	52.00	23.61	Decrease
1 in 10 TSS Loading (kg)	60.75	27.59	Decrease
1 in 25 TSS Loading (kg)	70.95	32.22	Decrease
1 in 100 TSS Loading (kg)	142.55	61.20	Decrease

Block F - Post-Development Conditions With BMPs

Return Period	Land Use	Area m^2	Area-ha	Runoff C	Precipitation (m)	Total Runoff (m^3)	TP-mg/L	TP-kg	TSS - mg/L	TSS - kg
1 in 2	Medium-Density Residential	44,429	4.44	0.38	0.083	1395.49	0.2	0.28	30.5	42.56
1 in 5		44,429	4.44	0.38	0.107	1799.01	0.2	0.36	30.5	54.87
1 in 10		44,429	4.44	0.38	0.125	2101.65	0.2	0.42	30.5	64.10
1 in 25		44,429	4.44	0.38	0.146	2454.72	0.2	0.49	30.5	74.87
1 in 100		44,429	4.44	0.65	0.176	5082.66	0.2	1.02	30.5	155.02

				Uncontrolled		End of Treatment Train	
	Land Use	TP - mg/L	TSS - mg/L	TP - kg	TSS-kg	TP - kg	TSS - kg
1 in 2	Medium-Density Residential	0.2	30.5	0.28	42.56	0.215	21.165
1 in 5		0.2	30.5	0.36	54.87	0.278	27.285
1 in 10		0.2	30.5	0.42	64.10	0.324	31.875
1 in 25		0.2	30.5	0.49	74.87	0.379	37.231
1 in 100		0.2	30.5	1.02	155.02	0.785	77.088

Treatment Train Summary	
BMP #1	Vegetated Filter Strip
BMP #2	Enhanced Grass Swale
TP Weighted Removal Effeciency	22.8%
TSS Weighted Removal Effeciency	50.3%

Block G - Post-Development Conditions With BMPs

Return Period	Land Use	Area m^2	Area-ha	Runoff C	Precipitation (m)	Total Runoff (m^3)	TP-mg/L	TP-kg	TSS - mg/L	TSS - kg
1 in 2	Medium-Density Residential	49,555	4.96	0.38	0.083	1563.36	0.2	0.31	30.5	47.68
1 in 5		49,555	4.96	0.38	0.107	2015.42	0.2	0.40	30.5	61.47
1 in 10		49,555	4.96	0.38	0.125	2354.46	0.2	0.47	30.5	71.81
1 in 25		49,555	4.96	0.38	0.146	2750.01	0.2	0.55	30.5	83.88
1 in 100		49,555	4.96	0.65	0.176	5669.12	0.2	1.13	30.5	172.91

				Uncontrolled		End of Treatment Train	
	Land Use	TP - mg/L	TSS - mg/L	TP - kg	TSS-kg	TP - kg	TSS - kg
1 in 2	Medium-Density Residential	0.2	30.5	0.31	47.68	0.125	6.469
1 in 5		0.2	30.5	0.40	61.47	0.161	8.339
1 in 10		0.2	30.5	0.47	71.81	0.188	9.742
1 in 25		0.2	30.5	0.55	83.88	0.219	11.379
1 in 100		0.2	30.5	1.13	172.91	0.452	23.458

Treatment Train Summary	
BMP #1	Vegetated Filter Strip
BMP #2	Enhanced Grass Swale
TP Weighted Removal Effeciency	60.1%
TSS Weighted Removal Effeciency	86.4%

Charleswood Roadway - Post-Development Conditions With BMPs

Return Period	Land Use	Area m^2	Area-ha	Runoff C	Precipitation (m)	Total Runoff (m^3)	TP-mg/L	TP-kg	TSS - mg/L	TSS - kg
1 in 2	Paved Public Road	16,813	1.68	0.53	0.083	732.63	0.47	0.34	57.8	42.35
1 in 5		16,813	1.68	0.53	0.107	944.47	0.47	0.44	57.8	54.59
1 in 10		16,813	1.68	0.53	0.125	1103.35	0.47	0.52	57.8	63.77
1 in 25		16,813	1.68	0.53	0.146	1288.72	0.47	0.60	57.8	74.49
1 in 100		16,813	1.68	0.85	0.176	2515.22	0.47	1.18	57.8	145.38

				Uncontrolled		End of Treatment Train	
	Land Use	TP - mg/L	TSS - mg/L	TP - kg	TSS-kg	TP - kg	TSS - kg
1 in 2	Paved Public Road	0.4675	57.8	0.34	42.35	0.123	0.953
1 in 5		0.4675	57.8	0.44	54.59	0.159	1.228
1 in 10		0.4675	57.8	0.52	63.77	0.186	1.435
1 in 25		0.4675	57.8	0.60	74.49	0.217	1.676
1 in 100		0.4675	57.8	1.18	145.38	0.423	3.271

Treatment Train Summary	
BMP #1	None
BMP #2	Enhanced Grass Swale
TP Weighted Removal Effeciency	64.0%
TSS Weighted Removal Effeciency	97.8%

Effect of urbanization with BMPs (Sum of Block F, G, and Charleswood)

	Existing Land Use	Future Land Use	Net Change
1 in 2 TP Loading (kg)	0.497	0.463	Decrease
1 in 5 TP Loading (kg)	0.640	0.597	Decrease
1 in 10 TP Loading (kg)	0.748	0.698	Decrease
1 in 25 TP Loading (kg)	0.874	0.815	Decrease
1 in 100 TP Loading (kg)	1.755	1.660	Decrease

	Existing Land Use	Future Land Use	Net Change
1 in 2 TSS Loading (kg)	48.914	28.587	Decrease
1 in 5 TSS Loading (kg)	63.058	36.853	Decrease
1 in 10 TSS Loading (kg)	73.666	43.053	Decrease
1 in 25 TSS Loading (kg)	86.042	50.286	Decrease
1 in 100 TSS Loading (kg)	172.870	103.817	Decrease

Effect of urbanization with BMPs (Sum of All Blocks (A to G), Cumberland and Charleswood)

	Existing Land Use	Future Land Use	Net Change
1 in 2 TP Loading (kg)	0.91	0.85	Decrease
1 in 5 TP Loading (kg)	1.17	1.10	Decrease
1 in 10 TP Loading (kg)	1.36	1.28	Decrease
1 in 25 TP Loading (kg)	1.59	1.50	Decrease
1 in 100 TP Loading (kg)	3.20	2.97	Decrease

	Existing Land Use	Future Land Use	Net Change
1 in 2 TSS Loading (kg)	89.25	46.91	Decrease
1 in 5 TSS Loading (kg)	115.06	60.47	Decrease
1 in 10 TSS Loading (kg)	134.41	70.64	Decrease
1 in 25 TSS Loading (kg)	156.99	82.51	Decrease
1 in 100 TSS Loading (kg)	315.42	165.01	Decrease