SASKATCHEWAN

Water Security Agency

Stormwater Guidelines

June 2015
EPB 322

Preface

Under *The Environmental Management and Protection Act, 2010* (EMPA) and *The Waterworks and Sewage Works Regulations*, stormwater quality and most aspects of its management at present are not specifically regulated. The purpose of this guideline is to provide high-level technical guidance to municipal authorities, individuals and consultants who plan to develop and implement drainage systems for stormwater in urban/built-up municipal areas, and commercial and industrial areas in Saskatchewan. Although the guidelines provide technical and practical guidance, users must exercise judgment in planning, designing and implementing stormwater management works.

Stormwater management solutions are site specific, which must be recognized when using the guidance provided in this document. The designer has to determine if a single practice, or a combination of practices, is needed to meet the stormwater objectives and goals for any given site, and is responsible for the design and decisions made with respect to stormwater management.

The Water Security Agency (WSA) encourages the development and use of novel designs and best available technologies in developing stormwater management solutions. The WSA believes that the guidelines, when employed as a "Code of Practice," will aid minimizing the impacts on receiving waters due to stormwater discharges and may serve as a "diligent" approach to improved stormwater management in the province.

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1. Rationale and Background for Stormwater Management Guidelines

Stormwater is rainfall and snowmelt that runs off the land into storm sewers, streams and nearby lakes or rivers. The degradation of water quality has received increasing attention over the past several decades. The cause of degradation may be attributed to point sources of pollution such as wastewater treatment plants or industrial waste discharges. Although a great deal of progress has been made to minimize or eliminate point sources of pollution, water quality degradation of some watercourses may occur due to non-point pollution such as stormwater runoff.

It is recognized that urbanization increases the quantity of localized stormwater runoff and affects the quality of water in receiving water bodies, thereby resulting in significant environmental impacts, which affect aquatic habitats of receiving waters. Environment Canada has estimated that urbanization of a natural drainage basin can result in increases in stormwater runoff of 400 per cent or more.

Where urbanization occurs, undisturbed pervious surfaces become impervious with the construction activities. Impervious surfaces produce an increase in stormwater runoff, both quantitatively and qualitatively. It is anticipated that these changes may cause pollution in receiving waters; affect the aquatic habitats and their functions; disrupt the natural balance of physical, chemical and biological processes; and result in soil erosion that creates damage downstream, reduces infiltration of water into the ground and in extreme cases may also cause flooding.

Municipal stormwater collection systems discharge many substances in addition to water. As stormwater collects and flows over pavement, lawns, driveways and other urban surfaces, it collects considerable quantities of pollutants such as oil and grease, fertilizers, pesticides and metals. Sediment from active construction sites often discharges into storm drainage systems. Private citizens may also contribute to stormwater pollution by improper disposal of lawn clippings, used oil or household chemicals. Industrial and commercial facilities may discharge pollutants into stormwater collection systems through cross-connection of storm drains and sanitary sewers.

Under *The Environmental Management and Protection Act, 2010* (EMPA) and *The Waterworks and Sewage Works Regulations,* stormwater quality, and most aspects of its management, at present is not specifically regulated. Neither EMPA nor *The Waterworks and Sewage Works Regulations* presently require a permit for the construction or operation of a dedicated stormwater works. However, EMPA does provide authority for the creation of regulations governing stormwater by virtue of:

> *98(1)(eee) respecting stormwater and stormwater works, including prohibiting any matter or action related to stormwater works and protecting the environment as it is affected by stormwater and requiring the holding of a permit to do any matter or undertake any action related to stormwater works and protecting the environment as it is affected by stormwater.*

The Waterworks and Sewage Works Regulations define stormwater as:

> *2(1)(hh) "storm sewer" means a system of conduits, drains, mains, manholes, basins and pipes intended to convey stormwater exclusively or principally.*

The Waterworks and Sewage Works Regulations only prohibit the permittee of a sanitary sewage works from interconnecting a sanitary sewers and storm sewers by means of Section 7 as follows:

> *7 No permittee shall cause any sanitary sewers and storm sewers to be interconnected in a manner that permits sewage in the sanitary sewer to be discharged through the storm sewer.*

Prior to the revisions to water-related legislation in 2002, the management of stormwater was specifically exempted from permitting by clause 6(1)(d) of *The Water Pollution Control and Waterworks Regulations* which state:

> *6(1) The following discharge of contaminants are exempted from Clause 17(a) of the Act:*
>
> *(d) any stormwater discharge other than stormwater discharge at any industrial operation that has a permit pursuant to clause 17(a) or 17(c) of the Act.*

Interconnection of stormwater and sanitary sewers was also prohibited under the former *Water Pollution Control and Waterworks Regulations* that was in effect from 1987 to 2002.

Although management aspects of stormwater management are presently limited as outlined above, section 8(2) of EMPA prohibits discharges that may cause or are causing an adverse effect as follows:

8(1) No person shall discharge or allow the discharge of a substance into the environment in an amount, concentration or level or at a rate of release that may cause or is causing an adverse effect unless otherwise expressly authorized pursuant to:

(a) this Act or the regulations;

(b) any other Act, Act of the Parliament of Canada or the regulations made pursuant to any other Act or Act of the Parliament of Canada;

(c) any approval, permit, licence or order issued or made pursuant to:

(i) this Act or the regulations; or

(ii) any other Act, Act of the Parliament of Canada or the regulations made pursuant to any other Act or Act of the Parliament of Canada;

(d) the code; or

(e) an accepted environmental protection plan.

Pollution resulting from stormwater runoff carries the potential to affect the quality of water and environment in natural receiving systems. The WSA believes it is essential to develop and implement 'Stormwater Management Guidelines' as a "Code of Practice" for municipal authorities, individuals and consultants who plan to develop and implement drainage systems for stormwater in urban areas, commercial and industrial areas. Voluntary observance of these guidelines will then serve as a "diligent" approach to improved stormwater management in the province and thereby avoid the potential consequences of adverse impacts to aquatic ecosystems.

2. Stormwater Quantity and Quality

2.1 General

Stormwater quantity is variable in duration, frequency and location. The amount of stormwater runoff reaching a receiving water body will also depend upon the surface over which it travels. An increase in stormwater runoff in urban areas results in increased peak flows, which must be determined in order to design and implement any stormwater works. The quality of stormwater runoff is often a function of several mechanisms and the type and amount of pollutants in runoff are associated with a given land use or activity. As is the case with the design of any wastewater treatment works, the incoming quality of stormwater runoff must be known prior to designing any stormwater works.

2.2 Stormwater Quantity

The hydraulic sizing of drainage and conveyance structures in urban areas always requires estimation of peak flow rates. Peak flow is the maximum rate of flow passing a given point during or after a rainfall event. Historically, the Rational Method is the most widely used method of estimating the peak runoff rates for the design of urban drainage systems. The Rational Method is based on an empirical formula relating the peak flow rate to the drainage area, the rainfall intensity and a runoff coefficient. The Rational formula is:

$Q = 0.0028\ C\ I\ A$ (m^3/s) [metric units], or

$Q = C\ I\ A$ (ft^3/s) [British units]

where

Q = peak runoff rate

C = dimensionless runoff coefficient

I = rainfall intensity for a duration that equals time of concentration (tc) of the basin (mm/hr and in/hr in metric and British units, respectively)

A = basin area (hectares and acres in metric and British units, respectively), and

tc = time of concentration for the basin for the particular event (min).

The fundamental assumptions underlying the Rational Method are: [1]

- The rainfall intensity is constant over a period that equals the time of concentration of the basin;
- The rainfall intensity is constant throughout the basin;
- The frequency distribution of the event rainfall and the peak runoff rate are identical (this assumption is true for all event-based computations);
- The time of concentration of a basin is constant and is easily determined; and
- The runoff coefficient is invariant, regardless of season of the year or depth or intensity of rainfall.

Typically, rainfall intensities are determined from Intensity-Duration-Frequency curves (IDF curves) or Depth-Duration-Frequency curves (DDF curves). These are plots of rainfall intensity (or depth) versus duration of event rainfall. The runoff coefficient (C) that is commonly used in estimating peak runoff rate is shown in Table 1.

There are a number of computer programs (models) that are available to perform hydrologic and hydraulic computations for large watersheds. However, only a few programs are designed as general application models that can be applied to a wide variety of problems in different locations. There are two types of models for doing hydrologic and hydraulic computations for a system: continuous simulation models and event-based models. These models can be used as long as the designer can demonstrate that the model is appropriate and accurate.

Table 1. Runoff Coefficients for Urban Areas [2]

Type of drainage area	Runoff coefficient
Business:	
Downtown areas	0.70–0.95
Neighbourhood areas	0.50–0.70
Residential:	
Single-family areas	0.30–0.50
Multi-units, detached	0.40–0.60
Multi-units, attached	0.60–0.75
Suburban	0.25–0.40
Apartment dwelling areas	0.50–0.70
Industrial:	
Light areas	0.50–0.80
Heavy areas	0.60–0.90
Parks, Cemeteries	0.10–0.25
Playgrounds	0.20–0.40
Railroad yard areas	0.20–0.40
Unimproved areas	0.10–0.30
Lawns:	
Sandy soil, flat, 2%	0.05–0.10
Sandy soil, average, 2 to 7%	0.10–0.15
Sandy soil, steep, 7%	0.15–0.20
Heavy soil, flat, 2%	0.13–0.17
Heavy soil, average, 2 to 7%	0.18–0.25
Heavy soil, steep, 7%	0.25–0.35

Streets: Asphaltic Concrete Brick Drives and walks	 0.70–0.95 0.80–0.95 0.70–0.85 0.75–0.85
Roofs:	0.75–0.95

2.3 Stormwater Quality

Numerous studies have indicated that there can be significant pollution in receiving waters due to stormwater runoff. The pollutant loading from urban/rural runoff may be similar to that of wastewater effluent and industrial discharges and have significant impacts on potable water supply, aquatic habitat, recreation, agriculture and aesthetics. Stormwater runoff is usually high in suspended solids and organic matter that exert oxygen demand in the receiving waters.[3] Other pollutants or physical conditions associated with urban/rural runoff that are harmful to receiving waters include nitrogen/phosphorus, temperature, pathogens, metals, hydrocarbons, organics and salt.

Significant impacts on receiving waters associated with stormwater discharges include: [4]

- water quality changes (short-term) during and after storm events including temporary increases in the concentration of one or more pollutants, toxins or bacteria levels;
- long-term water quality impacts caused by the cumulative effects associated with repeated stormwater discharges from a number of sources; and
- physical impacts due to erosion, scour and deposition associated with the increased frequency and volume of runoff that alters aquatic habitat.

Pollutants frequently found in stormwater runoff, their source and the impact on receiving waters are summarized in Table 2. Stormwater samples were collected by the WSA during spring 2005 (immediately after snowmelt) from selected storm sewer outfalls located in a Saskatchewan community and the results of selected parameters are shown in Table A-1 of Appendix A. The results of stormwater samples collected during summer 2003 from selected stormwater outfalls located in another Saskatchewan community are shown in Table A-2 of Appendix A. Table A-3 in Appendix A provides compilation of selected parameters from a study on urban runoff conducted by the USEPA.[5] Table A-4 in Appendix A shows the concentration of certain parameters in stormwater collected from two storm outfalls located in the City of Edmonton.

Table 2. Summary of Main Stormwater Pollutants, Sources, Effects, and Related Impacts[4]

Stormwater Pollutant	Sources	Effects	Related Impacts
Nitrogen/phosphorus (nutrients)	Urban landscape runoff (fertilizers, detergents, plant debris, sediments, dust, gasoline, tires); agricultural runoff (fertilizers, animal waste); failing septic systems.	Phosphorus is the limiting nutrient in most freshwater systems. Nitrogen is the limiting nutrient in most saltwater systems, but can be a concern in streams as well.	Algal growth; reduced clarity; lower dissolved oxygen (DO); release of other pollutants. Nutrients can limit recreational values (swimming, boating, fishing and other uses), reduce animal habitats and contaminate water supplies.
Suspended solids	Construction sites; other disturbed and non-vegetated lands; eroding banks; road sanding; urban runoff.	Increased turbidity and deposition of sediment.	Increased turbidity; lower DO; deposition of sediments; smothered aquatic habitat.

Pathogens (bacteria/ viruses)	Animal waste; urban runoff; failing septic systems.	Presence of bacteria and viral strains. Bacteria levels are usually high in summer when warm temperatures are beneficial to reproduction.	Human health risks via drinking water supplies; contaminated shellfish-growing areas and swimming beaches.
Metals	Industrial processes; normal wear of automobile brake lines and tires; automobile emissions and fluid leaks; metal roofs.	Increased toxicity of runoff and accumulation in the food chain.	Toxicity of water column and sediment; bioaccumulation in aquatic species and through the food chain.
Hydrocarbons (oil and grease, polycyclic aromatic hydrocarbons (PAHs)	Industrial processes; automobile wear; automobile emissions and fluid leaks; waste oil.	Degraded appearance of water surfaces; limiting water and air interactions (lower DO). Hydrocarbons have a strong affinity for sediment.	Toxicity of water column and sediment; bioaccumulation in aquatic species and through the food chain.
Organics (pesticides, polychlorinated biphenyl/PCBs, synthetic chemicals)	Pesticides (herbicides, insecticides, fungicides, etc.); industrial processes.	Increased toxicity to sensitive animal species and fishery resources and accumulation in the food chain.	Toxicity of water column and sediment; bioaccumulation in aquatic species and through the food chain.
Salt (sodium, chlorides)	Salting of roads and uncovered salt storage	Toxicity to organisms, reduction of fishery resources and increased levels of sodium and chloride in surface and groundwater. Could stress plant species respiration processes through their effect on soil structure.	Toxicity of water column and sediment. Salt can cause the loss of sensitive animal species, plant species, and fishery resources, and contaminate surface and groundwater.

In Saskatchewan, the General Surface Water Quality Objectives (Table 4.1 of Surface Water Quality Objectives, EPB 356, June 2015) are applicable to all receiving waters except that portion designated by the WSA as an effluent mixing zone. However, within the mixing zone, the General Objectives for Effluent Discharges (section 3 of Surface Water Quality Objectives, EPB 356, June 2015) apply. Further, specific water quality objectives (section 4.2 of Surface Water Quality Objectives, EPB 356, June 2015) are applicable to receiving waters based on the type of use such as recreational use, agricultural use and protection of aquatic life and wildlife. Hence, the owners and designers of stormwater management systems in Saskatchewan who plan to discharge the treated stormwater into receiving waters should consider these objectives during planning, designing and implementation of stormwater drainage systems. At present, WSA's Surface Water Quality Objectives are being revised and are applicable as and when revised.

3. Stormwater Management Practices and Guidelines

3.1 General

Stormwater management practices are a series of practices or treatment methods that reduce the effects of stormwater pollution and meet stormwater management objectives for a given area. Effective stormwater management is often achieved from a management systems approach rather than focusing on individual practices. That is, the pollutant control achievable from any management system is viewed as the sum of parts, taking into account the range of effectiveness associated with each single practice, the cost of each practice, and the resulting overall cost and effectiveness. Some individual practices may not be very effective alone but, in combination with others, may provide a key function in highly effective systems.

The selection and design of management practices must incorporate water quantity and water quality concerns. Stormwater management practices that are considered for the control of urban stormwater runoff are as follows: [3,4,5,6,7]

- source controls;
- on-site (lot-level) and conveyance system controls; and
- end-of-pipe controls.

The minor and major (piped) systems should be designed for 1:5 and 1:100 year events, respectively. The minor systems consist of drainage works that transport flows from a catchment during minor rainstorms. The major systems consist of drainage routes that transport flow during major storm events. All of the municipalities should give considerations regarding mosquito control programs near any open stormwater systems, such as wet ponds. Regarding interconnection, as per Section 8 of *The Waterworks and Sewage Works Regulations,* no interconnection is permitted between sanitary and storm sewers and the discharge of sewage from sanitary sewers into storm sewers is not permitted in Saskatchewan.

First flush is a common phenomenon encountered during first runoff from a storm and often it is contaminated. It is caused by the rapid mobilization of contaminants attached to fine sediments on impervious surfaces and by the flushing of catchbasins and manholes. Sufficient storage requirements are recommended to reduce the effect of first flush in detention systems such as wet ponds, dry ponds and constructed wetlands.

3.2 Source Controls

Adoption of pollution prevention and source control practices minimize the level of pollutants entering stormwater systems. Source control is a simple concept, which can be cost effective and requires public participation. Source control measures include:

- pet waste collection;
- street cleaning;
- storm drain system cleaning;
- catchbasin cleaning;
- pesticide control; and
- eliminating non-stormwater discharges.

Pet waste collection, as a source control, involves using a combination of education programs and compliance to encourage residents to clean up after their pets. The presence of pet waste in stormwater runoff has a number of implications for urban stream water quality, with perhaps the greatest impact from fecal bacteria. According to a recent research study,[8] nonhuman waste represents a significant source of bacterial contamination in urban watersheds. These bacteria can pose health risks to humans and other animals and result in the spread of disease. Pet waste may also be a factor in the eutrophication of lakes. The release of nutrients from the decay of pet waste promotes weed and algae growth, limiting light penetration and the growth of aquatic vegetation. This situation, in turn, can reduce oxygen levels in the water, affecting fish and other aquatic organisms. Pet waste collection programs use awareness and education, signs and pet waste control ordinances to alert residents to the proper disposal techniques for pet droppings.

Street cleaning practices such as street sweeping on a regular basis, minimize pollutant level in stormwater runoff and receiving waters. These cleaning practices are designed to remove from road and parking lot surfaces sediment debris and other pollutants that are a potential source of pollution impacting urban waterway.[9] Street sweeping practice removes sediment buildup and large debris from curb gutters. The effectiveness of street sweeping in regard to reduction of pollutant level depends on factors such as frequency, time of year, type of sweeping equipment, rainfall intensity, length of time between rainfall events and type of road surface. In colder climates, street sweeping is recommended immediately after the spring snowmelt to reduce pollutant loads from road salt and to reduce sand export to receiving waters. Seventy per cent of cold-climate stormwater experts recommend street sweeping during the spring snowmelt as a pollution prevention measure.[10]

Storm drain systems need to be cleaned regularly. Routine cleaning reduces the amount of pollutants, trash and debris both in the storm drain system and in receiving waters. Clogged drains and storm drain inlets can cause the drains to overflow, leading to increased erosion.[11] Benefits of cleaning include increased dissolved oxygen, reduced levels of bacteria, and support of in-stream habitat. Areas with relatively flat grades or low flows should be given special attention because they rarely achieve high enough flows to flush themselves.

Catchbasin cleaning is an efficient and cost-effective method for preventing the transport of sediment and pollutants to receiving water bodies. Catchbasins are chambers or sumps, usually built at the curb line, which allow the surface water runoff to enter the stormwater conveyance system. Many catchbasins have a low area below the invert of the outlet pipe intended to retain coarse sediment. By trapping sediment, catchbasins prevent solids from clogging the storm sewer and being washed into receiving waters. Catchbasins must be cleaned periodically to maintain their ability to trap sediment and consequently their ability to prevent flooding.

Pesticide management measures involve limiting the impact of pesticides on water quality by educating residents and businesses on alternatives to pesticide use, on proper storage and on application techniques. The presence of pesticides in stormwater runoff has a direct impact on the health of aquatic organisms and can present a threat to humans through contamination of drinking water supplies. The major source of pesticides to urban streams is home application of products designed to kill insects and weeds in the lawn and garden. Pesticide pollution prevention programs try to limit adverse impacts of insecticides and herbicides by providing information on alternative pest control techniques other than chemicals or explaining how to determine the correct dosages needed to manage pests.

One of the important source control measures is identifying and eliminating non-stormwater discharges to storm sewers, which is cost-effective and improves the water quality of runoff. Non-stormwater discharges can include discharge of process water, air conditioner condensate, non-contact cooling water, vehicle wash water or sanitary wastes, and are typically the result of unauthorized connections of sanitary or process wastewater drains to storm sewers.

Environmental impact evaluations have shown that the elimination of non-stormwater discharges is an effective management practice because such discharges may contain significant loading of pollutants.[12]

3.3 On-site (Lot-level) and Conveyance System Controls

3.3.1 On-site (Lot-level) Controls

On-site (lot-level) controls are practices that reduce the quantity of stormwater runoff and improve the water quality before the runoff reaches the conveyance system. These practices are applied at a single lot level or multiple lots in a small area.

3.3.1.1 Reduced Lot Grading

The development standards require a minimum lot grade of two per cent to ensure adequate drainage of stormwater away from the buildings. In order to avoid foundation drainage problems, grading within two to four metres of buildings should be maintained at two per cent or higher. In areas outside this envelope, grading can be flattened to 0.5 per cent. A reduction in the lot grading should be evaluated if the land is flat. In hilly areas, alterations to natural topography should be minimized. Areas outside this envelope should be graded at less than two per cent (Figure 1).

Reduced lot grading can be implemented where soils have an infiltration rate of ≥ 15 millimetres per hour and it is applicable to all soils coarser than loam; clay soils are usually not suitable. In areas where reduced lot grading is implemented, roof leaders should extend two metres away from the building to discharge to the surface.

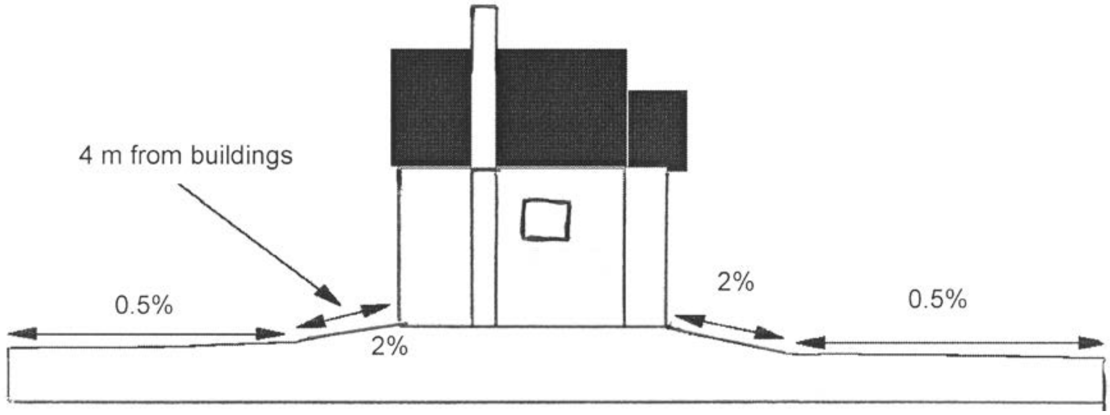


Figure 1. Lot Grading Guidelines[7]

3.3.1.2 Roof Leader to Ponding Areas and Rooftop Storage

Roof leaders discharge water to the surface and water is directed to the ponding area. Water is retained in the ponding area and surface ponding reduces the potential for downstream flooding and erosion and helps maintain pre-development end-of-pipe discharge rates. The same benefits can result from the use of rooftop storage that are likely suitable for commercial, industrial and institutional buildings.

Surface ponding may be used for parking lots or parking areas and for any new developments. The area for ponding should be a shallow depression and pond depth can be up to a maximum of 300 millimetres. The roof leader should discharge into the ponding area via a splash pad and flow paths should be provided to direct overland flow to the pond. The area of ponding should be at least four metres away from any building foundations to ensure the ponded water does not increase the amount of foundation drainage. Ponding areas can be created along the rear lot lines by raising rear yard catchbasins such that they are used as an overflow system. Infiltration in the ponding areas can be enhanced by providing an on-lot infiltration system.

3.3.1.3 On-lot Infiltration System

On-lot infiltration systems or soakway pits are used for detention of stormwater from small drainage areas, mainly single-family dwellings. They provide some reduction in overflows and enhance the quality of stormwater. They also can be used in areas without adequate minor system conveyance. On-lot infiltration systems are pits with a filter liner and rock drain material or more complex systems with catchbasin sumps and inspection wells. Example of on-lot infiltration systems is shown in Figure 2.

General design considerations for on-lot infiltration systems are as follows:

- There should be a significant distance from the bottom of the pit to the high groundwater table. This may vary from ≥ 0.8 to ≥ 1.2 metres, depending on local conditions and constraints. Local authorities should be consulted or test holes should be drilled to ensure proper distances are provided;
- The distance between the bottom of the pit and bedrock should be ≥ 1.2 metres;
- The trench should be located at least four metres away from the foundation of the nearest building;
- The trench should comprise clean (properly washed) 50-millimetre diameter stone and be lined with suitable geotextile;
- The total void volume of the trench should be based on the storage required for the appropriate design storm, based on the effective porosity of the trench media (usually assumed to be 35 to 40 per cent). The required infiltration surface area (bottom surface area) to drain the system within 48 hours is calculated from the 24-hour sustained percolation rate;
- The trench should be located close to the ground surface but factors such as the depth of trench storage, frost heave potential and surrounding soil stratification should be considered;

- A filter should be incorporated into the soakway pit design or the sump to limit solids and debris entering the system. An overflow pipe should be included where possible;
- On-lot infiltration systems should generally not be constructed on fill material, under parking lots or under multi-use areas; and
- For infiltration systems draining parking lots, one or two pretreatment devices in series should be used before the infiltration system to extend its useful life without clogging.

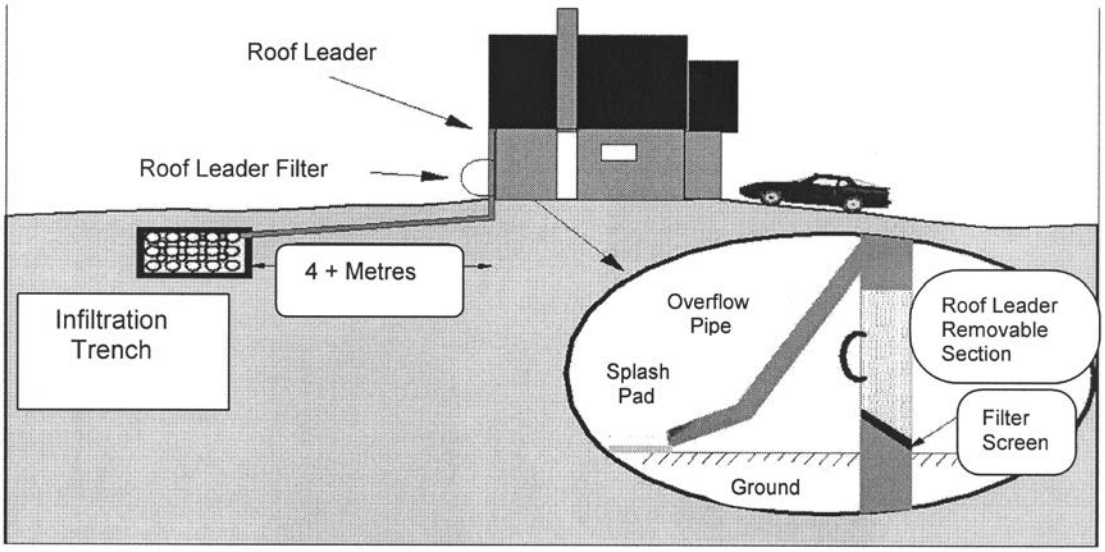


Figure 2. Infiltration System with Roof Leader[7]

3.3.1.4 Sump Pumping of Foundation Drains

Development standards may permit foundation drains to be connected to the storm sewer in some municipalities. Instead of connecting to the storm sewer, an alternative can be made by pumping foundation drainage to surface ponding/infiltration trench systems. Since foundation drainage is relatively clear water, keeping it separate from storm and sanitary sewers may reduce the cost of stormwater management and sewage treatment. Local municipalities should be contacted for consent before commencing this type of work. Sump pump foundation drainage to surface ponding/infiltration system is shown in Figure 3.

Sump pump discharges should be at least two metres away from foundations and be discharged to rear yards away from sidewalks. There should be sufficient grading away from the foundation wall when the sump pump is discharging the foundation drainage to the surface of the ground. The outlet for sump pumps that discharge to the ground surface should be at least 0.5 metres above the ground to prevent blockage from ice and snow during the winter.

3.3.2 Conveyance System Controls

Stormwater conveyance systems transport drainage from developed areas. Stormwater conveyance controls are part of the stormwater conveyance system and can be classified into following categories:

- pervious pipe systems;
- pervious catchbasins;
- grassed swales; and
- vegetated filter strips.

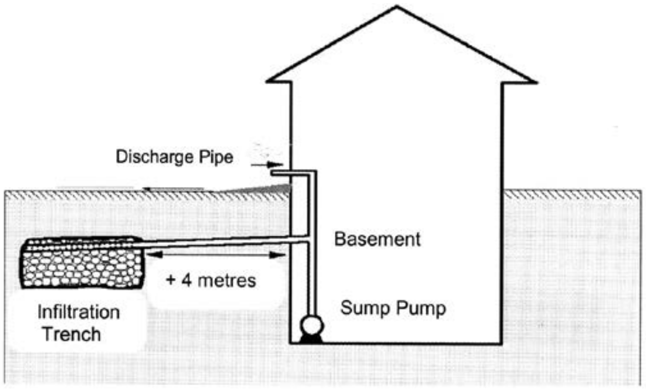


Figure 3. Sump Pump Foundation Drainage[7]

3.3.2.1 Pervious Pipe Systems

Pervious pipe systems are designed to convey the road drainage. These systems have not been commonly used because of some problems and are still experimental in nature. Pervious pipe systems are perforated along their length, thereby allowing exfiltration of water through the pipe wall as it is conveyed downstream. Pervious pipe systems are components of roadway drainage systems.

Since roadway drainage carries a high level of suspended sediment, pretreatment components are essential to remove the sediment. The runoff from the roadway is directed toward grassed areas that filter sediment prior to flowing into the stormwater catchbasin. The stormwater catchbasin is connected to the pervious pipe and is raised to allow some ponding and further sediment removal.

Pervious pipes can be used where soils have a percolation rate of ≥ 15 millimetres per hour. The minimum storage volume should be equal to the runoff from a four-hour 5-millimetre storm over the contributing drainage area and the maximum storage should be equal to the runoff from a four-hour 25-millimetre storm over the contributing drainage area. The exfiltration storage bedding depth should be between 75 and 150 millimetres deep above the pervious pipe. The bedding should drain within 24 hours and the minimum diameter for the pervious pipe should be 200 millimetres.

3.3.2.2 Pervious Catchbasins

Pervious catchbasins are designed to convey the road drainage and these systems have large sumps that are physically connected to an exfiltration storage medium. The storage medium is located below or beside the catchbasin. Pervious catchbasin details for road drainage are shown in Figure 4.

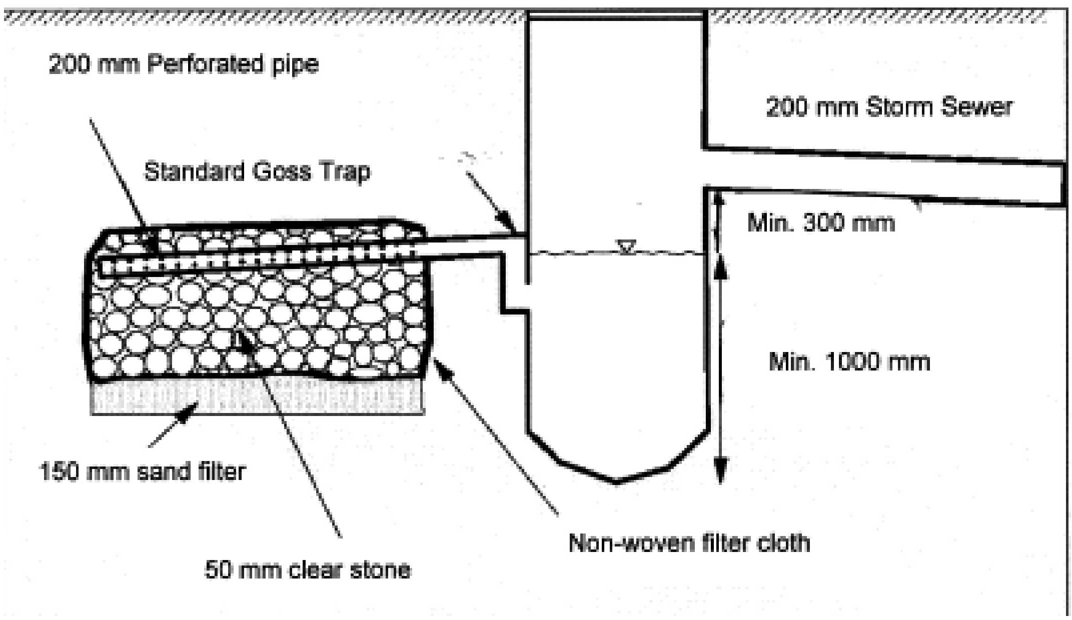


Figure 4. Pervious Catchbasin[7]

Pretreatment of road drainage is necessary prior to catchbasins so as to prevent frequent clogging. It is recommended that pervious catchbasins be constructed at least one metre above the groundwater table. The exfiltration storage depth is dependent on the native soil type/characteristics. Clear stone (50 millimetres) should be used as the exfiltration storage medium to promote filtration with a low clogging frequency. The criteria for storage volume are similar to that of pervious pipes.

3.3.2.3 Grassed Swales

Swales can be natural or manmade and are designed to trap particulate pollutants (suspended solids and trace metals), promote infiltration, and reduce the flow velocity of stormwater runoff. In the past, grassed swales were constructed for stormwater conveyance. However, stormwater objectives have changed and now grassed swales are being used to store, infiltrate and convey road and on-lot stormwater runoff. As stormwater runoff flows through the channels, it is treated through filtering by the vegetation in the channel, filtering through a subsoil matrix and/or infiltration into the underlying soils. Variations of the grassed swale include the grassed channel, dry swale and wet swale. The specific design features and methods of treatment differ in each of these designs. These designs incorporate modified geometry and other features for use of the swale as a treatment and conveyance practice.

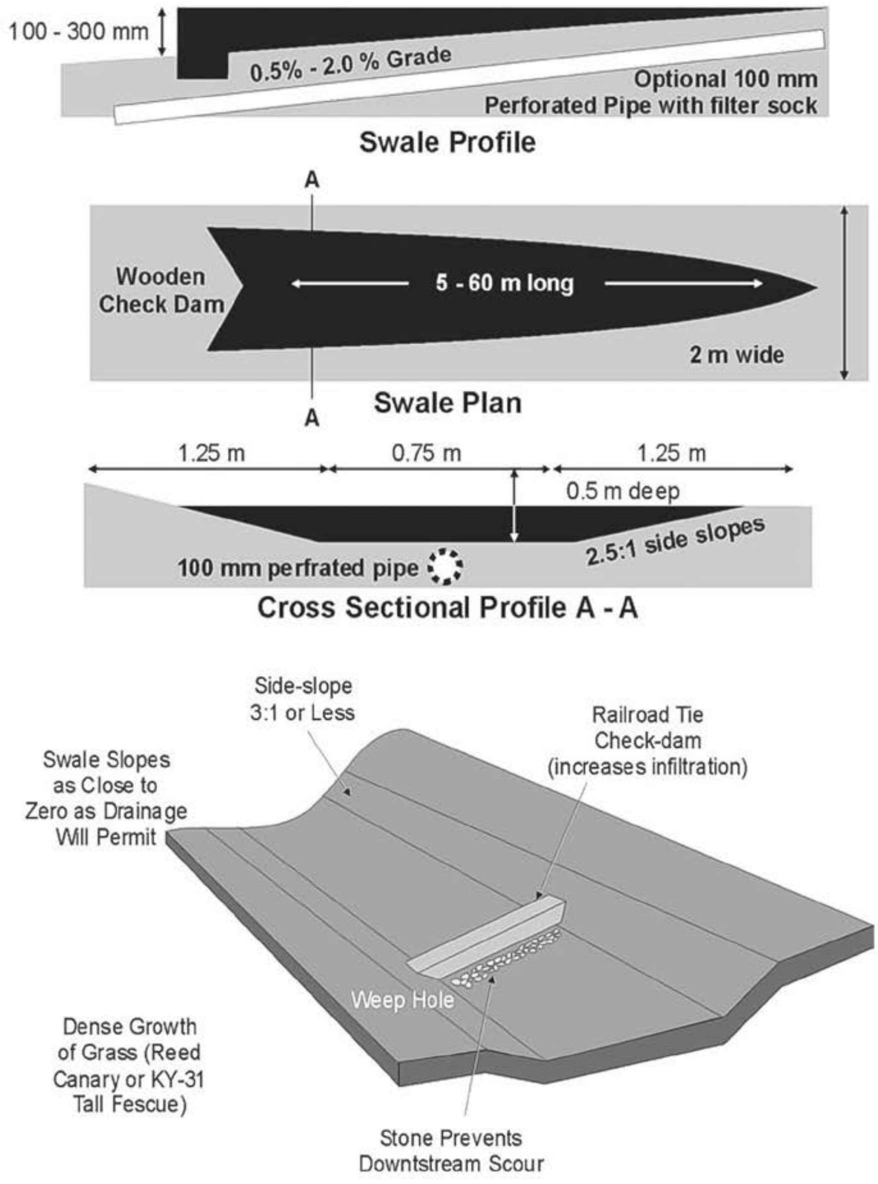


Figure 5. Grassed Swale Systems[7]

In rural areas and in urban applications, grassed swales have been shown to effectively infiltrate runoff and remove pollutants. They are also very well suited for treating highway runoff because they are linear practices. Grassed swales infiltrate stormwater and reduce the end-of-pipe discharge volumes normally associated with curb and gutter controls. Figure 5 shows grassed swale systems.

Grassed swales are generally used for small drainage areas of less than two hectares and should be used on sites with relatively flat slopes of less than four per cent slope; one to two per cent slope is recommended. Runoff velocities within the channel become too high on steeper slopes. This can cause erosion and does not allow for infiltration or filtering in the swale. Grass in the channel should be allowed to grow higher than 75 millimetres but less than 300 millimetres to enhance the filtration of suspended solids.

The dense vegetation also helps to reduce velocities and protect the channel from erosion. Deep narrow swales are less effective for pollutant removal than shallow wide swales. Typical urban swale dimensions are 0.75 metres bottom width, 2.5:1 side slopes, and a depth of 0.5 metres. The maximum velocity in the swale should be 0.5 metres per second and if velocities are greater than 0.5 metres per second, check dams to be used to promote infiltration and settling of pollutants.

3.3.2.4 Vegetated Filter Strips

Vegetated filter strips (grassed filter strips, filter strips and grassed filters) are vegetated surfaces that are designed to remove pollutants from overland runoff. Typically, filter strips treat small drainage areas (< 2 hectares). Filter strips function by slowing runoff velocities, filtering out sediment and other pollutants, and by providing some infiltration into underlying soils. With proper design and maintenance, filter strips can provide relatively high pollutant removal.

Vegetated filter strips should be located in flat areas (< 10 per cent slope) to promote sheet flow and maximize the filtration potential. Filter strips should be designed on slopes between one and five per cent. Greater slopes than this would encourage the formation of concentrated flow. The width of the vegetated filter strip should be 10 to 20 metres in the direction of flow to provide sufficient stormwater quality enhancement.

3.4 End-of-pipe Controls

End-of-pipe controls are the final treatment methods that are intended to reduce the pollutants and enhance the quality of stormwater runoff before discharging into receiving waters. Although a number of end-of-pipe controls are available for treating stromwater runoff, selection of a suitable treatment depends on the site conditions, upstream runoff characteristics and requirements for treated water quality. End-of-pipe controls are as follows:

- wet ponds;
- dry ponds;
- constructed wetlands;
- infiltration trench;
- infiltration basin;
- sand filters; and
- oil/grit separators.

End-of-pipe controls, such as wet ponds or dry ponds should be designed for 1:100 year event with a safe overflow route so as to avoid flooding for large events.

3.4.1 Wet Ponds

Wet detention ponds are stormwater control structures designed to retain and treat the contaminated stormwater runoff. Although there are several different versions of the wet pond design, the most common design is the extended detention wet pond where adequate storage is provided above the permanent pool in order to detain stormwater runoff and provide settling. Wet ponds are among the most cost-effective and widely used stormwater practices.

The pond consists of a permanent pool of water into which stormwater runoff is directed. Runoff from each rain event is detained and treated in the pond until it is displaced by runoff from the next storm. Sedimentation processes remove particulates, organic matter and metals, while nutrients are removed through biological uptake. Wet detention ponds require periodic sediment removal and proper measures should be taken to control blue-green algae, if any. In general, a higher level of nutrient removal and better stormwater quantity control can be achieved in wet ponds than can be achieved with other practices, such as dry ponds, infiltration trenches or sand filters.[13] A typical wet pond is shown in Figure 6.

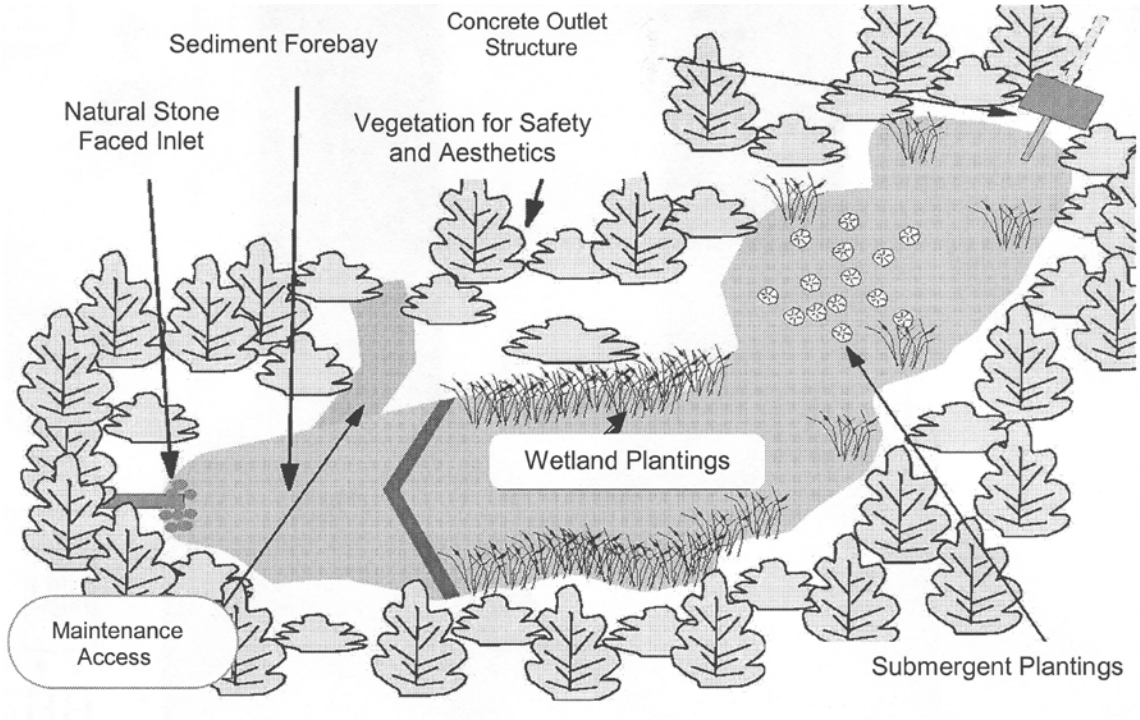


Figure 6. Wet Detention Pond[7]

Several modifications can be made to the ponds so as to increase their pollutant-removal efficiency. The first modification is increasing the settling area for sediments by adding a sediment forebay (Figure 7) near the inlet. Heavier sediments will settle as runoff passes through the sediment forebay, while lighter sediments will settle out as the runoff is retained in the permanent pool. A second modification is constructing shallow ledges along the edge of the permanent pool. These shallow peripheral ledges can be used to establish aquatic plants that can impede flow and trap pollutants as they enter the pond. The plants also increase biological uptake of nutrients. Finally, perimeter wetland areas can also be created around the pond to aid in pollutant removal.

The minimum drainage area required for wet ponds is five hectares and the preferred size is ≥ 10 hectares. Design guidelines for wet ponds are summarized in Table 3.

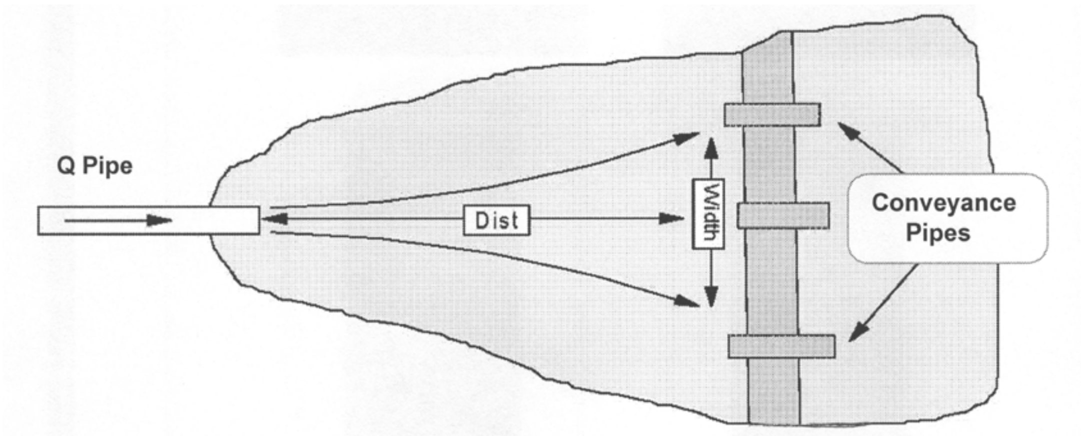


Figure 7. Wet Pond Forebay[7]

Table 3. Design Guidelines for Wet Ponds

Design component	Minimum criteria	Preferred criteria
Drainage area	5 hectares	≥ 10 hectares
Detention time	24 hours	24 hours
Side slopes	Side slopes above permanent pool are 4:1 to 5:1 Side slopes in permanent pool 5:1 to 7:1	Side slopes above permanent pool are 4:1 to 5:1 Side slopes in permanent pool 5:1 to 7:1
Length to width ratio	From 4:1 to 5:1 Forebay: minimum 2:1	From 4:1 to 5:1
Permanent pool depth	Maximum depth: 3 m Mean depth: 1 to 2 m	Maximum depth: 2.5 m Mean depth: 1 to 2 m
Forebay	Minimum depth: 1 m	Minimum depth: 1.5 m Length to width ratio of 2:1 or greater Surface area not to exceed one-third of the permanent pool surface area
Active storage depth	Water quality and erosion control: maximum 1.5 m Total (including quality control): 2 m	Water quality and erosion control: maximum 1 m Total (including quality control): 2 m

Forebay length can be calculated using the following equation:

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

where

L_{FB} = forebay length (m)

r = length to width ratio of forebay

Q_p = peak flow rate from the pond during design quality storm (m^3/s)

V_s = settling velocity (dependent on desired particle size to settle) (m/s)

The dispersion length refers to the length of fluid required to slow a jet discharge (i.e. pipe flow). It is recommended the fluid jet will disperse to a velocity of less than or equal to 0.5 m/s at the forebay berm. The forebay should be separated from the rest of the pond by an earthen berm. The berm can be submerged slightly below the permanent pool or it can extend into the extended detention portion of the pond. The length of dispersion required to dissipate flows from the inlet pipe can be calculated using the following equation:

$L_{dis} = (8Q)/(dV^f)$

where

L_{dis} = length of dispersion (m)

Q = flow rate from the inlet pipe (m^3/s)

d = depth of the permanent pool in the forebay (m)

V_f = desired velocity in the forebay (m/s)

Forebay bottom width can be calculated using the following equation:

Width, $W = L_{dis}/8$

3.4.2 Dry Ponds

Dry ponds are basins whose outlets have been designed to detain the stormwater runoff for some minimum time (i.e. 24 hours) to allow particles and associated pollutants to settle. Unlike wet ponds, these facilities do not have a large permanent pool. Dry ponds have only moderate pollutant removal when compared to other treatment methods. Although dry ponds can be effective at removing some pollutants through settling, they are less effective at removing soluble pollutants because of the absence of a permanent pool. Dry ponds operating in a continuous or batch mode have been reported to be less effective at pollutant removal compared to wet ponds. Generally, dry ponds should be implemented if wet ponds cannot be implemented due to site or planning constraints. The design guidelines for dry ponds are presented in Table 4 and some of the design guidelines are similar to those of wet ponds.

Table 4. Design Guidelines for Dry Ponds

Design component	Minimum criteria	Preferred criteria
Drainage area	5 hectares	10 hectares
Detention time	24 hours	48 hours
Side slopes	4:1	4:1 to 5:1
Length to width ratio	3:1	From 4:1 to 5:1
Depth	Maximum depth: 3m Mean depth: 1 to 2m	Maximum depth: 2m Mean depth: 1 to 2m
Forebay	Minimum depth: 1m	Minimum depth: 1.5m

3.4.3 Constructed Wetlands

Constructed wetland is a suitable treatment method for stormwater quality enhancement where a large area of land is available for construction. They require a large area of land because of their shallower depth (both in the permanent pool and active storage depth). Pollutant removal effectiveness and water quality enhancement in wetland systems are achieved through physical, chemical and biological processes. The design guidelines for constructed wetlands are shown in Table 5 and some of the design guidelines are similar to those of wet ponds.

Table 5. Design Guidelines for Constructed Wetlands

Design component	Minimum criteria
Drainage area	5 hectares 10 hectares preferable
Detention time	24 hours
Side slopes	Side slope of 5:1 for 3 m above and below permanent pool Maximum 3:1 elsewhere
Length to width ratio	Overall: minimum 3:1 Forebay: minimum 2:1
Permanent pool depth	Average permanent pool depth should range between 150 mm and 300 mm
Forebay	Minimum depth: 1 m Surface area not to exceed 20 per cent of the permanent pool surface area
Active storage depth	Maximum 1 m

3.4.4 Infiltration Trench

Infiltration trench in this guideline refers to infiltration systems designed to collect, store and treat the stormwater runoff from several lots as opposed to on-lot infiltration systems that are used for single lot application. An infiltration trench can be constructed at the ground surface to intercept overland flows or below ground as a component of a storm sewer system. These systems are suitable where limited land is available. However, the application of infiltration trench is limited because they provide marginal water quality control, but may be used as a secondary facility where the maintenance of groundwater recharge is a concern. They also can be used in conjunction with other practices, such as wet ponds, to provide water quality control and peak flow control.

Infiltration trenchs can be implemented for residential uses where soils should have an infiltration rate of ≥ 15 millimetres per hour. Infiltration trenches with details are shown in Figures 8 and 9. The design guidelines are shown in Table 6.

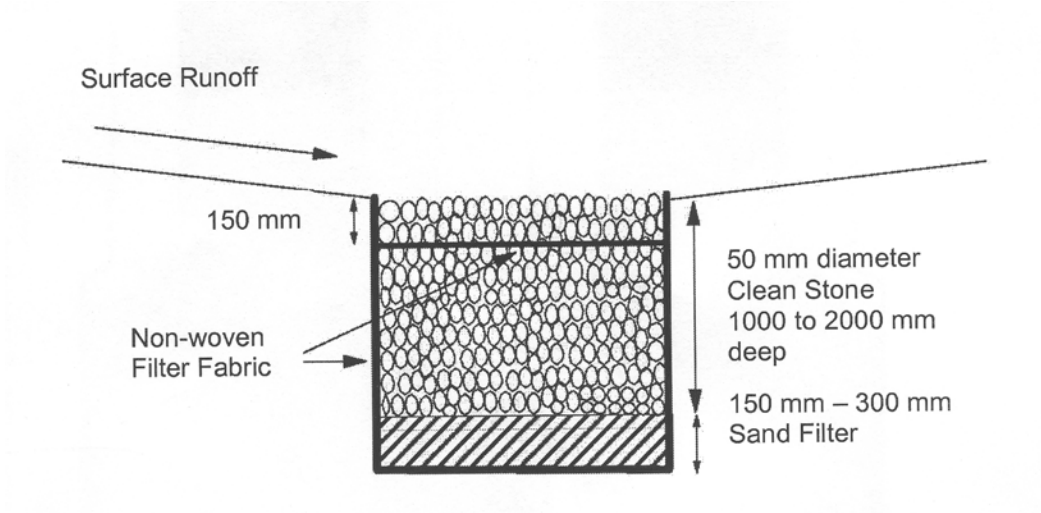


Figure 8. Surface Infiltration Trench[7]

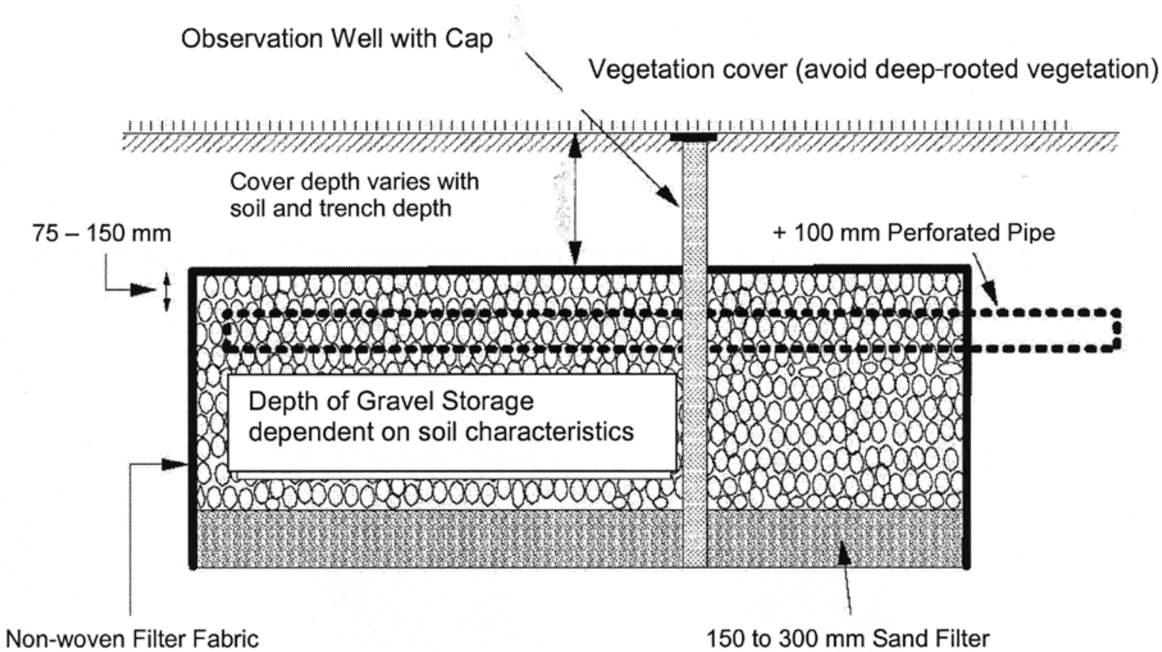


Figure 9. Subsurface Infiltration Trench[7]

Table 6. Design Guidelines for Infiltration Trench

Design component	Criteria
Drainage area	< 2 hectares
Depth to water table	> 1 m
Depth to bed rock	> 1 m
Storage	A maximum storage volume equal to the runoff from a 4-hour 15 mm storm should be provided. The storage media should hold the stormwater until it infiltrates into the surrounding material. Clear stone of 50 mm is recommended as a storage medium. Gravel also can be used as a medium.

3.4.5 Infiltration Basin

Infiltration basins are above-ground pond systems designed to collect, store and treat the stormwater runoff. Water infiltrates through the basin and either recharges the groundwater or is collected by an underground perforated pipe system and discharges to a downstream outlet. The appearance of an infiltration basin is similar to that of wet ponds.

Infiltration basins are suitable for residential land uses and not recommended for industrial/commercial areas where there is a high potential for groundwater contamination due to chemical spills and maintenance activities. Infiltration basins have a high rate of failure and the factors that contribute to the failure are poor site selection, poor design, large drainage area, inadequate pretreatment facilities and lack of maintenance. The design guidelines for infiltration basins are summarized in Table 7.

Table 7. Design Guidelines for Infiltration Basin

Design component	Criteria
Drainage area	< 5 hectares
Depth to water table	> 1 m
Depth to bed rock	> 1 m
Storage depth	< 0.6 m
Length to width ratio	3:1 preferred
Percolation rate	≥ 60 mm/hr

3.4.6 Sand Filters

Sand filters used in many parts of the United States have proven to be effective in removing several common pollutants from stormwater runoff.[14] Sand filters are not widely used in Canada and it is not yet known about their performance in winter conditions. Sand filters generally control stormwater quality, providing very limited flow rate control. There are many forms of sand filters, among these surface and underground filters are the most commonly used. Sand filters are suitable for small drainage areas (less than or equal to five hectares).

In general, sand filters are preferred over infiltration practices, such as infiltration trenches, when contamination of groundwater with conventional pollutants (Biochemical Oxygen Demand, suspended solids, fecal coliform) is of concern. Sand filters generally require less land than other practices such as ponds or wetlands. Sand filters can be effective stormwater management practices and can achieve high removal rates for sediment, BOD and fecal coliform bacteria. However, silt/sediment deposited on the surface of the filter medium should be removed periodically so as to avoid clogging and to remove trapped contaminants.

The cross-section details and design guidelines of a sand filter are shown in Figure 10 and Table 8, respectively.

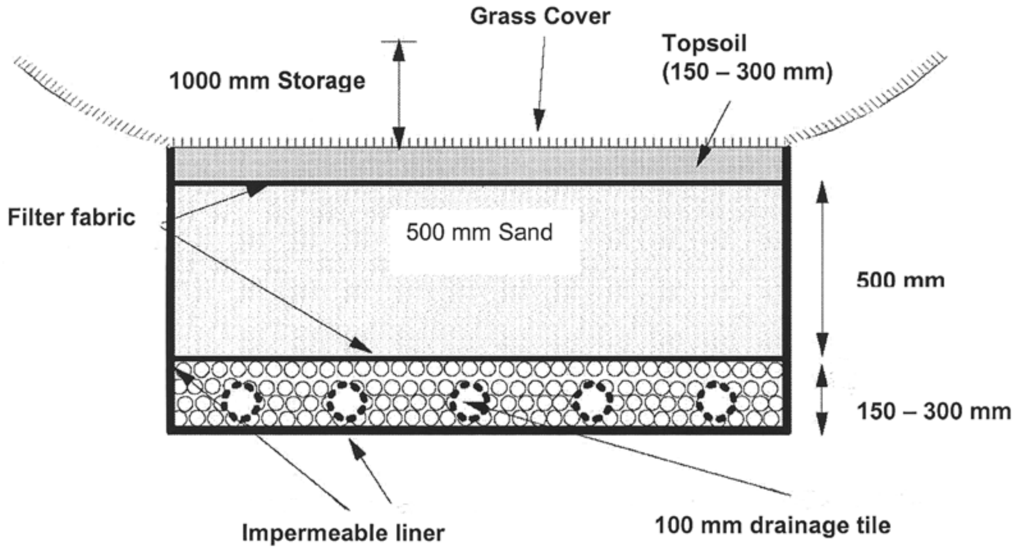


Figure 10. Cross-section of Sand Filter[7]

Table 8. Design Guidelines for Sand filter

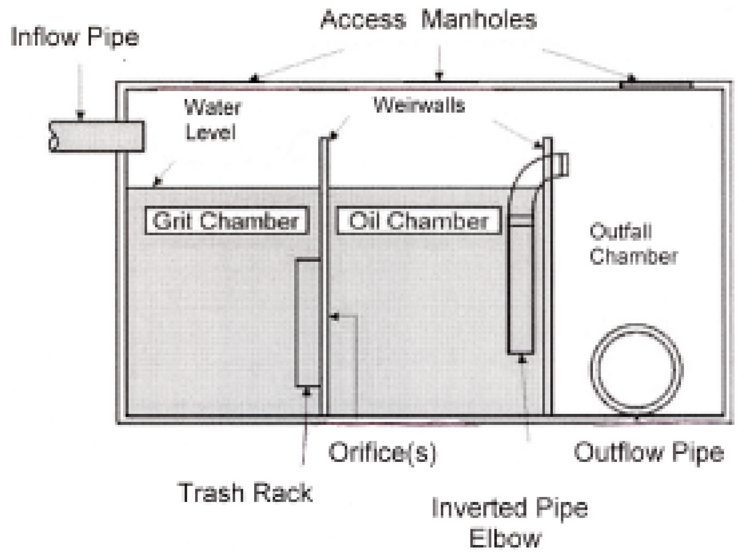
Design component	Criteria
Drainage area	< 5 hectares
Pretreatment	Pretreatment to be provided by sedimentation chamber or forebay, filter strip, swale
Filter media depth	Sand: 0.5 m
Underdrain	Minimum 100 mm perforated pipes

3.4.7 Oil/grit separators

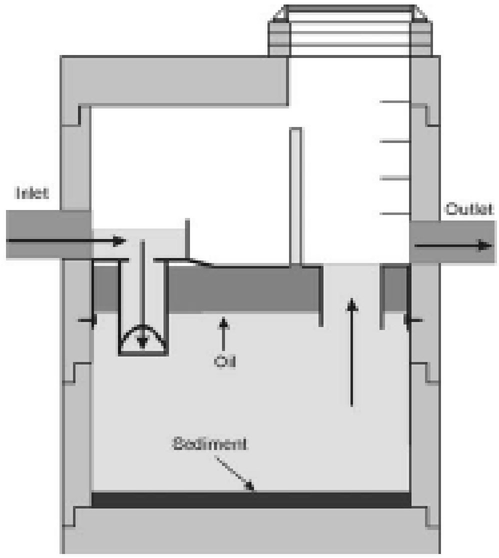
Oil/grit separators consist of a series of chambers to trap and retain oil and grit and/or sediment in the chambers. They are usually located below ground and often are used as spill controls, pretreatment devices or end-of-pipe controls as part of multi-component management practices for water quality control.

Oil/grit separators are used for small drainage areas (< 2 hectares). They can be used for industrial and commercial areas, parking lots, automobile service station parking areas and airports that generate high hydrocarbon concentrations and where there is a high risk of spills.

There are two types of oil/grit separators available and these are shown in Figure 11. Oil/grit separators from automobile service stations should not discharge into storm sewer or surface water because of high oil/grit loading of the wastewater.



a) Three-chamber Oil/grit Separator



b) By-pass Oil/grit Separator

Figure 11. Oil/grit Separator[4]

Appendix A

Table A-1. Selected Pollutant Concentration in Stormwater (Saskatchewan community)*

Parameter	Storm sewer outfall 1	Storm sewer outfall 2	Storm sewer outfall 3
BOD (mg/L)	12	18	16.5
COD (mg/L)	78.5	103	121
TSS (mg/L)	129	350	324
Nitrate –N (mg/L)	0.64	0.42	1.48
TKN (mg/L)	2.3	3.1	4.1
Total P (mg/L)	0.95	1.08	1.06
Total Alkalinity (mg/L $CaCO_3$)	82	92	94
Bicarbonate (mg/L)	100	112	115
Sodium (mg/L)	81	72	113
Magnesium (mg/L)	6	5	5
Calcium (mg/L)	24	21	24
Total Hardness (mg/L $CaCO_3$)	85	73	81
Chloride (mg/L)	113.4	105.6	159.5
Potassium (mg/L)	11	10	13
Zinc (mg/L)	0.077	0.19	0.19
Cadmium (mg/L)	< 0.001	< 0.001	0.001
Copper (mg/L)	0.015	0.038	0.028
Iron (mg/L)	5.09	14.5	10.2
Lead (mg/L)	0.022	0.053	0.052
Nickel (mg/L)	0.01	0.02	0.021
Coliforms, org/100mL	10900	98800	10900
E.coli, org/100mL	727	13400	959

* Samples collected during 2005

Table A-2. Selected Pollutant Concentration in Stormwater (Saskatchewan community)*

Parameter	Site 1	Site 2	Site 3	Site 4
BOD (mg/L)	8.4	4.5	1	9
TSS (mg/L)	102	139	52	58
Nitrate –N (mg/L)	1.16	2.07	< 0.02	0.09
TKN (mg/L)	2.2	1.5	0.8	4
Total P (mg/L)	0.36	0.41	0.18	0.49
Coliforms, org/100mL	>2400000	150000	360	460000
Fecal Colifoms, org/100mL	93000	4300	90	930

* Samples collected during 2003

Table A-3. Selected Pollutant Median Event Mean Concentrations and Associated Coefficient of Variation (CoV) in Stormwater Runoff as a Function of Land Use

Pollutant	Units	Residential		Mixed		Commercial		Open/Non-urban	
		Median	CoV	Median	CoV	Median	CoV	Median	CoV
BOD	mg/L	10	0.41	7.8	0.52	9.3	0.31	--	--
COD	mg/L	73	0.55	65	0.52	57	0.39	40	0.78
TSS	mg/L	101	0.96	67	1.14	69	0.85	70	2.92
NO_2+NO_3	mg/L	736	0.83	558	0.67	572	0.48	534	0.91
Total P	mg/L	383	0.69	263	0.75	201	0.67	121	1.66
Total Cu	mg/L	33	0.99	27	1.32	29	0.81	--	--
Total Pb	mg/L	144	0.75	114	1.35	104	0.68	30	1.52
Total Zn	mg/L	135	0.84	154	0.78	226	1.07	195	0.66
TKN	mg/L	1900	0.73	1288	0.50	1179	0.43	965	1.0

(Source: USEPA, 1983)

Table A-4. Selected Pollutant Concentration in Stormwater (City of Edmonton)

Parameter	Groat Rd Storm		30th Ave Storm	
	Spring	Summer	Spring	Summer
BOD (mg/L)	28	19	20	13
COD (mg/L)	145	--	102	--
TSS (mg/L)	290	227	155	104
NH_3-N (mg/L)	1.6	0.67	1.14	0.48
TKN (mg/L)	5.2	0.9	4	2.3
Total N (mg/L)	6.2	4.2	5.9	4.2
Total P (mg/L)	1.08	0.69	0.88	0.42
Total Dissolved P (mg/L)	0.4	--	0.54	--
Chloride (mg/L)	157	40	168	26
Phenol (mg/L)	0.06	0.01	0.05	0.01
Zinc (mg/L)	0.961	0.101	0.631	0.075
Cadmium (mg/L)	0.005	0.0006	0.005	<0.0005
Copper (mg/L)	0.17	0.019	0.11	0.008
Iron (mg/L)	73.4	7.1	44.7	2.56
Lead (mg/L)	0.21	0.024	0.14	0.012
Fecal Coliforms, org/100mL	58,000	91,000	26,000	40,000

(Source: City of Edmonton; Infraguide, 2003)

References:

1. L. W. Mays. (2001). *Stormwater Collection Systems Handbook*. McGraw-Hill, NY. ISBN 0-07-135471-9.
2. *California Department of Transportation Highway Design Manual*, Chapter 810 (July 1, 1995).
3. Alberta Environment. (1999). *Stormwater Management Guidelines for the Province of Alberta*. Edmonton, Alberta.
4. Infraguide. (2003). *Source and On-Site Controls for Municipal Drainage Systems*. National Guide to Sustainable Municipal Infrastructure, NRC-CNRC, Ottawa.
5. USEPA. (1983). *Results of the Nationwide Urban Runoff Program*: Volume 1 – Final report. Water Planning Division. Washington, DC, NTIS publication.
6. Infraguide (2005). *Conveyance and End-of-Pipe Measures for Stormwater Control*. National Guide to Sustainable Municipal Infrastructure, NRC-CNRC, Ottawa.
7. Ministry of the Environment (MOE). (2003). *Stormwater Management Planning and Design Manual*. Ontario. ISBN 0-7794-2969-9.
8. Alderserio, K., D. Wait, and M. Sobsey. (1996). “Detection and characterization of male-specific RNA coliphages in a New York City reservoir to distinguish between human and non-human sources of contamination.” In *Proceedings of a Symposium on New York City Water Supply Studies*, ed. McDonnell et al. TPS-96-2. American Water Resources Association. Herndon, VA.
9. Bannerman, R. (1999). Sweeping Water Clean. *American Sweeper Magazine*, Huntsville, AL. Volume 7, Number 1.
10. Caraco, D., and R. Claytor. (1997). *Stormwater BMP Design Supplement for Cold Climates*. Center for Watershed Protection, Ellicott City, MD.
11. Livingston, E., E. Shaver, and J.J. Skupien. (1997). *Operation, Maintenance, & Management of Stormwater Management Systems*. Watershed Management Institute, Inc. Ingleside, MD
12. USEPA. (1999). Stormwater management fact sheet. *Non-Stormwater Discharges to Storm Sewers*. EPA 832-F-99-022. Washington, DC.
13. USEPA. (1999). Stormwater management fact sheet. *Wet Detention Ponds*. EPA 832-F-99-048. Washington, DC.
14. USEPA. (1999). Stormwater management fact sheet. *Sand Filters*. EPA 832-F-99-007. Washington, DC.