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

Part 5
Stormwater Management Guidelines
of a Total of 5 Parts

March 2013

Alberta Government

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Part 5 STORMWATER MANAGEMENT GUIDELINES
March 2013

TABLE OF CONTENTS

Additional Parts published separately are:

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

FOREWORD TO PART 5 STORMWATER MANAGEMENT GUIDELINES (2013)

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

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

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

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

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

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

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

DEFINITIONS / ABBREVIATIONS

AO	-	Aesthetic Objectives
AESRD	-	Alberta Environment and Sustainable Resource Development
AWWA	-	American Water Works Association
BDOC	-	Biodegradable Dissolved Organic Carbon
BNR	-	Biological Nutrient Removal
BPJ	-	Best Professional Judgement
BPR	-	Biological Phosphorus Removal
BPT	-	Best Practicable Technology
CBOD	-	Carbonaceous Biochemical Oxygen Demand at 5 days and 20 ^oC
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 ^oC
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^{o}. 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

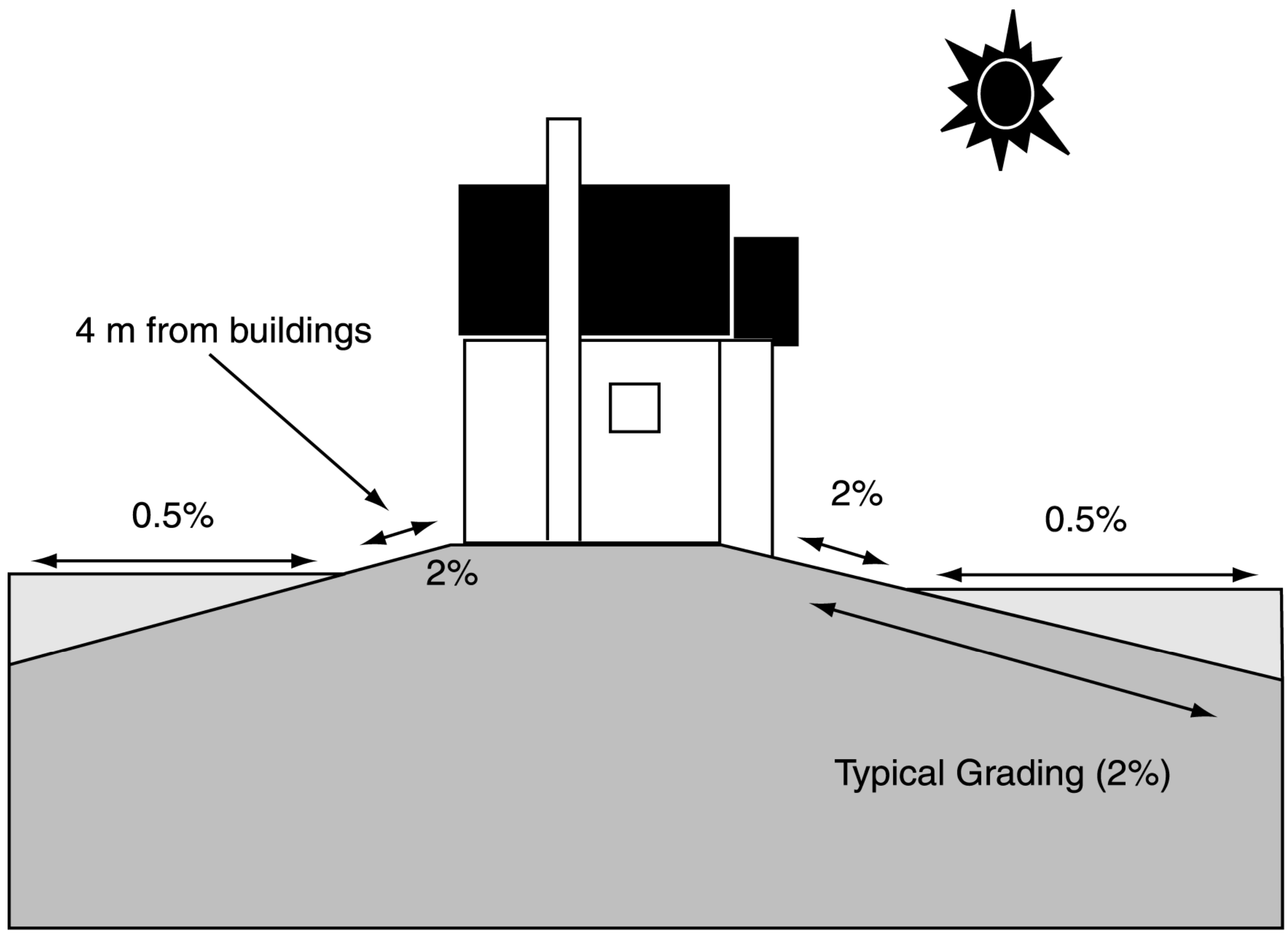


Figure 5.1
Lot Grading Guidelines

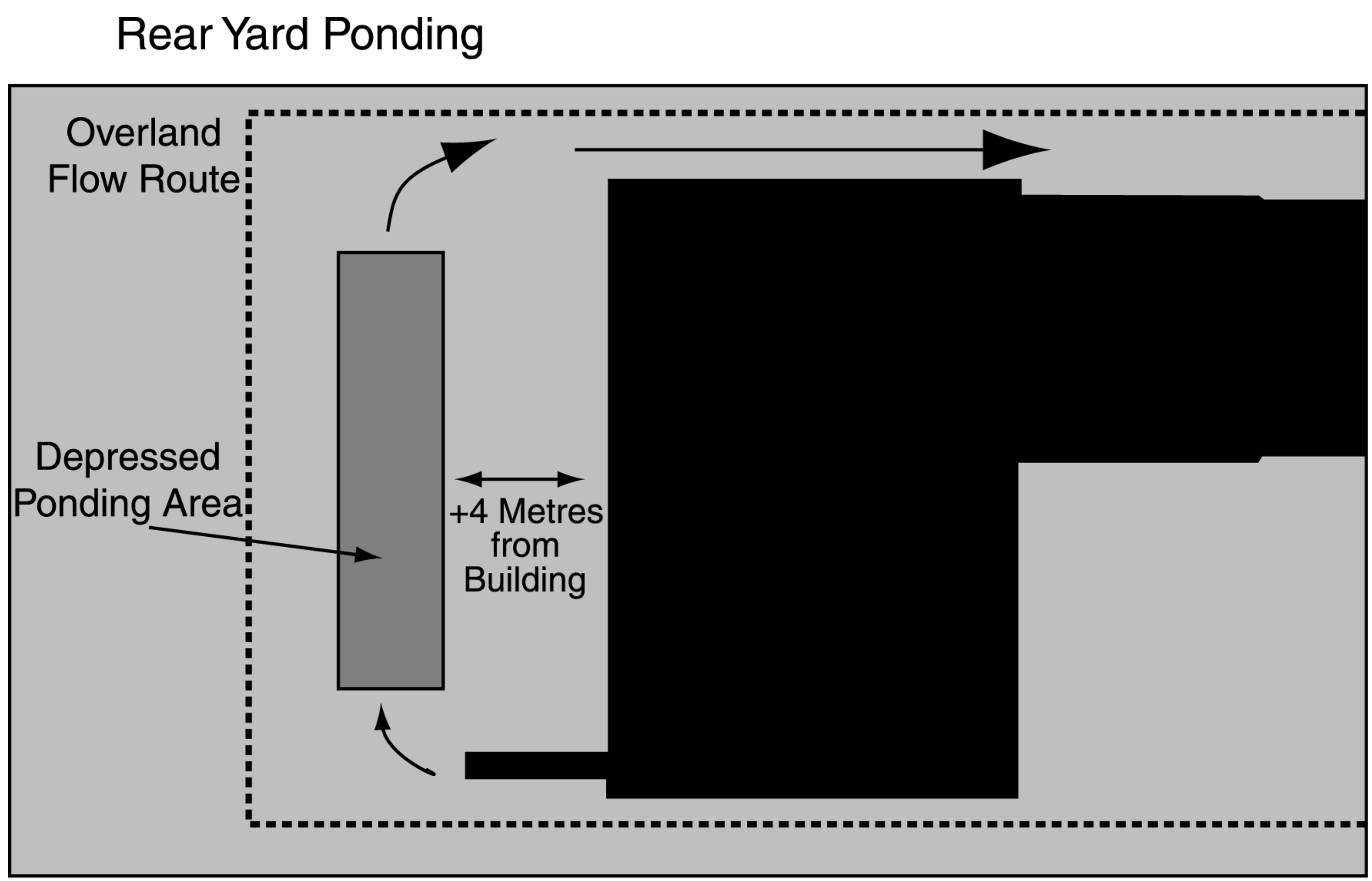


Figure 5.2
Rear Lot Ponding Guidelines

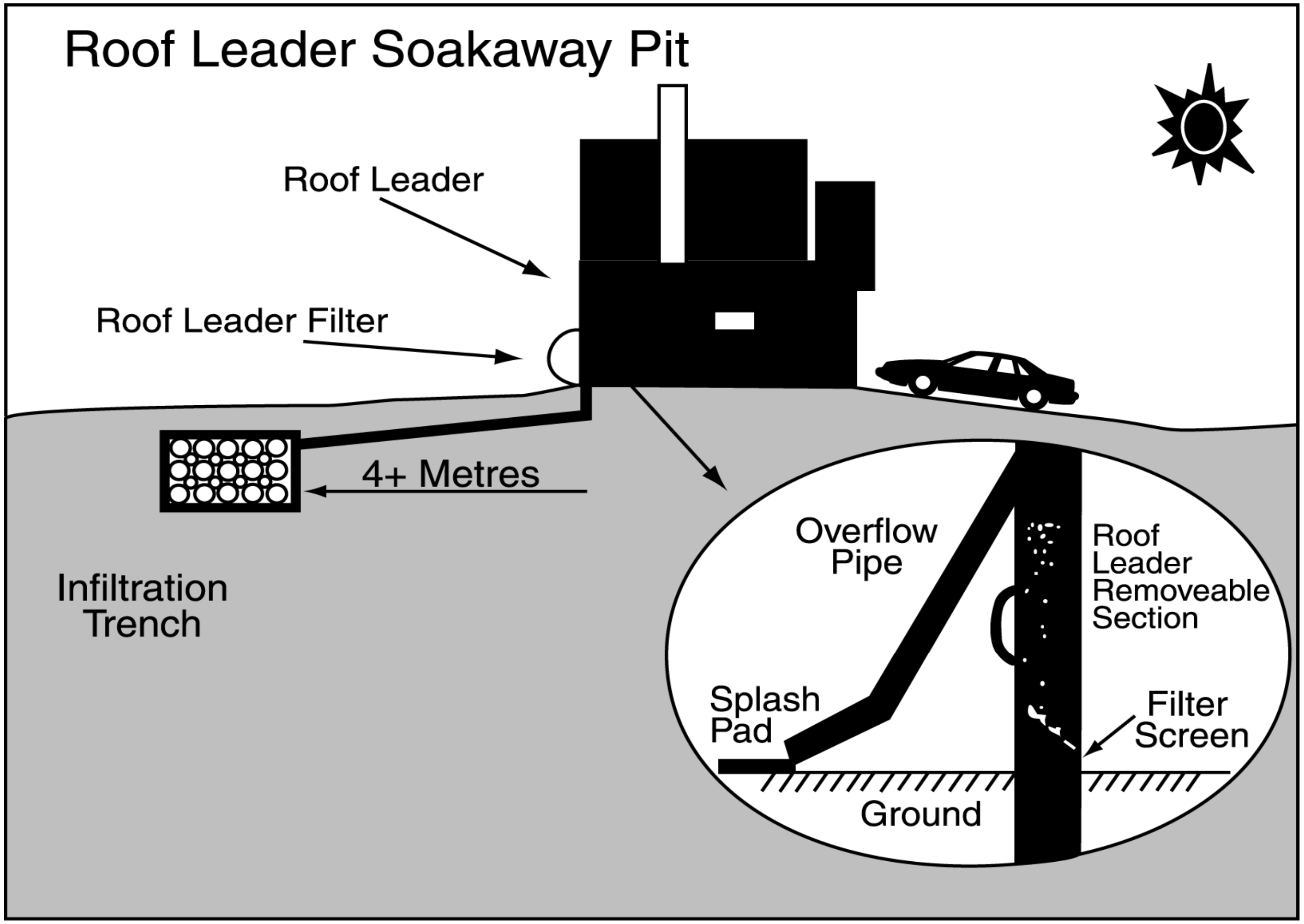


Figure 5.3
Infiltration System with Roof Leader Filter

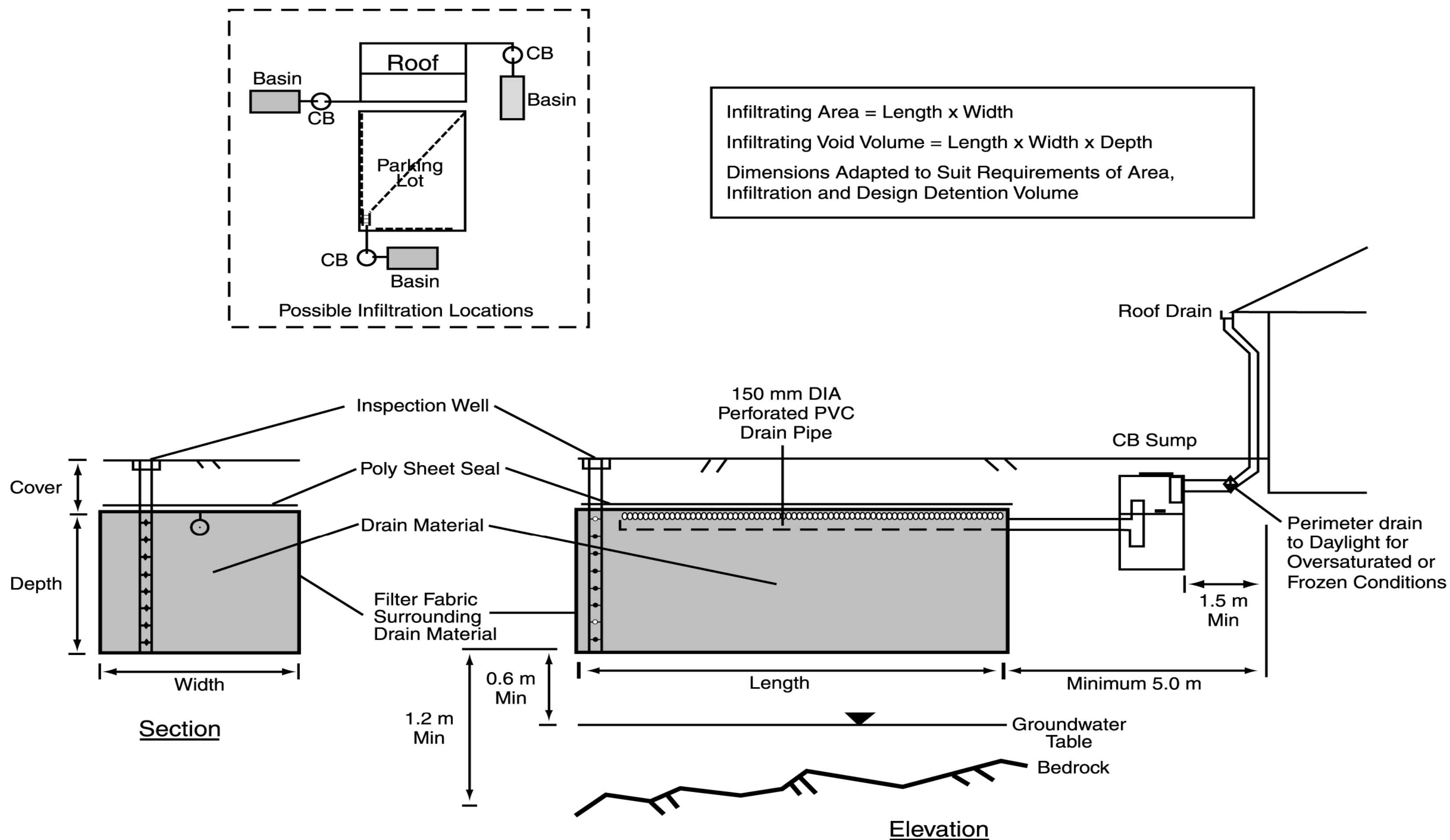


Figure 5.4
Infiltration System with Pretreatment Sump

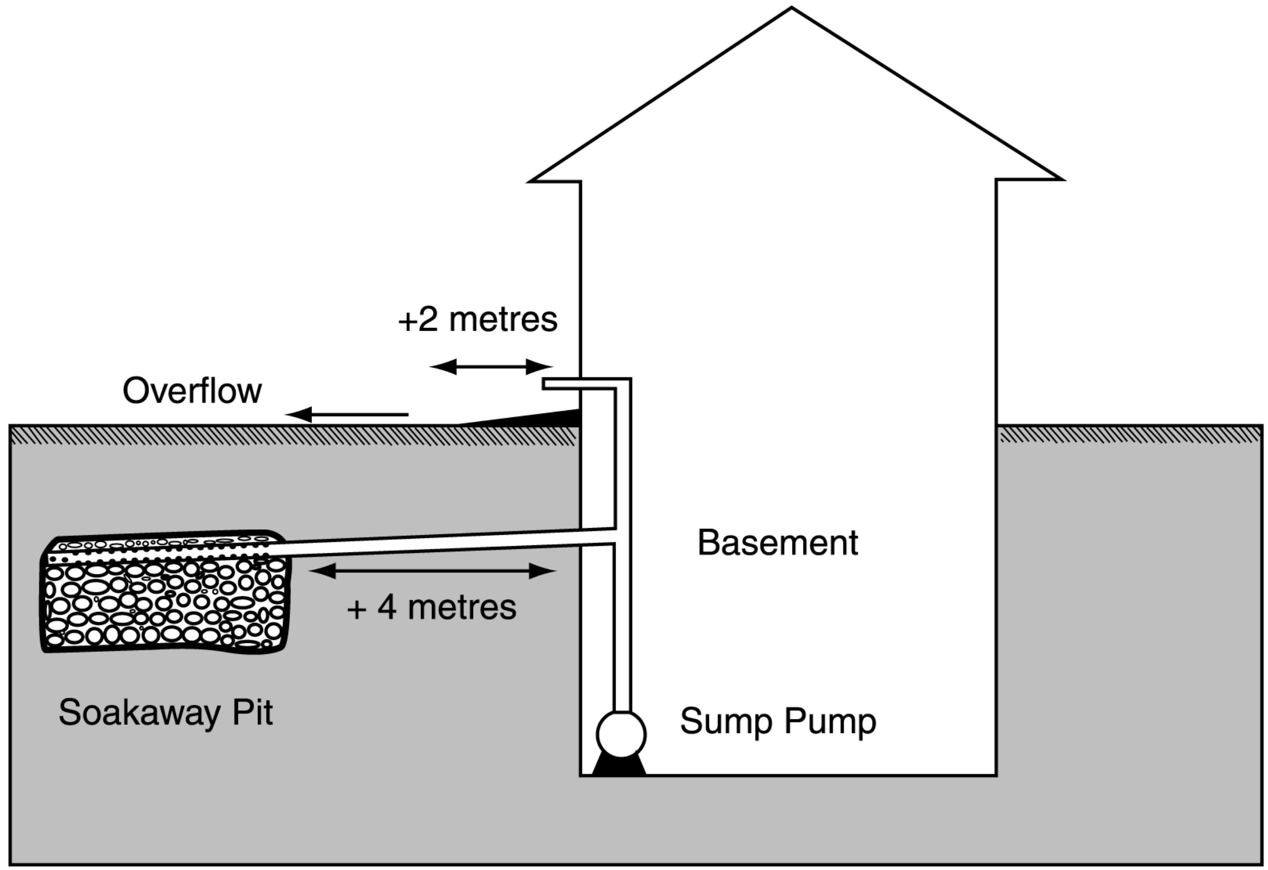


Figure 5.5
Sump Pump Foundation Drainage

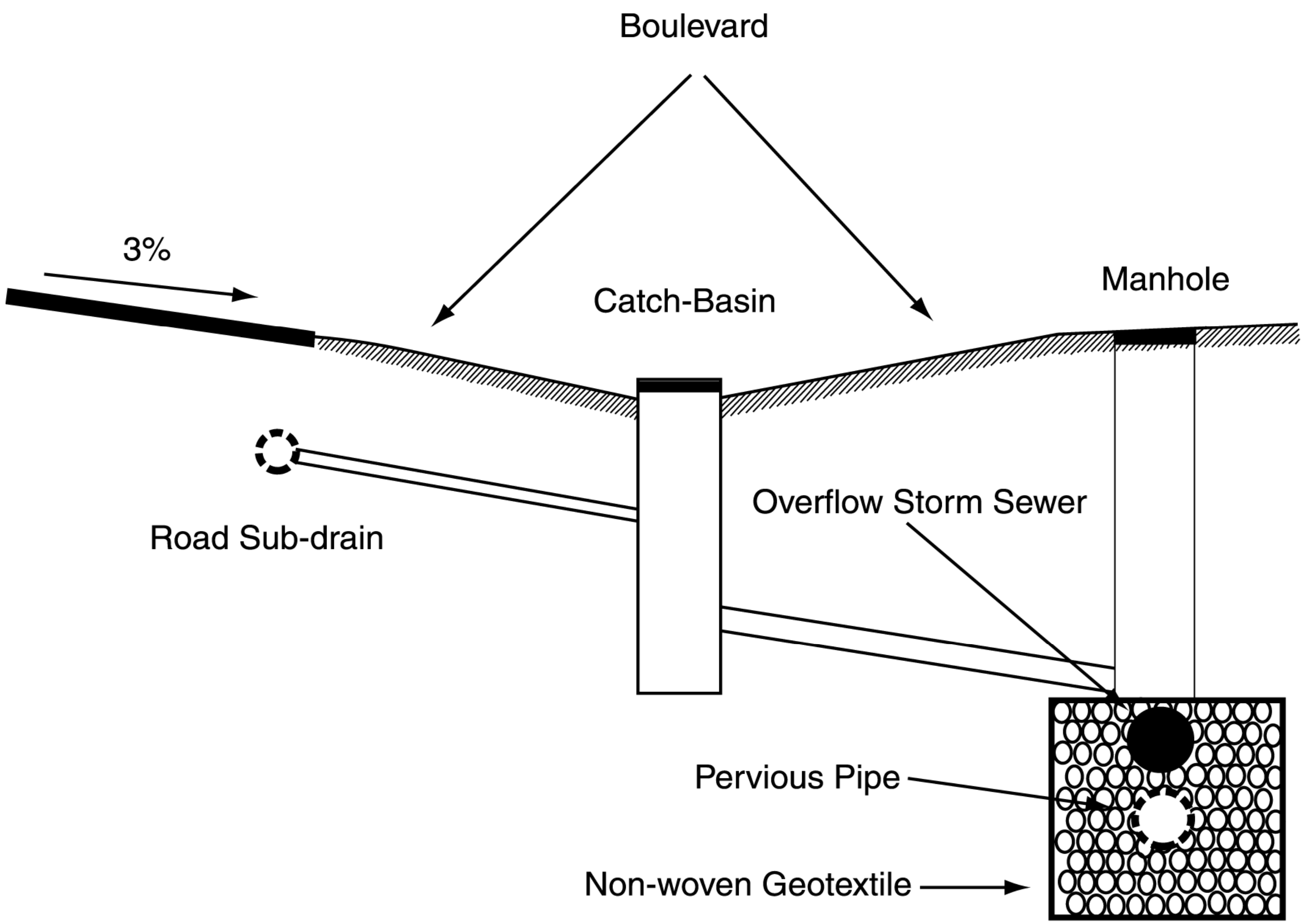


Figure 5.6
Pervious Pipe System

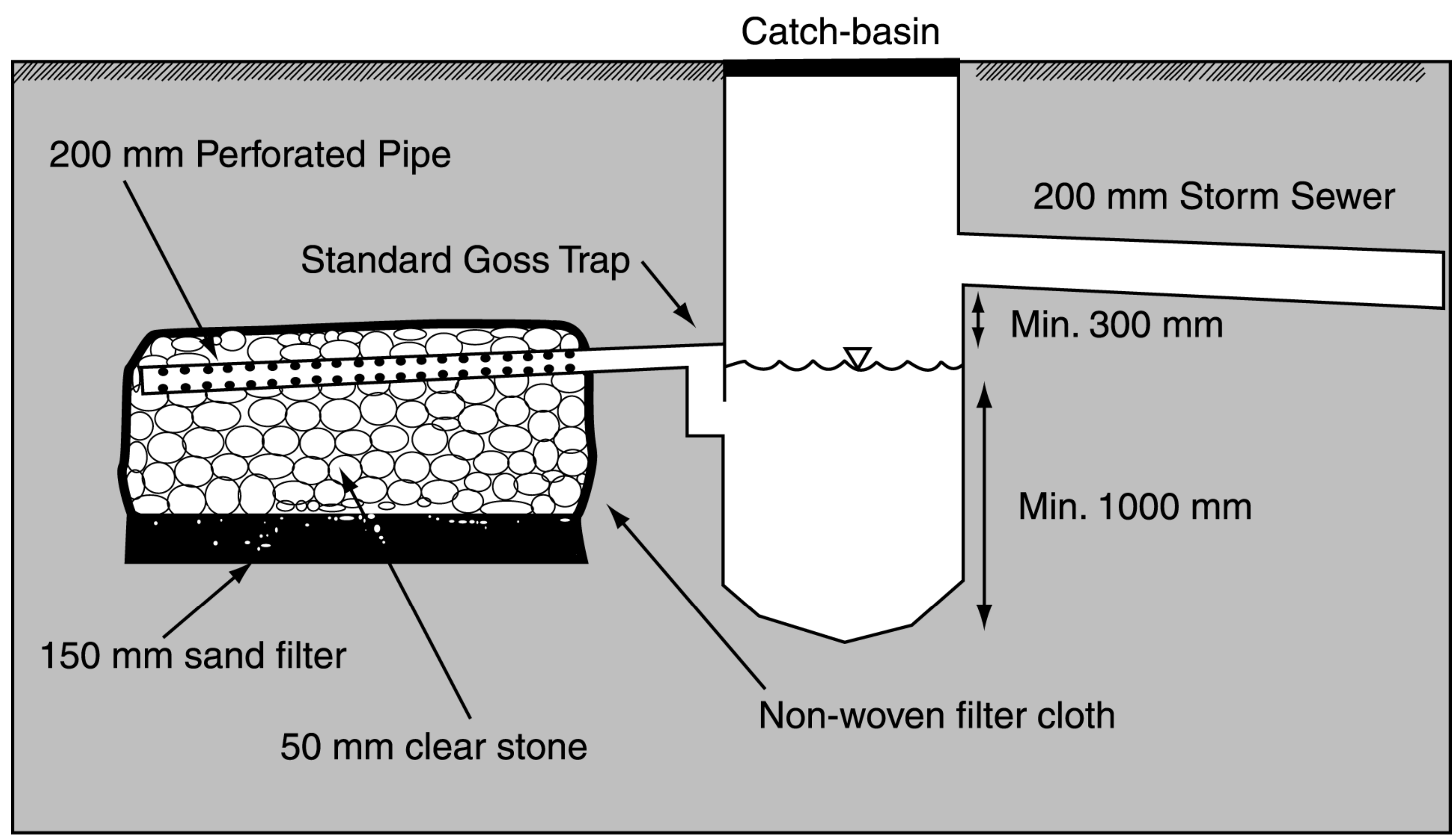


Figure 5.7
Pervious Catch-Basin

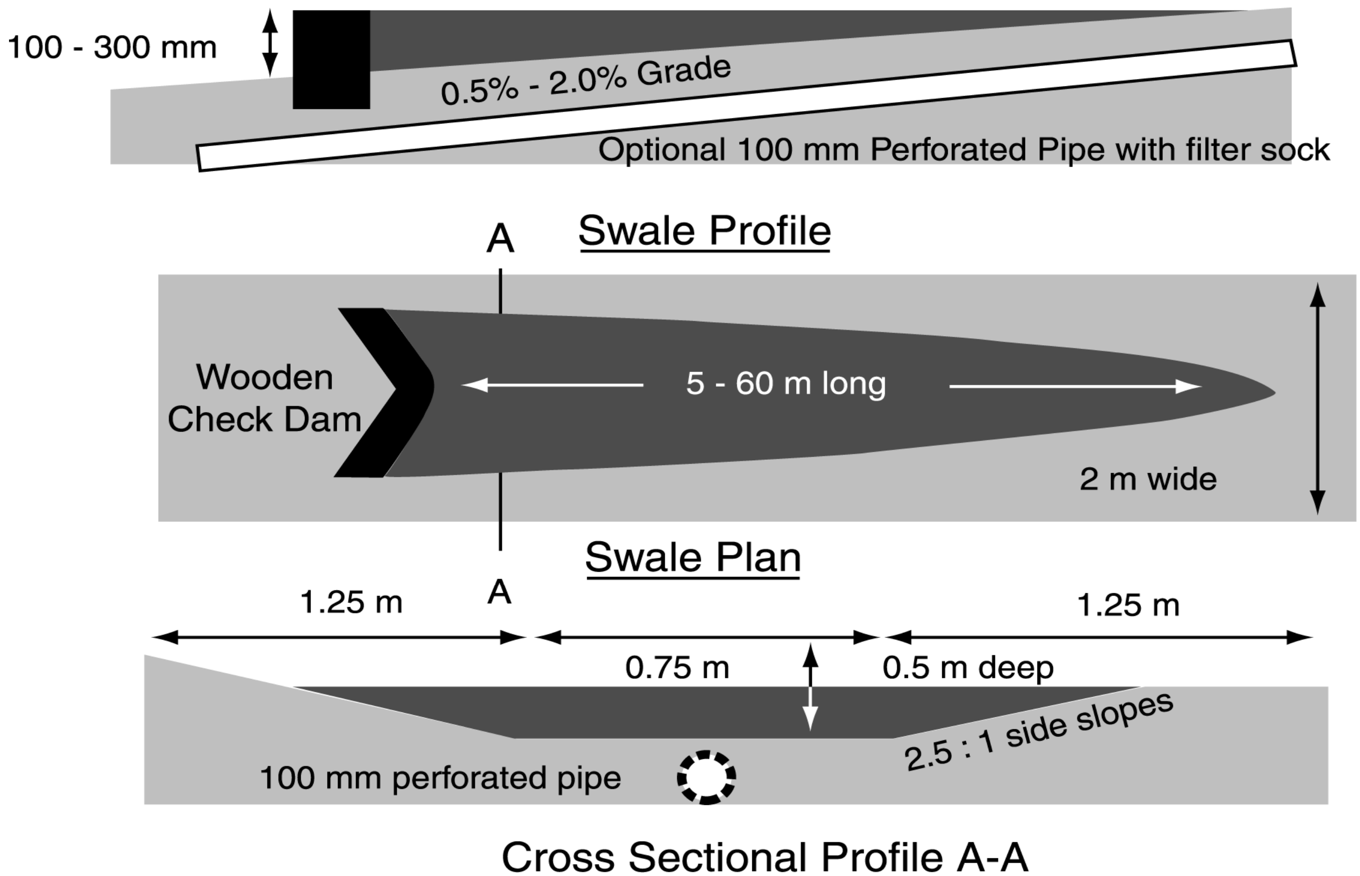


Figure 5.8
Grass Swale Design

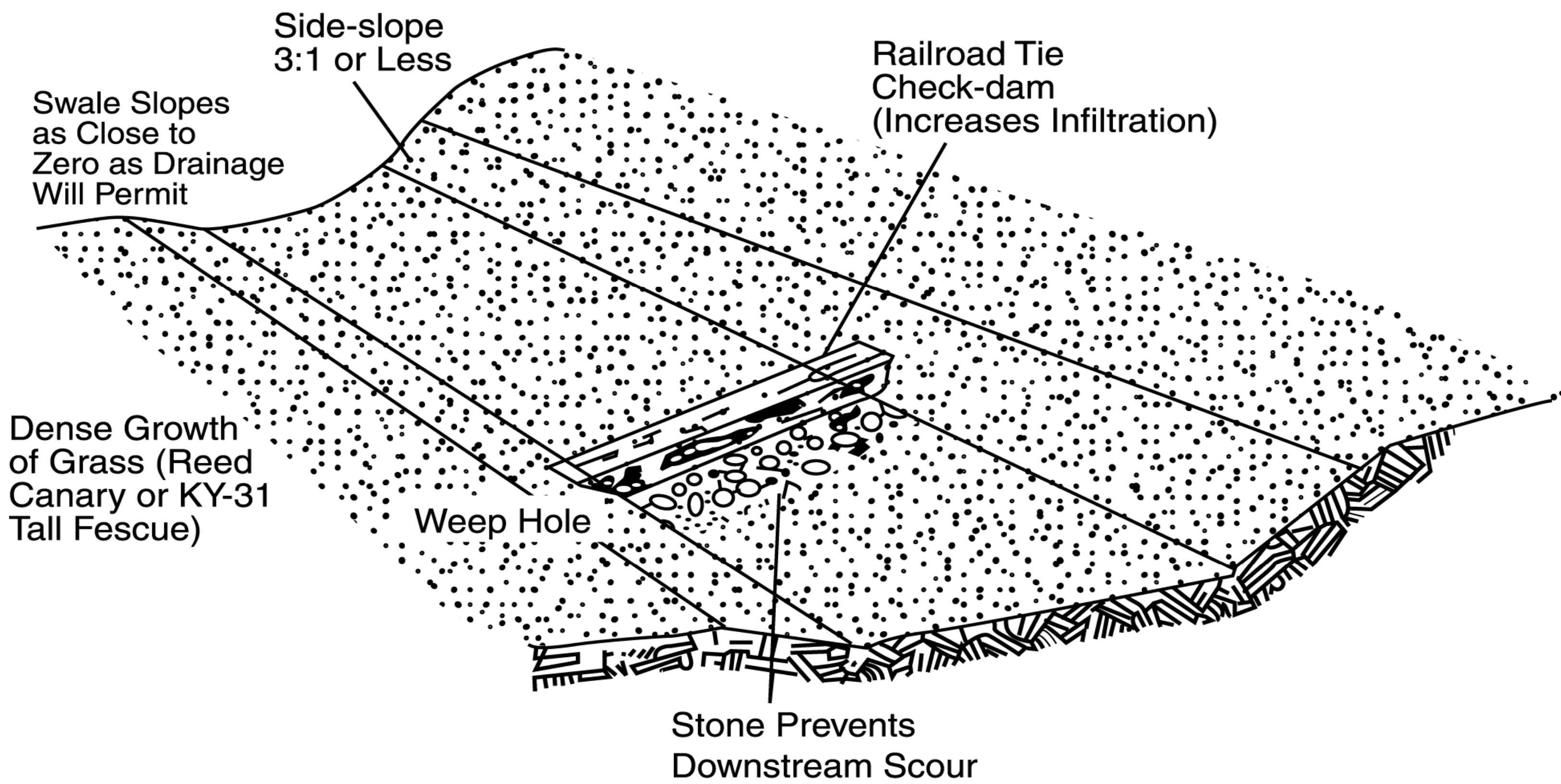


Figure 5.9
Grass Swale with Check Dam

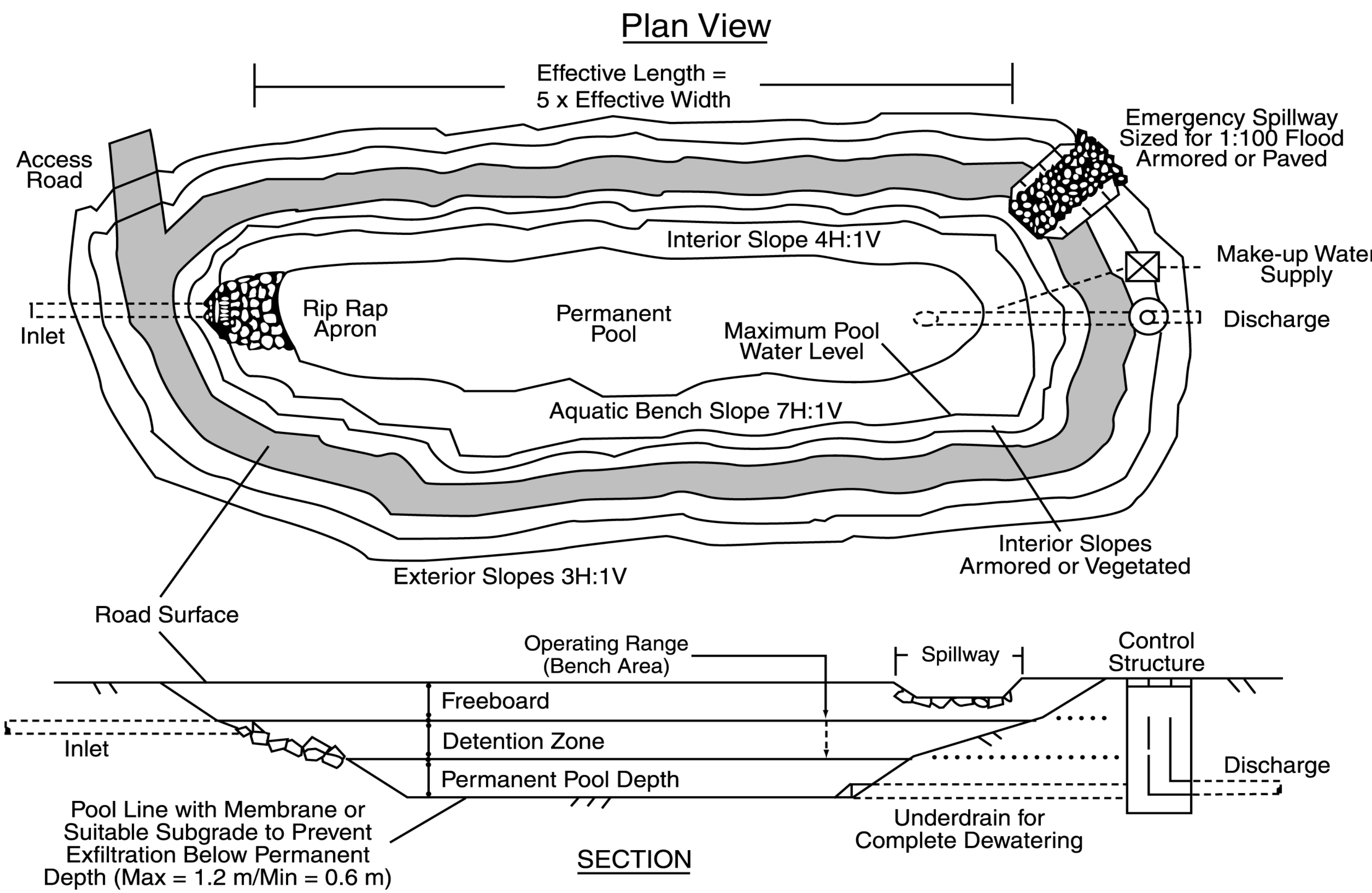


Figure 5.10
Wet Detention Pond Plan and Sections

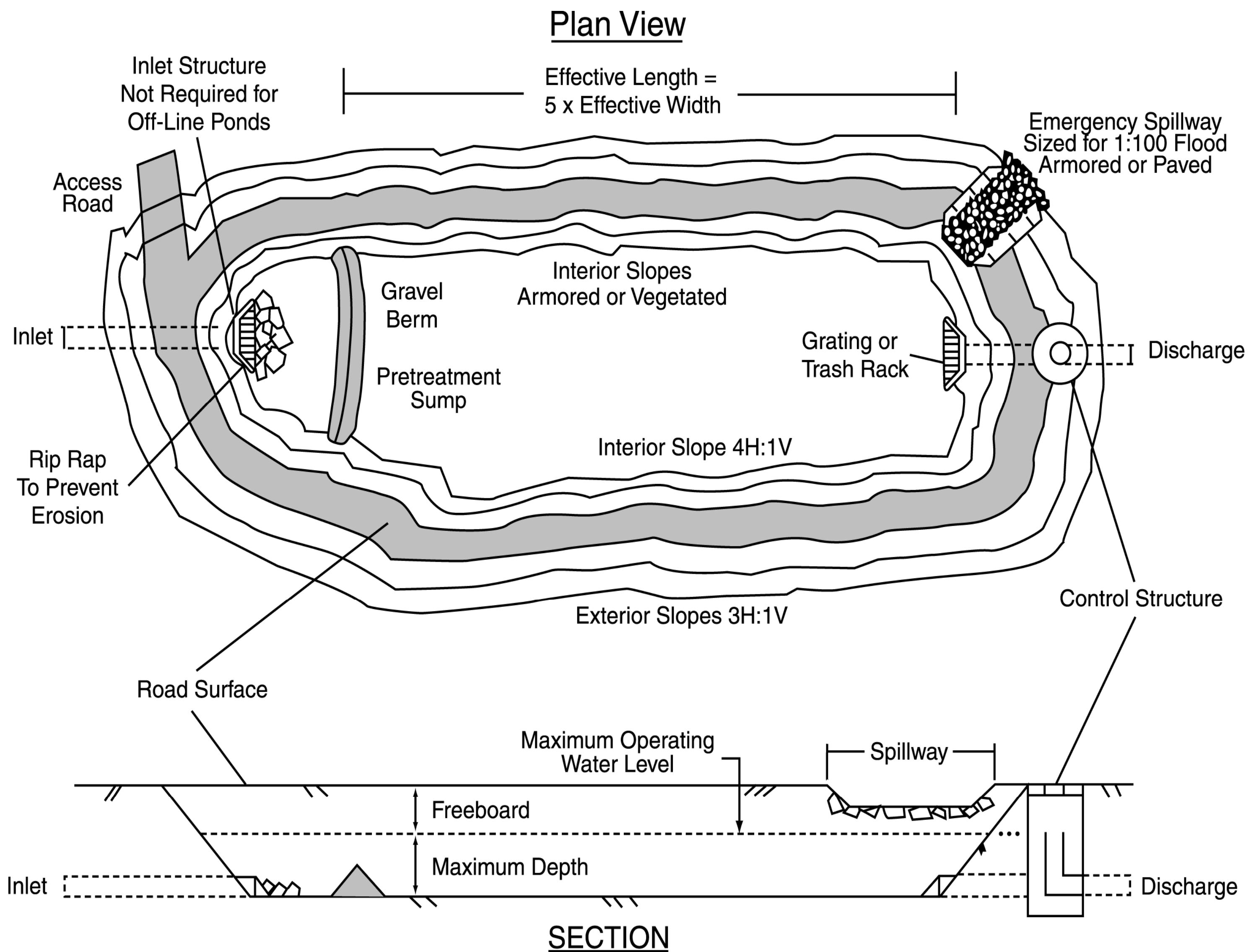
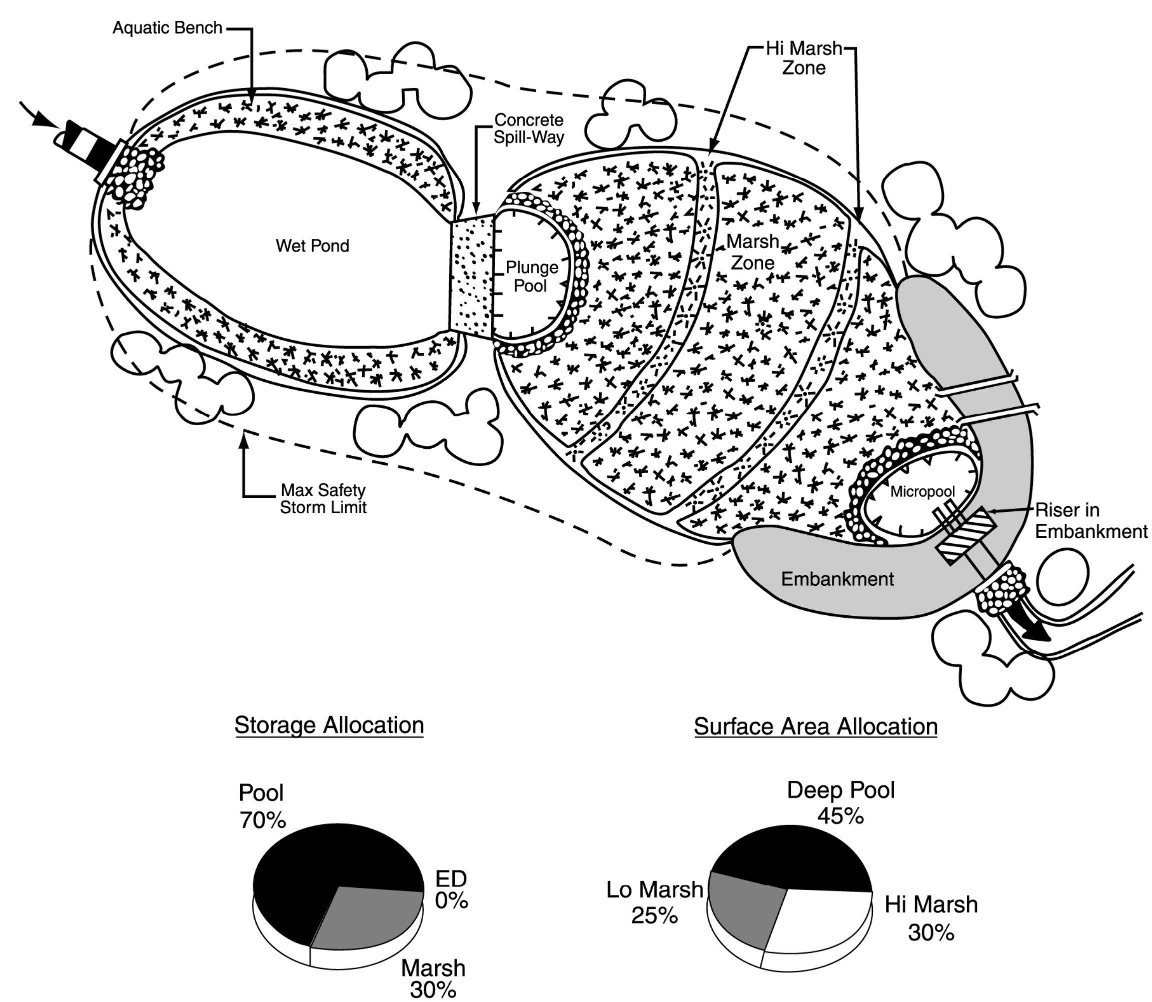


Figure 5.11
Dry Detention Pond Plan and Sections



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

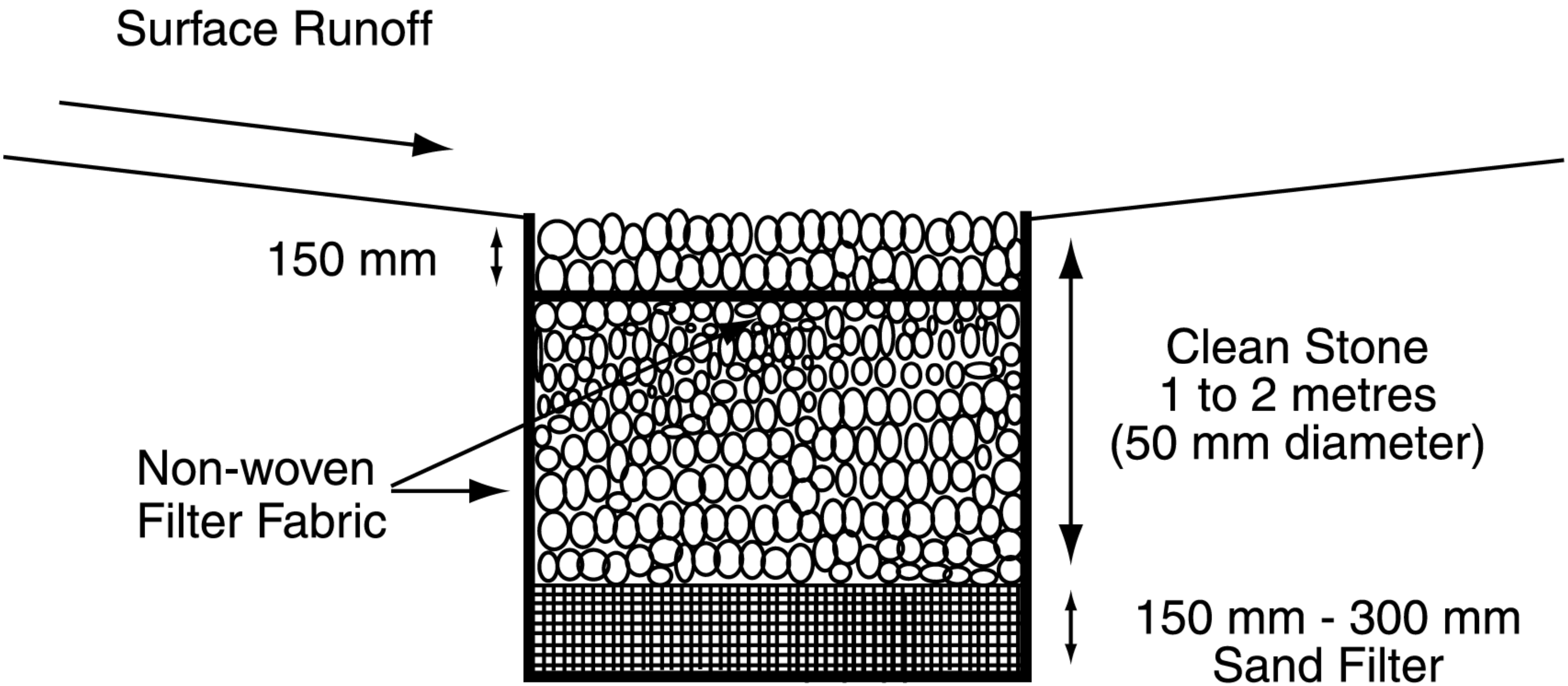


Figure 5.13
Surface Infiltration Trench

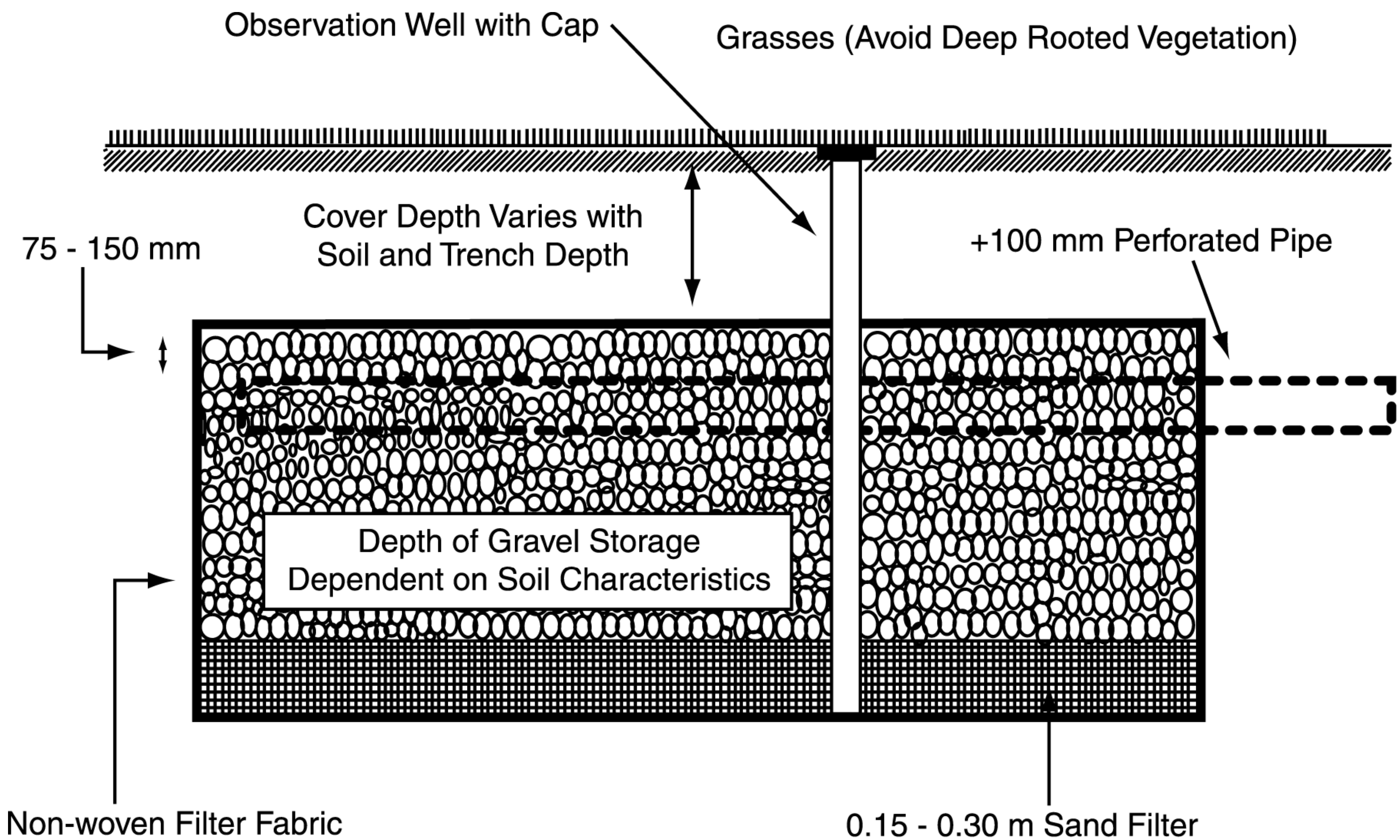


Figure 5.14
Subsurface Infiltration Trench

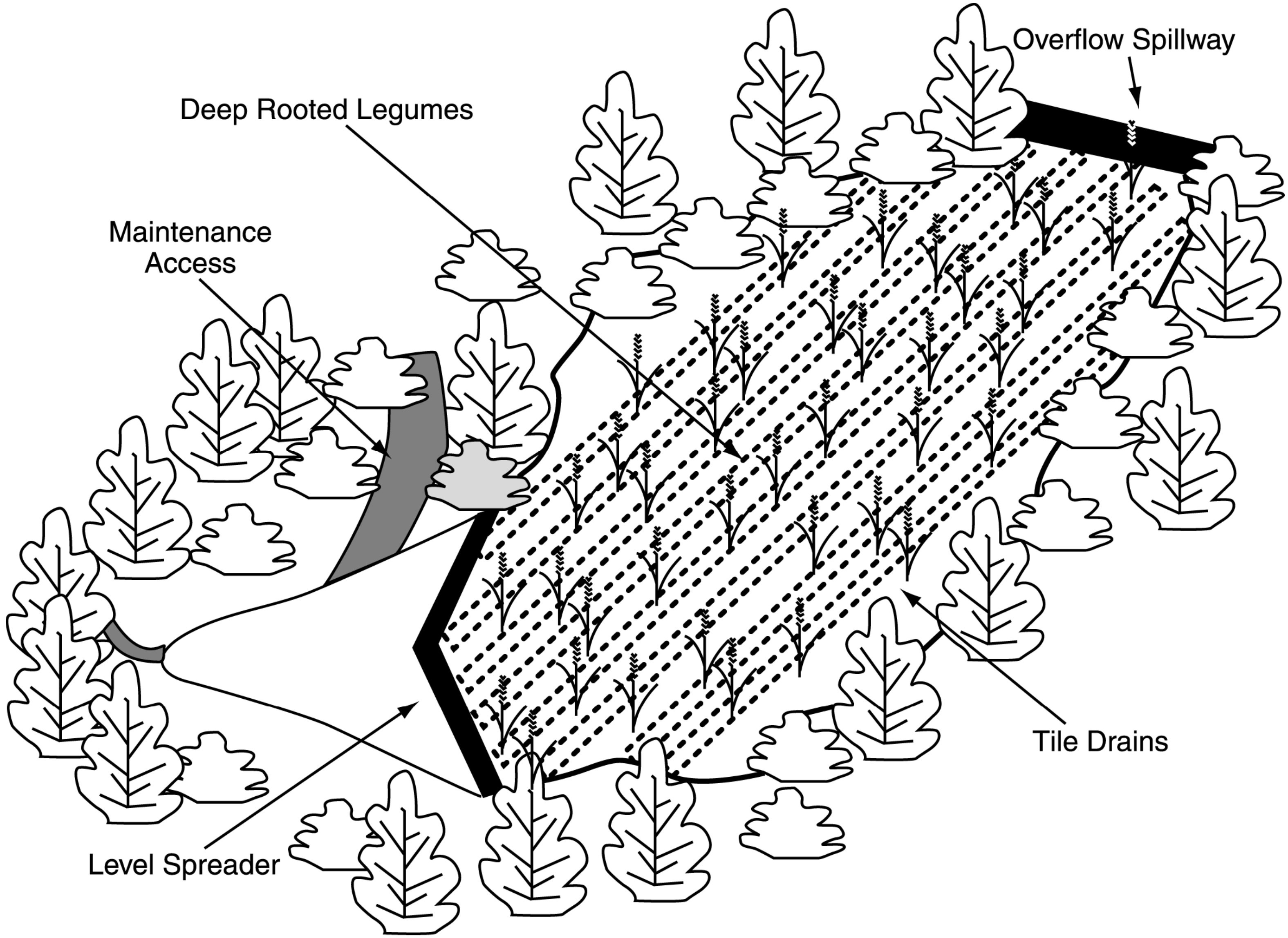


Figure 5.15
Infiltration Basin

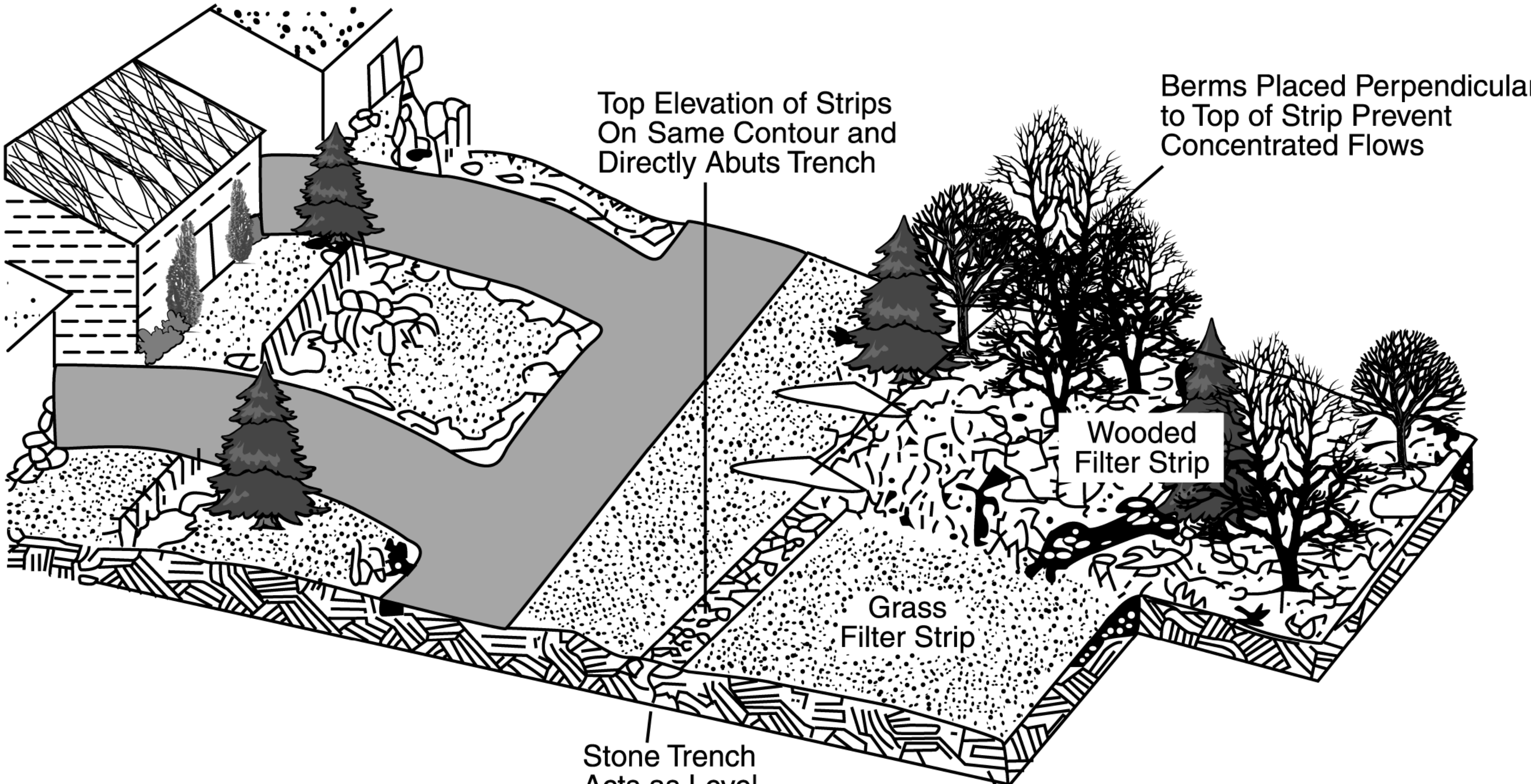


Figure 5.16
Schematic of Grassed and Wooded Filter Strip

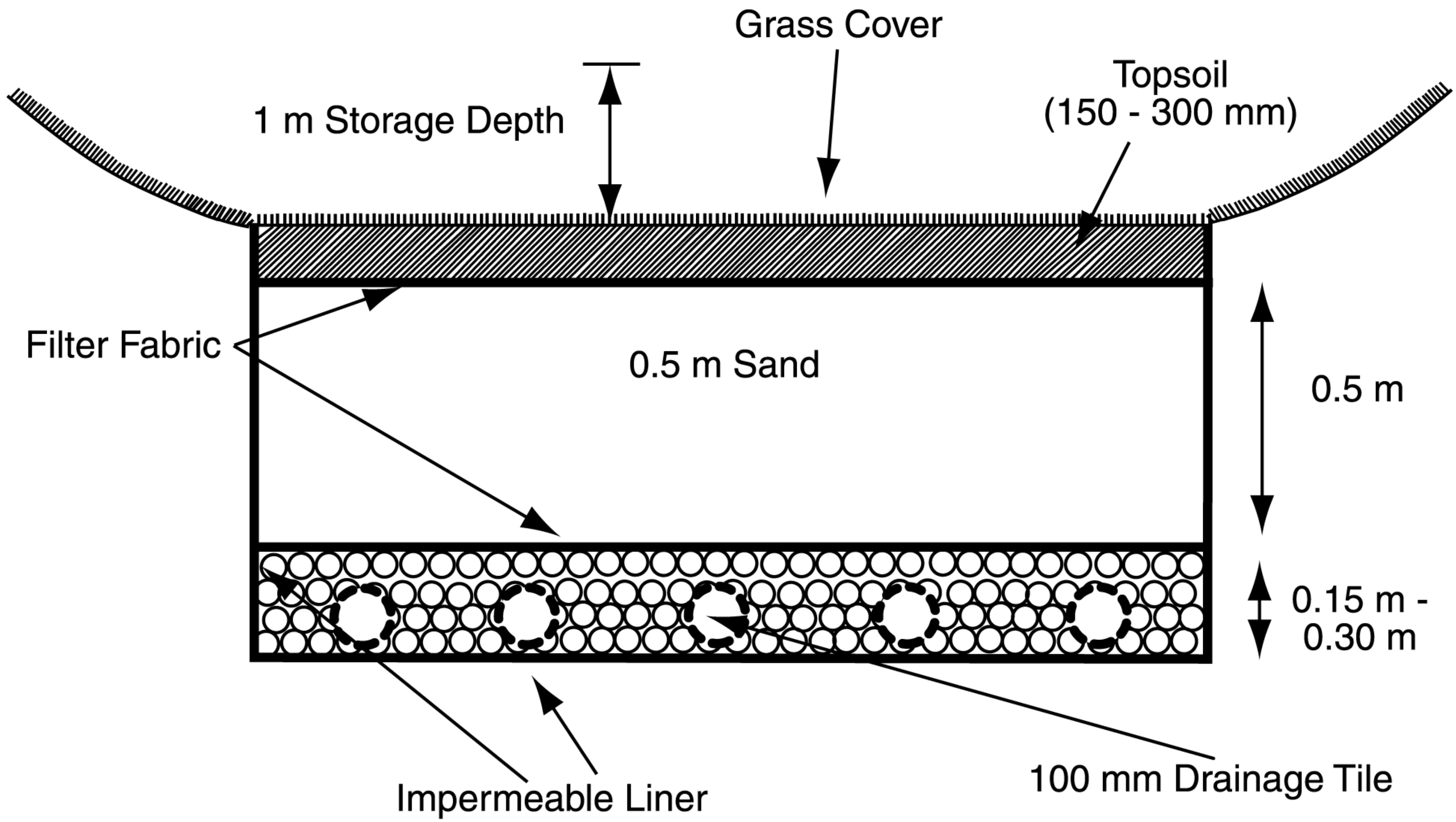


Figure 5.17
Sand Filter Cross Section Profile

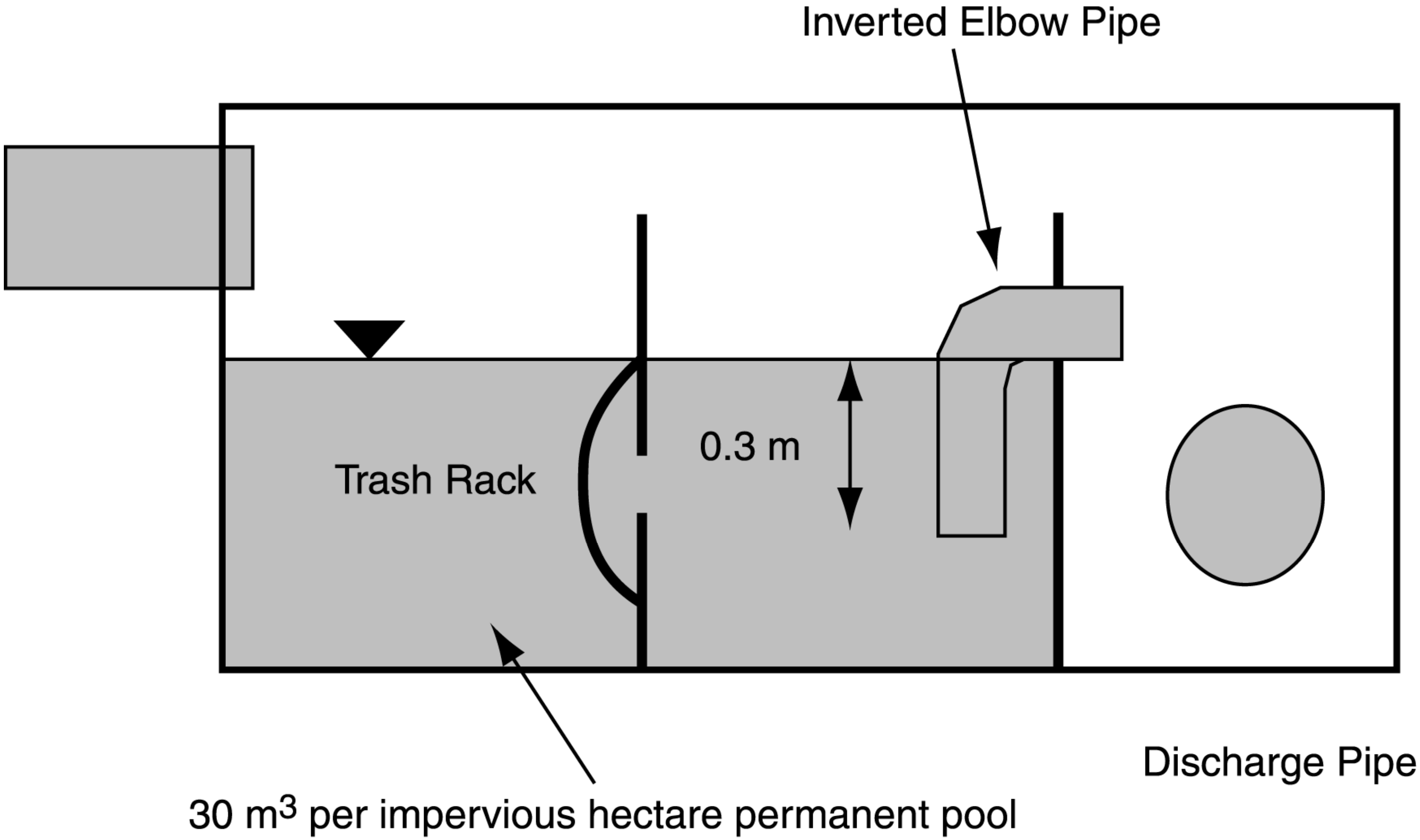


Figure 5.18
Standard 3 Chamber Oil / Grit Separator

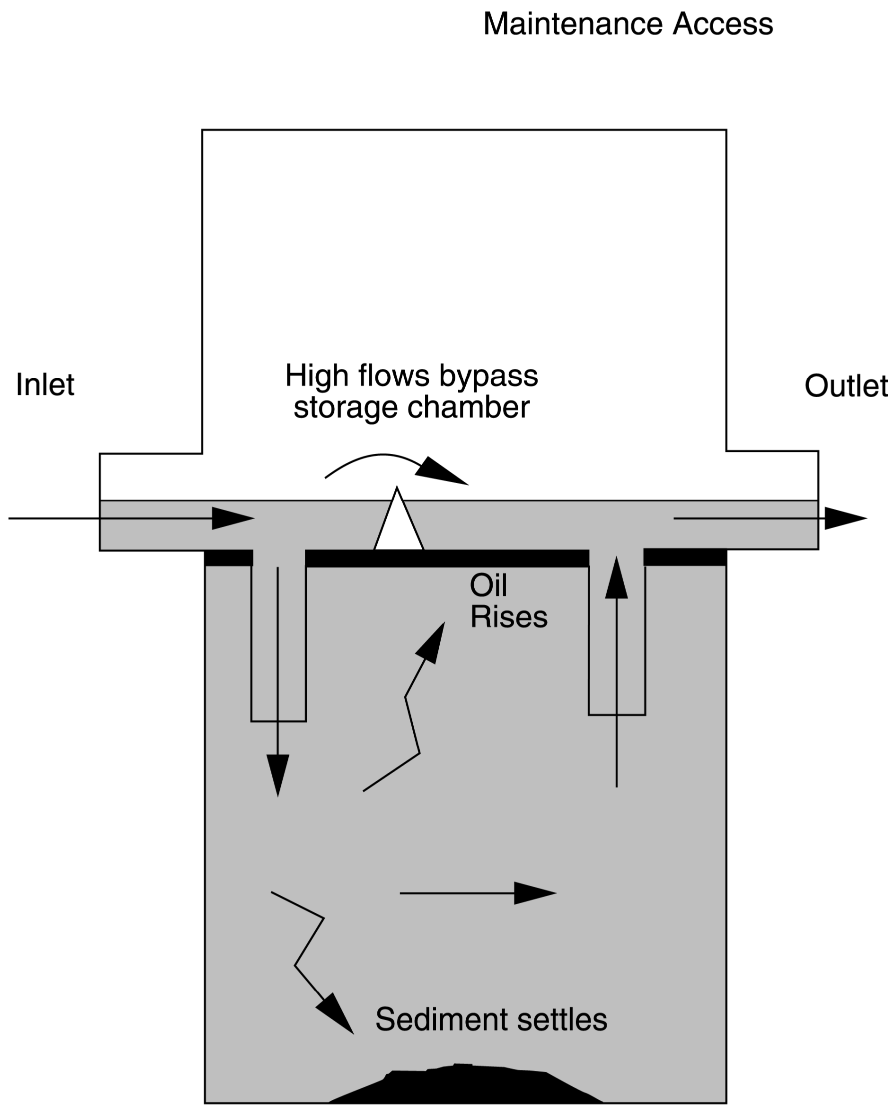


Figure 5.19
Bypass Separator

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