DISTRICT OF WEST KELOWNA

Storm Water Best Management Practices Manual

RSB ENGINEERING

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District of West Kelowna
2760 Cameron Road
West Kelowna BC V1Z 2T6

Attention: Mr. Gary O'Rourke, P. Eng
Director of Engineering

Re: Storm Water Best Management Practices Manual
Final Copy Submittal

We are pleased to enclose the Final copy of the Storm Water Best Management Practices manual. The enclosed manual is intended to provide guidance for the design and implementation of Construction and Permanent Best Management Practices (BMP's) for storm water management.

Should you have any questions regarding the enclosed, please feel free to contact our office.

Sincerely

R.S. (Robin) Barnes, P. Eng
RSB Engineering Inc.

DISTRICT OF WEST KELOWNA-

STORM WATER BEST MANAGEMENT PRACTICES MANUAL

Table of Contents

ACRONYMS

ASTM American Society for Testing and Materials
BC MoE British Columbia Ministry of Environment
BFM Bonded Fibre Matrix
BMPs Best Management Practices
C&D Construction and Demolition
EC Erosion Control
EPA United States Environmental Protection Agency
H:V Horizontal to vertical slope
LOS lines of study
MEP maximum extent practicable
NFPA National Fire Protection Association
PCBs Polychlorinated Biphenyls
SC Sediment Control
SM Site Management
Tm recurrence interval
TMDL total maximum daily load
WQDV water quality design volume
WQFR water quality flow rate
WQLS water quality limited segments

DEFINITION OF KEY TERMS

BEST MANAGEMENT PRACTICE (BMP) – Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution.

CONTRACT PROJECT – A construction project, which is designed either by District personnel or by engineering consultant firms, and is constructed by a private contractor.

DETENTION VOLUME – The volume of runoff that is held and treated in a BMP structure.

DISCHARGE RATE – The rate at which water is discharged out of the BMP after being stored and treated.

DRAINAGE AREA – The specific land area that drains water into a storm system or receiving water. Drainage area can also refers to the drainage basin or watershed.

FREEBOARD – The vertical distance between the water surface of the design discharge and a point of interest such as a low chord of a bridge or top of a channel bank.

GEOMORPHIC BALANCE – The balance of changes in hydrology and hydraulics that affect stream shape, planform, slope, and sediment transport.

GROUNDWATER RECHARGE – The process of water soaking into the ground to become groundwater.

HYDROLOGIC CYCLE – The cycle of water movement from the atmosphere to the earth and returning to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

HYDRAULIC GRADE LINE – A line characterized by a plotted ordinate position, which represents the sum of pressure head plus elevation head for the various positions along a given fluid flow path such as a pipeline or groundwater stream line.

HYDRAULIC GRADIENT – The slope of the water surface. The gradient or slope of a water table or piezometric surface in the direction of the greatest slope, generally expressed in m per m. Specifically, the change in static head per unit of distance in a given direction, generally the direction of the maximum rate of decrease in head. The difference in hydraulic heads divided by the distance along the flow path, or expressed in percentage terms.

IMPERVIOUS SURFACE – Surface area which allows little or no infiltration. Impervious surfaces include pavements and roofs.

IN-HOUSE PROJECT – A construction project that is performed by District personnel.

LAND USE – The way land is developed and used in relation to the types of allowable activities (agriculture, residences, industries, etc.) and the sizes of buildings and structures permitted. Certain types of pollution problems are often associated with particular land uses such as sedimentation from construction activities.

LINES OF STUDY (LOS) – Line used for drainage calculations where storm water runoff leaving a site in a sheet flow fashion.

PERVIOUS SURFACE – Surface area which allows infiltration of water.

POLLUTANTS – Refer to the waste material that contaminates air, soil, or water. In the context of storm water quality, pollutants often refer to the following:

• Nutrients- phosphorous and nitrogen;
• Suspended solids- sediment suspended in the water;
• Organic carbon and hydrocarbons;
• Bacteria;
• Trace metals;

• Pesticides; and
• Trash and debris.

REDEVELOPMENT PROJECT – A project that consists of reconstruction of or new construction on an existing impervious area 450 m^2

ROUGHNESS COEFFICIENT – A value based on the material used to construct a channel such as earth, rock, and gravel; the surface irregularity of the side slopes and bottom of the channel, the variations of successive cross sections in size and shape, obstructions which may remain in the channel and affect the channel flow, vegetation effects should be carefully assessed, channel meandering should also be considered.

RUNOFF VOLUME – The volume of water that flows off of a surface during a storm event.

SHEET FLOW – Flow that occurs overland in places without defined channels. The flood water spreads out over a large area at a uniform depth. Also referred to as overland flow.

SHORT-CIRCUITING – The minimizing of "dead spaces" (areas where little or no exchange occurs during a storm event) to minimize the distance between the inlet and outlet.

STORM WATER RUNOFF – Precipitation which flows over the ground.

SWALE – An elongated depression in the land surface that is at least seasonally wet, usually heavily vegetated, and normally without flowing water. Swales discharge storm water into primary drainage channels and may provide some groundwater recharge.

TAILWATER EFFECT – Water located just downstream of a hydraulic structure, such as a dam, culvert, or bridge.

TOPOGRAPHIC MAP – A type of map depicting a limited set of features but including at the minimum information about elevations or landforms. Topographic maps are commonly used for navigation and reference purposes.

WETLANDS – Lands where water saturation is the dominant factor determining the nature of soil development and the types of plants and animal communities living in the surrounding environment. Wetlands are also referred to as bogs, ponds, estuaries, or marshes.

INTRODUCTION

The purpose of this manual is to provide guidance on Best Management Practices (BMPs) installation and maintenance procedures for construction activities as well as for permanent site conditions. Implementation of these BMPs is intended to prevent or reduce the discharge of pollutants to the District storm systems and/or receiving waters. The BMPs contained in this manual do not constitute an exhaustive list of BMPs. This manual includes references to BMPs contained in the BC Environment Municipal Best Management Practices for Urban Runoff dated April, 2011.

This manual is intended for use by District staff and Consultants involved in construction projects (contract, in-house and maintenance) and consultants or contractors involved in projects which require work within the District

The BMPs included in this manual focus on the areas of site management, erosion control, and sediment control. Site Management (SM) BMPs include preventative measures implemented during the planning or construction stage of a project. They are established practices and procedures to control potential pollutants at their source. Erosion Control (EC) BMPs are devices installed or constructed by the contractor on disturbed soil to protect the ground surface from erosion due to wind, rain, or runoff. Sediment Control (SC) BMPs are measures to intercept and detain sediment-laden runoff prior to discharge off-site or to the storm sewer system. These devices detain runoff to promote infiltration and/or sedimentation.

Each BMP measure provided in this manual consists of the following:

- General description;
- Applications;
- Installation and implementation requirements;
- Challenges; and
- Inspections and Maintenance.

BMP selection should be determined by an evaluation of the existing conditions and requirements of the project area. Continued inspections and maintenance of BMPs are essential to maximizing the effectiveness of the device, application, or procedure. BMPs should be inspected weekly as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall.

We have also considered the following criteria: where structural facilities for contaminant removal are required and single event runoff models are used, facilities shall be designed to treat runoff from the 24-hour storm with a six month return frequency. The six-month, 24 hour storm can be estimated as 70 percent of the two-year, 24-hour storm. Where continuous runoff modeling is used, contaminant removal facilities should be designed to treat 90 percent of the runoff volume in an average year.

Any project within the District boundaries that involves the District storm sewer system must comply with the Sanitary Sewer/Storm Drain Regulation By-Laws.

A listing of District By-Laws referenced in this manual can be found at the following location:

http://www.districtofwestkelowna.ca/index.aspx?page=360

Green Design Techniques

Urban development significantly alters the natural features and hydrology of a landscape. Development and redevelopment usually creates impervious surfaces like concrete sidewalks and asphalt roadways, commercial and residential buildings, and even earth compacted by construction activities. Prevented from soaking into the ground, rainwater runs across parking lots and streets, collecting used motor oil, pesticides, fertilizers, and other pollutants.

In most cities, a complex system of piping usually feeds contaminated storm water flows directly into streams and coastal waters. More recently, storm water control structures (sometimes called Best Management Practices or BMPs) like dry extended detention ponds or wet retention ponds have been installed, most in new development, to intercept storm water on its way to surface waters.

Historically, the goal of storm water planning has been to prevent localized flooding by moving large amounts of water offsite as quickly as possible. However, experience has shown that traditional storm water management has many limitations.

Expensive, ever-expanding storm sewer systems strain municipal budgets. Fast moving storm water discharges cause downstream flooding, erode stream banks, and contribute to water quality violations. Bacteria and other pathogens carried in storm water contaminate receiving waters, often requiring beach closures. Rainwater diverted or otherwise unable to soak into the soil cannot recharge aquifers. This reduces stream base flows, which can cause streams to dry-up for extended periods of time. Storm water that collects in detention basins or flows over impervious surfaces is often much warmer than the streams into which it flows. This is a problem because a temperature increase of just one or two degrees can stress fish and other aquatic organisms.

Mimicking Natural Hydrology

Efforts to address storm water problems resulting from traditional development methods have produced a number of innovative design alternatives. For example, researchers and developers are experimenting with minimizing the distance between land uses to decrease infrastructure requirements. Another method reduces storm water runoff by conserving forests and green spaces and protecting stream buffers. Yet another technique diminishes impervious surfaces, narrows road and sidewalk widths, reduces parking lot sizes, minimizes or removes cul-de-sacs, and replaces traditional paving materials with pervious concrete.

Such innovative site design grew out of concerns that rapid urban development was not only impairing water quality but eroding quality of life. Concerned by the development of sensitive agricultural and wetlands, and burdened by the rising costs of storm water damage, some communities are implementing Green Design strategies, such as Low Impact Design (LID), Conservation Development, Better Site Design, and Smart Growth. The complementary goals of these design schemes lessen the impact of storm water while still providing opportunities for development.

Like other alternative development strategies, LID seeks to control storm water at its source. Rather than moving storm water offsite though a conveyance system, the goal of LID is to restore the natural, pre-developed ability of an urban site to absorb storm water.

LID integrates small-scale measures scattered throughout the development site. Constructed green spaces, native landscaping, and a variety of innovative bioretention and infiltration techniques capture and manage storm water on-site. LID reduces peak runoff by allowing rainwater to soak into the ground, evaporate into the air, or collect in storage receptacles for irrigation and other beneficial uses. In areas with slow drainage or infiltration, LID captures the first flush before excess storm water is diverted into traditional storm conveyance systems. The result is development that more closely maintains pre-development hydrology. Furthermore, LID has been shown to be cost effective, and in some cases, cheaper than using traditional storm water management techniques.

LID Techniques

LID can be simple and effective. Instead of relying solely on complex and costly collection, conveyance, storage and treatment systems, LID employs a range of economical devices that control runoff at the source.

- Bioretention cells, commonly known as rain gardens, are relatively small-scale, landscaped depressions containing plants and a soil mixture that absorbs and filters runoff.
- Cisterns and rain barrels harvest and store rainwater collected from roofs. By storing and diverting runoff, these devices help reduce the flooding and erosion caused by storm water runoff. Since they contain no salts or sediment, they can provide "soft" chemical-free water for garden or lawn irrigation, reducing water bills and conserving municipal water supplies.
- Green roofs are roof-tops partially or completely covered with plants. Used for decades in Europe, green roofs help mitigate the urban "heat island" effect and reduce peak storm water flows. The vegetated cover also protects and insulates the roof, extending its life and reducing energy costs.
- Permeable and porous pavements reduce storm water runoff by allowing water to soak through the paved surface into the ground beneath. Permeable pavement encompasses a variety of mediums, from porous concrete and asphalt, to plastic grid systems and interlocking paving bricks suitable for driveways and pedestrian malls. Permeable pavement helps reduce runoff volumes at a considerably smaller cost than traditional storm drain systems.
- Grass swales are broad, open channels sown with erosion resistant and flood tolerant grasses. Used alongside roadways for years primarily as storm water conveyances, swales can slow storm water runoff, filter it, and allow it to soak into the ground. Swales and other biofiltration devices like grass filter-strips improve water quality and reduce in-stream erosion by slowing the velocity of storm water runoff before it enters the stream. They also cost less to install than curbs, storm drain inlets, and piping systems.

Conservation Development

Like LID, Conservation Development tries to mitigate the effects of urbanization, but it places additional emphasis on protecting aquatic habitat and other natural resources. Conservation Development subdivisions are characterized by compact clustered lots surrounding a common open space. Conservation Development's goal is to disturb as little land area as possible while simultaneously allowing for the maximum number of residences permitted under zoning laws.

Prior to new construction, conservation developers evaluate natural topography, natural drainage patterns, soils and vegetation. They deploy storm water best management practices to help prevent flooding and protect natural hydrology. By maintaining natural hydrological processes, Conservation Development creates conditions that slow, absorb, and filter storm water runoff onsite.

As future development threatens valuable natural features, Conservation Development provides specific provisions for long-term and permanent resource protection. Conservation easements, transfer of development rights, and other "in perpetuity" mechanisms ensure that protective measures are more than just temporary.

Better Site Design

The goals of Better Site Design are to reduce impervious cover, preserve natural lands, and capture storm water onsite. To meet these goals, designers employ a variety of methods. To reduce impervious cover, they narrow streets and sidewalks, minimize cul-de-sacs, tighten parking spaces, and reduce the size of driveways and housing lots.

To reduce storm water runoff, designers preserve natural lands, using them as buffer zones along streams, wetlands and steep slopes. They employ landscaping techniques that flatten slopes and preserve native vegetation and clusters of trees. They create bioretention areas - open channels, filter strips and vegetated swales - to increase storm water infiltration, helping to protect streams, lakes, and wetlands.

Development Districts

Development districts are areas zoned specifically for the purpose of permitting property development. Development districts concentrate intense, mixed-use development in an area typically 2 Ha and larger. Although a development district's percentage of imperviousness may exceed those of surrounding areas, such focused, compact development creates a smaller "footprint" than traditional development patterns.

A well-designed development district can contribute to a number of water quality benefits. Compact development lends itself to more environmentally friendly transportation options, like biking or walking, and shorter and less frequent automobile trips. A development district that redevelops an urban area reuses existing infrastructure, which can reduce the demand for new construction elsewhere in a watershed. Many development districts incorporate tree-lined streets, rain gardens, green roofs and other best management practices into their designs, helping manage storm water onsite.

Smart Growth

Smart Growth is a set of development strategies that seek to balance economic growth, urban renewal, and conservation. In newly developing areas, Smart Growth advocates compact, town-centered communities composed of open green space, businesses, and affordable housing, interconnected by pedestrian walkways and bicycle lanes. Smart Growth's emphasis on walkable communities and alternative forms of transportation can help alleviate the environmental consequences of automobile use. Smart Growth also advocates the revitalization of inner cities and older suburbs. Reusing existing infrastructure often costs less than new construction, and it helps slow the spread of large-scale impervious surfaces.

Ten core principles guide Smart Growth:

1. Mix land use.
2. Take advantage of compact building design.
3. Create a range of housing opportunities and choices.
4. Create walkable neighbourhoods
5. Foster distinctive, attractive communities with a strong sense of place.

6. Preserve open space, farmland, natural beauty and critical environmental areas.
7. Strengthen and direct development toward existing communities.
8. Provide a variety of transportation choices.
9. Make development decisions predictable, fair and cost effective.
10. Encourage community and stakeholder collaboration in development decisions.

While not explicitly mentioned as a guiding principal, storm water management nevertheless benefits from Smart Growth policies. Compact, high-density development reduces the spread of impervious surfaces on a watershed scale. This helps reduce overall storm water runoff. Infill and redevelopment that reuses existing infrastructure can be cheaper than greenfield development, which requires expensive new infrastructure. The `Fix it First' management philosophy advocates repairing and upgrading existing, frequently crumbling infrastructure before spending on new infrastructure.

All of these development strategies can contribute to reducing sprawl and slow the rapid spread of impervious surfaces. All of the site design frameworks discussed in this fact sheet can be coupled with the Smart Growth approach so that small-scale reductions in run-off aren't offset by watershed-scale increases in run-off.

Holistic Planning

The damaging effects of storm water runoff can be mitigated if urban planners use development designs that reduce the "footprint" of impervious structures. Traditional storm water approaches, with their emphasis on collection, conveyance, storage and discharge, cannot adequately address the environmental problems caused by sprawling urbanization.

New land and storm water management strategies take a more holistic approach. Communities employing conservation development techniques have found that natural features like undeveloped landscapes, vegetation, and buffer zones effectively reduce and filter storm water flows. There are also other benefits like recreation, wildlife habitat, and increased property values.

Case studies of green design practices have shown substantial decreases in storm water runoff in pre-existing communities refitted with bioretention basins, permeable pavements, vegetated roof covers, and grass swales.

LID integrates ecological considerations into each phase of urban development, from design to construction to post-construction. Pilot programs conducted in the U.S. and around the world show that LID saves money by reducing construction costs for curbing, paving materials, drainage pipes and land clearing. Techniques that manage runoff onsite, such as swales and rain gardens, deliver tangible improvements in water quality and ground water recharge. LID practices also improve air quality, reduce the heat island effect, and enhance community appearance.

Green Design concepts used individually can yield measurable improvements in storm water runoff management. Used in combination, they can help local governments address significant sources of storm water pollution, particularly in older urban and suburban areas.

As Green Design practices like LID blend multiple technologies, they are more versatile than the more limited drain-and-discharge methods of traditional storm water management. LID can effectively address sources of water pollution in new and existing developments, in brownfields and greenfields, in warm climates and cold, and wet and dry climates. In urban areas, green roofs used in combination with rain gardens, permeable pavement, bio-retention cells and rain barrels produce results far greater than a single technology used alone.

Sound engineering principals form the basis of Green Design practices. Years of experience derived from storm water management, sanitary engineering, agriculture, and other disciplines, demonstrate soil's ability to effectively absorb and digest many waterborne pollutants. By capturing storm water onsite, Green Design techniques not only reduce pollutants and runoff volume, but they do so cost-effectively.

PART A – CONSTRUCTION BEST MANAGEMENT PRACTICES

Chapter A1 - Site Management BMPs

During the planning and/or construction stages of a project, Site Management (SM) BMPs, which are preventative measures, are to be implemented to control potential pollutants at their source through the use of good house-keeping practices.

Chapter A1 includes BMPs for:

1.1 Training;
1.2 Material Management;
1.3 Waste Management;
1.4 Vehicle and Equipment Management; and
1.5 Site Planning and General Practices.

1.1 Training

Employee Training - SM-1

Description - Training programs should be designed to ensure that staff understands the requirements of the Storm Water Management Program Plan as applicable to their responsibilities. Training topics include but are not limited to storm water management, potential contamination sources, and BMPs. The program should be designed to promote awareness on non-point source pollution and that it can be considered a source control BMP as it encourages people to change their behaviors by preventing the introduction of contaminants from entering the water at all.

Applications - Employees involved in the planning, design, or construction phase of construction, repair, or maintenance activities.

Requirements

- Provide storm water management training through courses, seminars, workshops, product demonstrations, employee meetings, posters, and bulletin boards.
- Provide field training programs conducted by trained personnel for awareness of BMP monitoring and reporting.
- Maintain commitment and request input from senior management.
- Promote open communication between employees involved in various stages of the projects.
- Improve storm water quality management based on past experience involving water quality problems at construction sites. Implement revised practices and procedures in training.
- Develop standard operating procedures for storm water quality management.
- Conduct spill drills.

Challenges

- Success of the Training performance depends on the buy in of senior managers which will increase the degree of employee motivation and incentive to learn about BMP implementation; and
- The availability of staff time to coordinate and conduct training.

Inspections and Maintenance

Provide as-needed training (annual at a minimum) on construction BMP implementation for all employees involved with construction activities. A “lead” training officer should be designated.

1.2 Material Management

Material Delivery and Storage - SM-2

Description - This includes implementing the practices and procedures that promote proper handling and storage of construction materials in order to prevent or reduce; potential impacts to storm water, groundwater and soils as well as potential for injury to workers or visitors.

Applications - Storage and handling activities on construction sites involving one of the following:
• Soils, soil stabilizers or binders;
• Fertilizers;
• Pesticides and herbicides;
• Detergents;
• Plaster;
• Chemicals such as acids, lime, glues, paints, solvents, and curing compounds;
• Hydrocarbons products such as fuel, oil, and grease; and
• Asphalt and concrete products.

Requirements
• Provide training for employees and contractors on proper material delivery and storage practices and procedures.
• Designate material delivery and storage areas. Areas shall be located away from watercourses as far as possible. Containment measures shall surround storage areas.
• Flammable materials shall comply with the National Fire Code. Contact the District of West Kelowna Fire Department for any site specific requirements.
• Maintain accurate and up to date records of material delivered and stored on-site including Material Safety Data Sheets (MSDS) on site. Materials are to be stored in their original containers.
• Minimize on-site inventory or implement just-in-time practices.
• Minimize handling of hazardous materials or replace with less hazardous materials.
• Store materials under cover as needed and/or when possible.
• Store materials on pallets and when possible.
• If drums must be stored in an uncovered area, place them at a slight angle to minimize ponding of rainwater on the lids to minimize corrosion.
• Employees with emergency spill cleanup training shall be present during unloading of dangerous materials or liquid chemicals.
• If residual materials have potential to contaminate the soil, then the contaminated soil shall also be tested and managed properly.

Challenges – Diligence of staff to maintain storage requirements.

Inspections and Maintenance
• Storage areas shall be clean and well organized.
• An ample supply of spill cleanup materials shall be kept within material storage areas.
• Conduct inspections of: material containers for corrosion and damage to storage and containment areas.

Material Use - SM-3

Description – Preventing or minimizing discharge of pollutants to the storm drain system or adjacent water bodies by using low hazard materials, by reducing hazardous material usage, using alternative products, and training employees in proper handling and use of materials.

Applications Activities involving use of one of the following materials:
• Soils, soil stabilizers or binders;
• Fertilizers;
• Pesticides and herbicides;
• Detergents;
• Plaster;
• Chemicals such as acids, lime, glues, paints, solvents, and curing compounds;
• Hydrocarbons products such as fuel, oil, and grease; and
• Asphalt and concrete products.

Requirements
• Minimize use of materials.
• Reduce or eliminate on-site use of hazardous materials. Refer to SM-9 (Hazardous Waste Management) in this manual for more information regarding use of hazardous materials.
• Material containers to maintain correct labeling. Retain Material Safety Data Sheets (MSDS) on site
• Dispose container only after all of the product has been used.
• Consult weather reports prior to use of fertilizers or herbicides.
• An ample supply of cleanup materials for spills shall be readily accessible.
• Provide employee training on proper material use.

Challenges - Alternative or less hazardous materials may not be available or appropriate for certain construction activities.

Inspections and Maintenance
• Provide training to all new employees at the beginning of their employment.
• Provide periodic training to all employees involved in handling construction materials.

Protection of Stockpiles - SM-4

Description - Stockpile protection measures reduce the potential for release to air and/or storm water originating from stockpiles of construction materials. This includes soil and paving materials.

Applications - Projects requiring stockpiles of construction materials.

Requirements

- Stockpiles should be located at least 15m away from concentrated runoff
- Packaged materials to remain on pallets and under cover until needed.
- Runoff should be directed away from stockpiles.
- Stockpiles should be covered with impermeable material (i.e. plastic or comparable) until needed.
- Where possible, hydroseed or vegetate large stockpiles which will be on site for an extended period
- Place silt fence (or equivalent) around stockpiles.
- Contractor should consult District Soil Removal and Deposit Regulation By-Law 2011 No. 0127 prior to moving soil stockpiles >50m^3 on or off site. Soil volumes < 50m^3 are exempt.

Challenges

Stockpiles should only be considered as temporary storage of materials.

Inspections and Maintenance

Periodic replacement and repair of materials used for stockpile protection.

1.3 Waste Management

Concrete Waste Management - SM-5

Description - Procedures to prevent or reduce the discharge of concrete wastes to storm water system or adjacent receiving waters.

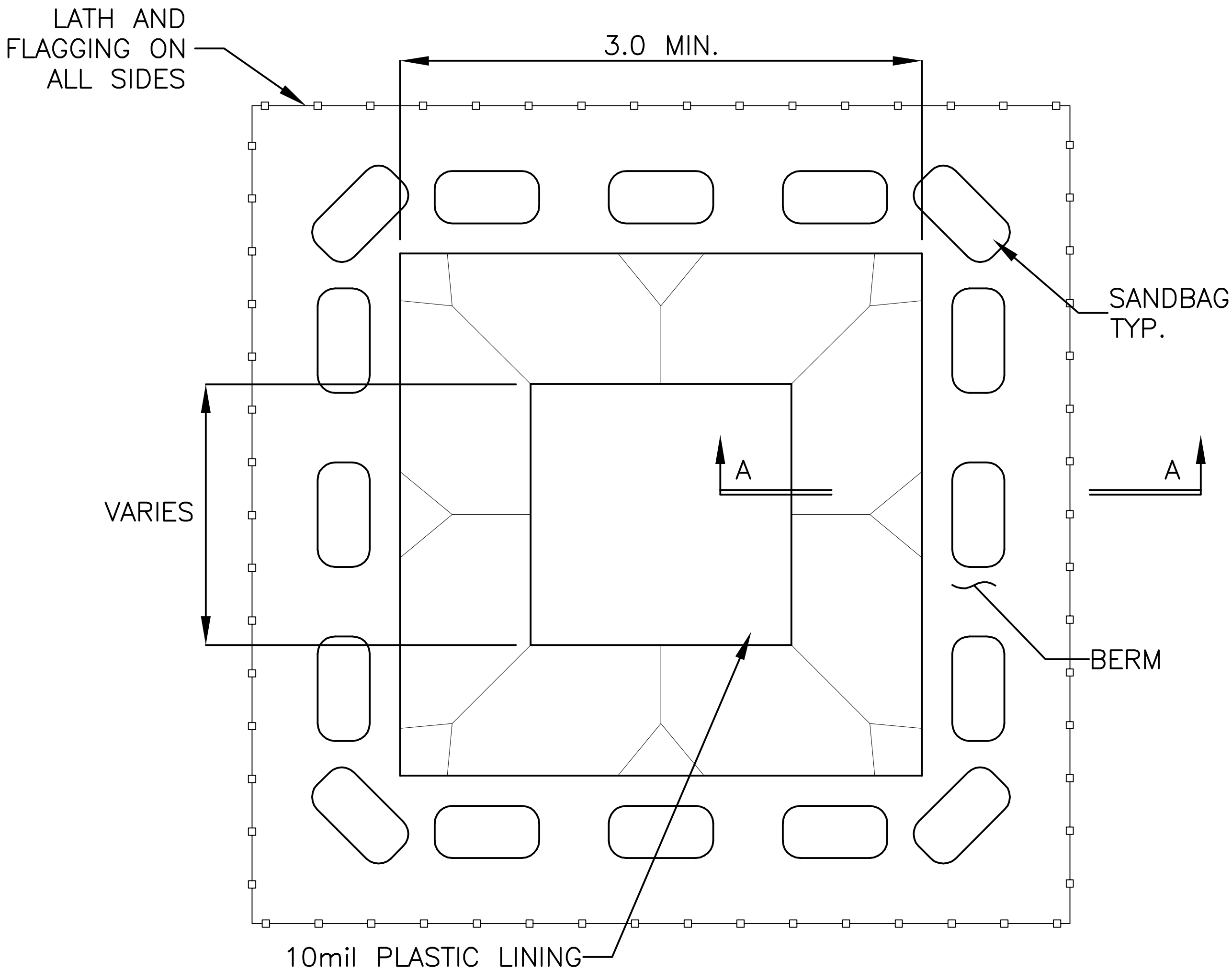
Applications - Projects involving the use of concrete as a construction material or demolition activities generating concrete dust and debris.
• On-site wash areas used for concrete-coated vehicles or equipment.
• Activities such as grinding and/or cutting, chipping and grinding which result in the formation of slurries containing cement products.

Requirements
• Store concrete materials away from runoff and under cover where possible.
• Avoid mixing excess concrete. Discard excess concrete in the designated area.
• Wash concrete-coated vehicles or equipment in the designated wash areas. Locate on-site concrete wash area a minimum of 15m from catch basins and/or receiving water bodies. Runoff from the on-site concrete wash area shall be contained on site in a temporary pit or bermed area where the concrete can set and water can evaporate if possible.
• Temporary pit shall be lined with impervious layer prevent seepage of the wash water into the ground. Allow wash water to evaporate or collect wash water and all concrete debris in a concrete washout system bin.
• Break up and properly dispose of hardened concrete from wash area.
• Collect and properly dispose of aggregate concrete sweepings.
• Must comply with District of West Kelowna Good Neighbour By-Law 2009 No. 0071.
• Provide concrete waste management training for employees and contractors.

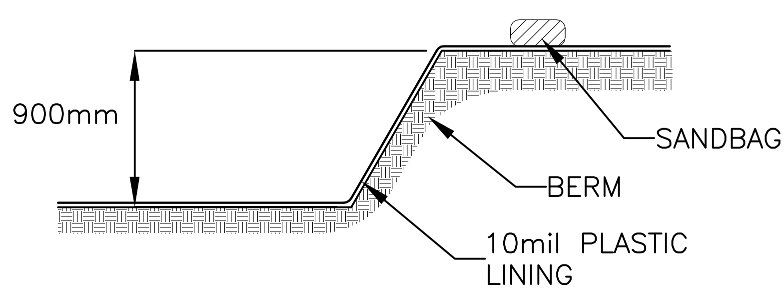
Challenges - Off-site concrete wash areas to be used only when on-site space requirements are too restrictive.

Inspections and Maintenance
• Inspect concrete wash areas for damage and repair as necessary.
• Remove and dispose of hardened concrete.
• Monitor personnel to ensure that proper concrete waste management measures are implemented.

See Figure SM- 5



PLAN



SECTION A–A

NOTES:
1. ACTUAL LAYOUT DETERMINED IN FIELD
2. THE CONCRETE WASH OUT SIGN SHALL BE INSTALLED WITHIN 3m OF THE TEMPORARY WASHOUT FACILITY.

N.T.S.

WASH AREA BELOW GRADE

SM–5

Solid Waste Management - SM-6

Description - Practices and procedures to prevent or reduce the discharge of solid wastes from construction sites into the storm water system and/or receiving waters.

Applications - Construction sites generate non-hazardous solid wastes from construction and demolition (C&D) activities including inert fill material, and recycle/reuse material. C&D materials include concrete, brick, bituminous concrete, wood, masonry, roofing materials, metals, plaster and glass.
Inert fill materials are wastes which are not contaminated and do not decompose or produce leachate or other products harmful to the environment. Inert fill materials include soil, granular fill, rock, asphalt, brick and concrete (no exposed steel-reinforcing bar).
Recycle/reuse materials include but are not limited to: asphalt, cardboard, concrete, electronic equipment, rock, soil, appliances, glass, green waste, metals, tires, and wood.

Requirements

- Separate contaminated materials from C&D wastes and inert wastes.
- Inert fill material shall not contain vegetation, organic material, or other solid waste.
- Must comply with District of West Kelowna Solid Waste Management By-Law 2009 No. 0065.

Challenges - None

Inspections and Maintenance

- Inspect construction waste and recycling stockpile areas regularly.
- Minimize quantities of solid wastes on site.
- Schedule recycling activities based on construction/demolition phases.

Sanitary/Septic Waste Management - SM-7

Description - Practices and procedures to reduce or prevent the discharge of sanitary wastes from construction sites into the storm water system and/or receiving waters.

Applications - Construction sites utilizing temporary or portable sanitary/septic waste systems.

Requirements

- Locate sanitary facilities away from drainage facilities.
- Untreated wastewater shall not be discharged to the ground.
- Comply with the BC Ministry of Health (MoH) Sewage Regulation when using an on-site disposal system (i.e. tile field).
- Sanitary/septic systems discharging to the sanitary sewer shall comply with the local wastewater treatment plant requirements.
- Schedule regular waste collection by a licensed transporter.
- Must comply with applicable Holding Tank By-Laws.

Challenges None

Inspections and Maintenance

- Inspect and maintain facilities regularly.
- Keep records of waste collection.

Contaminated Soil Management - SM-8

Description - Practices and procedures to prevent or reduce the discharge of pollutants (i.e. leachate from contaminated soils) to the storm water system or receiving waters.

Applications – Includes projects where previous site usage, undetected spills or leaks, illicit discharges, or underground storage tank (UST) leaks may have contributed to soil contamination.

Requirements

- Identify soil discolouration, odours, soil property differences, abandoned USTs or pipes, or buried debris to determine possible soil contamination.
- Prevent leaks and spills of potentially contaminating materials.
- Test soil at a certified laboratory if soil is suspected of contamination.
- Coordinate with the BC Ministry of Environment Contaminated Sites Regulation (CSR) for required actions to determine treatment and disposal options of contaminated soil.

Challenges - Generally will require a specialized consultant to advise on the assessment, treatments and/or disposal of contaminated soils.

Inspections and Maintenance

- Conduct inspections of excavated areas for evidence of contaminated soil and/or USTs and piping.
- Prevent leaks and spills by implementing Spill Prevention and control practices and procedures.

Hazardous Waste Management - SM-9

Description - Practices and procedures to prevent or reduce the discharge of hazardous materials to the land, storm water system, or receiving waters.

Applications – Management procedures on construction sites involving any of the following hazardous materials used for construction or from demolition and construction:

- Paints and solvents;
- Hydrocarbons (i.e. oils, fuels, and grease);
- Herbicides and pesticides;
- Acids;
- Concrete curing and repair compounds; and
- Stored contaminated materials.
- Sandblasted material lead, cadmium, or chromium-based paints;
- Asbestos; and
- Polychlorinated Biphenyls (PCBs).

Requirements

Recognize potentially hazardous waste by implementing the following:

- Review product label and shipping papers;
- Review material safety data sheets (MSDS) from the manufacturer and/or supplier of the product;
- Staff need to understand implications of key words in MSDS such as flammable (able to catch fire); carcinogenic (causes cancer); toxic or poisonous (injures or harms people or animals); and hazardous, danger, caustic or corrosive (burns through chemical action).
- Storage procedures must comply with the BC Waste Management Act.

Material use practices and procedures include the following:

- Dispose container only after all of the product has been used;
- Keep the original product label on the container;
- Minimize herbicide application. Comply with the recommended usage instructions. Do not apply herbicides during or just before a rain event; and
- Wash water from water-based paint brushes should be discharged to the District sanitary sewer system. Filter and re-use solvents and thinners. Dispose of oil-based paints and residue as a hazardous waste.

Waste recycling and disposal practices and procedures include the following:

- Designate areas for collection of hazardous wastes;
- Store hazardous materials and wastes in covered containers, including secondary containment;
- Separate wastes which will allow for more efficient recycling and disposal;
- Recycle useful materials such as oil or water-based paint;
- Liquid wastes such as solvents, used oils, and paints are not to be disposed of in dumpsters or to ground
- Schedule regular waste collection to prevent overflow of containers; and
- Ensure collection, removal, and disposal of hazardous waste complies with regulations (i.e. BC Waste Management Act).

Hazardous waste management training shall include the following:

- Identification and awareness of potential dangers from hazardous wastes;
- Proper hazardous waste storage and disposal procedures;

• Safety procedures for hazardous wastes;
• Placement of warning signs in areas recently treated with chemicals;
• Use of cleanup materials for spills;

Challenges - Hazardous waste that cannot be reused or recycled will need to be disposed of by a licensed hazardous waste hauler.

Inspections and Maintenance
• Regularly inspect hazardous waste collection and storage areas and containers.
• Schedule hazardous waste collection regularly.

Spill Prevention and Control - SM-10

Description - Practices and procedures to reduce or prevent leaks or spills which may be discharged into the storm system or receiving waters.

Applications - Construction projects involving the storage and use of hazardous materials.

Requirements
General Requirements include the following:
• Store hazardous materials and wastes in covered containers and protect containers from vandalism;
• Maintain an ample supply of cleanup materials for spills shall be readily accessible;
• Employees should be trained on proper spill prevention and cleanup; and
• Spill response requirements should be reviewed at least once per year at all applicable work sites.

Spill Cleanup Requirements include the following:
• Immediately contain spill
• Clean up spills as soon as possible;
• Use minimal water to clean up spills on hard surfaces. For small spills, use a cloth, a mop or absorbent materials accordingly. Properly dispose of materials used to clean up hazardous materials; and
• Avoid hosing down or burying dry material spills.

Reporting includes the following:
• Report significant spills to the Provincial Incident Reporting Agency on 1-800-663-3456

Mechanical equipment maintenance activities requirements include the following:
• Use a designated area and/or secondary containment for on-site repair or maintenance activities. These areas shall be located away from storm system;
• Complete regular inspections of on-site vehicles and equipment;
• Drop cloths and drain pans can be used to catch leaks or spills while removing or changing fluids from vehicles or equipment;
• Use absorbent materials on small spills. Avoid hosing down or burying spills. Remove and properly dispose of cleanup materials;
• Transfer used fluids to the appropriate waste or recycling containers as soon as maintenance is complete (i.e. avoid leaving full drip pans and open containers on-site);
• Drain excess oil from oil filters prior to disposal and/or recycle oil filters if possible; and
• Store used batteries inside secondary containment.

Mechanical equipment fueling activities requirements include the following:
• Fueling areas shall be located away from drainage courses in designated areas;
• Use secondary containment on fuel tanks.

Challenges – In the event of a significant spill (i.e. see BC Spill Reporting Regulations for minimum reportable spills of various materials) report to the Provincial Incident Reporting Hotline (1-800-663-3456). In addition, a commercial spill cleanup company may be necessary.

Inspections and Maintenance
Spill prevention and control plans should be updated at least once per year or whenever a new material is added to the on-site inventory

Ample supplies of materials for spill control and cleanup shall be located on-site near maintenance and material storage or unloading areas.

1.4 Vehicle and Equipment Management

Vehicle and Equipment Cleaning and Maintenance - SM-11

Description - Practices and procedures to reduce or prevent the discharge of pollutants from vehicle and equipment cleaning and maintenance activities to storm system and/or receiving waters.

Applications Construction or maintenance activities involving cleaning or maintaining of vehicles and equipment.

Requirements
• Use off-site vehicle and equipment commercial washing facilities when practical as they may be better equipped to properly handle and dispose of wash waters.
• Use off-site repair and maintenance facilities where possible.
• If on-site cleaning is necessary, designate bermed (sloped slightly) wash areas for cleaning activities.
• Minimize water use.
• Use phosphate-free, biodegradable soaps.
• Steam cleaning and de-greasers shall occur in contained areas only as significant pollutant concentrations can be generated.
• Keep vehicles and equipment clean. On-site vehicles and equipment shall be inspected regularly for leaks and all leaks shall be immediately repaired.
• Utilize a designated maintenance area away from the storm system.
• Place drip pans or drop cloths under vehicles and equipment to absorb spills or leaks.
• Maintain an adequate supply of readily accessible spill cleanup materials.
• Use absorbent materials on small spills. Promptly remove and properly dispose of absorbent materials.
• Do not hose down or bury small spills.
• Leaking vehicles and equipment shall not be allowed on-site.
• Segregate and recycle wastes from vehicle/equipment maintenance activities (i.e. used oil, oil filters, grease, cleaners, antifreeze, batteries, hydraulic and transmission fluids).
• Properly dispose of wastes generated by vehicle/equipment maintenance activities.
• Provide employee training on proper maintenance and spill cleanup practices and procedures.

Challenges - Do not discharge wash water directly into storm systems or receiving waters. Off-site maintenance facilities may not be convenient to access. Authorized recycling handlers will be required for off-site disposal of materials.

Inspections and Maintenance
• Train employees on implementation of pollution prevention procedures.
• Regularly inspect vehicle and maintenance areas.
• Adequate supplies of spill cleanup materials shall be kept on-site.

Vehicle and Equipment Refueling - SM-12

Description - Practices and procedures to prevent or reduce the discharge of pollutants from vehicle and equipment hydrocarbon leaks or spills to storm and/or receiving waters.

Applications - Construction or maintenance activities involving fueling of vehicles or equipment.

Requirements

- Use off-site fueling sites when practical
- If on-site fueling is necessary, locate fuel tanks away from drainage courses to prevent contamination of storm water.
- Comply with Provincial requirements regarding above ground (AST) or underground fuel storage (UST) tanks. ASTs are preferred in place of USTs
- Comply with District of West Kelowna Petroleum Products Storage Tank By-Laws.
- Avoid over-filling vehicle fuel tanks.
- Drip pans or drop cloths shall be used to absorb leaks or spills during fueling.
- Absorbent spill cleanup materials shall be available and located in fueling areas.
- Use absorbent materials on small spills instead of hosing down or burying the spill. Promptly remove and properly dispose the absorbent materials.
- Minimize mobile fueling of construction equipment, where possible, by transporting equipment to designated areas for fueling.
- Train employees on proper fueling and cleanup procedures.

Challenges - Off-site fueling of vehicles and equipment may not be practical.

Inspections and Maintenance

- Ample supplies of materials for fuel spill control and cleanup shall be located on-site near fueling areas.
- Regularly inspect fueling areas and storage tanks.

1.5 Site Planning and General Practices

Scheduling - SM-13

Description - Development of a plan that addresses the sequence of construction activities as it relates to the local climate. Scheduling considerations can minimize soil erosion resulting from exposure to wind, rain, snow, runoff, and vehicle tracking.

Applications - Proper scheduling shall be used on all projects.

Requirements

- Minimize work involving soil disturbing activities during periods of expected high rainfall.
- Schedule disturbed areas to be stabilized prior to additional grading of other areas.
- Schedule trenching activities to ensure trenches are closed prior to excavating new trenches (i.e. minimize the time that trenches are open).
- Implement erosion and sediment control plans year round.

Challenges - None

Inspections and Maintenance

- Utilize scheduling software to assist in monitoring progress of construction activities relative to construction schedule.

Location of Potential Sources of Sediment - SM-14

Description – Identification of potential sources of sediment in order to reduce erosion and sediment discharge from construction sites to storm system or receiving waters.

Applications - Any potential source of sediment on all projects.

Requirements

• Design construction sites to ensure vegetated areas buffer access roads and material stockpiles. Vegetation can reduce sediment discharged off-site.
• Place stockpiles away from drainage courses
• Direct off-site runoff away from exposed ground.
• Maintain vegetation in swales and natural drainage ways.
• Designate level areas for parking and equipment staging during construction.
• Contractor should consult District Soil Removal and Deposit Regulation By-Law 2011 No. 0127 prior to moving soil stockpiles.

Challenges - Additional BMPs such as mulching, planting, and structural controls, including berms, silt fences, and silt basins, shall also be implemented as necessary.

Inspections and Maintenance

Inspect construction site periodically and after rain events to identify areas requiring installation, repair, or replacement of additional BMPs to cover exposed areas or redirect off-site runoff.

Preservation of Existing Vegetation - SM-15

Description - Identification of existing vegetation to remain in order to provide erosion and sediment control

Applications - Preservation of existing vegetation practices can apply to the following areas:
• Where no construction activity is planned or will occur at a later date.
• Where existing vegetation should be preserved such as steep slopes, watercourses, and building sites in wooded areas.
• Natural resources or environmental protection areas requiring preservation by local, provincial, and federal governments such as wetlands and marshes.

Requirements
• Incorporate existing vegetation into final landscaping plans when possible.
• Consider aesthetic and environmental values, and space requirements when determining which vegetation to preserve.
• When preparing the landscaping plans, avoid non-native species.
• Establish setback distances based on vegetation species, location, size, and age. The type of construction activity in the vicinity of the vegetation shall also be considered.
• Vegetation can be protected by the following methods:
- Mark, flag, or fence areas of vegetation to be preserved;
- Designate limits of root system (tree drip line);
- Tree wells and retaining walls which are large enough to protect the root system;
- Limit grading to within 30cm of the tree drip lines, and
- Locate construction traffic routes away from existing vegetation.

• Must comply with applicable Noxious Weed and Grass Control By-Laws.
• Must comply with applicable Nuisance Trees and Shrubs By-Laws.

Challenges
• Requires coordination between the owner/ developer, designer and contractor.
• Limited usefulness if final site design does not incorporate existing vegetation.
• Diverse site topography may result in additional expenses to satisfy vegetation preservation and the grading required for the site improvements.

Inspections and Maintenance
Inspect protective measures and immediately repair or replace damaged protection measures.

Dewatering Operations - SM-16

Description - Practices that prevent or reduce the discharge of pollutants in groundwater (i.e. non-storm water) and accumulated precipitation from areas requiring dewatering activities into the storm system and/or receiving waters.

Applications
• Non-storm water from sources such as groundwater and water used during construction activities.
• Precipitation accumulated within depressed areas on construction sites.

Requirements
• Dewatering discharges may include pollutants such as sediment and/or toxic materials and hydrocarbons.
Hydrocarbon contamination is common in urban environments.
• Sediment Removal requirements include the following:
  o Use a sediment trap to remove sediment from dewatering discharges. Refer to SC-14 (Sediment Trap) and SC-15 (Sediment Basin) in this manual for more information and
  o Apply filtration methods to remove sediment from the sediment trap. These can include:
  - Sump pit should be combined with a perforated/slit standpipe with holes, which is wrapped in geotextile filter fabric. As water collects in the pit, stones placed around the standpipe filter the water, which collects in the pit prior to being pumped out. Due to the wrapped standpipe, an increased suction inlet area may be required to prevent clogging and unacceptable pump operation and
  - Floating suction hose, which allows cleaner surface water to be pumped out.

• Toxic materials and Petroleum Products Removal requirements include the following:
  o Areas of suspected groundwater contamination should be tested by a laboratory for known or suspected pollutants by a specialized environmental consultant.
  o Treatment of contaminated groundwater may be required. Ultimate discharge (post treatment) may be possible to the sanitary sewer system (will require District of West Kelowna approval).
• Must comply with the BC Groundwater Protection Act and associated Regulations

Challenges
Contaminated water may be an indication of contaminated soil. Refer to SM-8 (Contaminated Soil Management) in this manual for more information. The BC Contaminated Sites Regulations prevail over groundwater contamination. A specialized consultant will be required to assess, test and conduct remedial measures for groundwater contamination.

Inspections and Maintenance
• Inspect excavated areas daily for contaminated water indicated by discolouration, oily sheen, or odours.
• Remove and properly dispose of sediment collected in sediment control devices.
• Inspect the dewatering discharge point for erosion daily.

Dust Control - SM-17

Description - Application of control measures (e.g. water, salt,) including erected dust curtains, to minimize erosion due to wind or to reduce the amount of dust generated by construction activities.

Applications - Dust control shall be used on all exposed soils or on any construction activity generating dust. Dust control shall apply to the following:

- Clearing, grubbing, and grading;
- Vehicle travel on unpaved roads;
- Drilling and blasting;
- Sediment tracking onto paved roads;
- Soil and debris stockpiles; and
- Unstable soil areas.

Requirements

- Minimize exposed areas through scheduling of construction activities.
- Utilize vegetation, mulching, water sprinkling, and granular layering to stabilize exposed soils.
- Identify and stabilize primary site entrances/exits prior to starting construction.
- Minimize the amount of dust generated by considering prevailing winds during construction. Erect fencing and dust curtains when applicable;
- Use a minimum of water for dust control purposes.
- Discourage vehicle traffic on unstabilized roadways.

Challenges

- Daily or more frequent applications of water may be necessary during the summer.
- Erosion may result from overwatering.
- Oil shall not be used for dust control.
- Some dust suppression chemicals may cause soil to be water repellent resulting in increased runoff.

Inspections and Maintenance

Observe site conditions during high winds to determine effectiveness of BMPs. In addition, inspect construction site periodically and after rain to identify areas requiring installation, repair, or replacement of additional BMPs to cover bare ground or redirect off-site runoff.

Paving Operations - SM-18

Description - Practices and procedures to prevent or reduce the discharge of pollutants into the storm system or receiving waters from paving, cutting, or grinding activities.

Applications

- Paving equipment storage.
- Asphalt cleaning.
- Removal of existing asphalt or concrete.
- Concrete, asphalt, seal coat, tack coat, or slurry applications.
- Recycling of pavement.

Requirements

- Limit paving operations during wet weather when possible.
- Store materials for paving activities away from drainage courses.
- Use asphalt emulsions as prime coat when possible.
- Place drip pans under paving equipment to contain leaks and spills. Clean up spills with absorbent materials.
- Place geotextile filter fabric over drain inlet structures and manholes during application of tack coat, seal coat, slurry seal, and fog seal.
- Saw cut slurry shall be removed from site by vacuuming. Provide storm drain protection during saw cutting.
- Refer to SM-5 (Concrete Waste Management) in this manual for activities involving Portland cement concrete.
- Adhere to the following when paving involves asphaltic concrete (AC):
    - Properly dispose of old or spilled asphalt. Collect and remove broken asphalt. Recycle asphalt when possible;
    - Excess sand and gravel shall be swept to prevent discharge into the storm drainage system or adjacent water body; and
    - Comply with storm water permitting requirements for industrial activities if paving requires an on-site mixing plant.

- Must comply with applicable Noise Control By-Laws.

Challenges - Restrict paving operations during wet weather to prevent contact between storm water and paving materials.

Inspections and Maintenance

- Ample supplies of drip pans and absorbent materials shall be kept on-site.
- Inspect inlet protection equipment.
- Monitor employees to ensure appropriate paving practices and procedures are being implemented.
- Generally, paving activities stop when rainfall results in a saturated sub-base. Therefore paving activities are generally not susceptible to storm water runoff impacts.

Structure Construction and Painting - SM-19

Description - Practices and procedures to reduce or prevent the discharge of pollutants from structure construction and painting activities into the storm system and/or receiving waters. Potential pollutants can include solvents, paints, paint removers, thinners, hydrocarbons, asphalt and concrete materials, epoxy compounds, adhesive residues, and asbestos insulation. Refer to SM-5 (Concrete Waste Management), SM-6 (Solid Waste Management) and SM-9 (Hazardous Waste Management) for additional information.

Applications - Construction or maintenance activities involving painting or structure repair and construction.

Requirements

- Maintain a clean work site.
- Recycle or reuse products where possible and/or where required
- Use less hazardous products if practical.
- Comply with air quality regulations during painting activities.
- Properly store paints, solvents, and epoxy compounds.
- Properly store and dispose of waste materials generated from painting, structure repair and construction activities.
- Avoid paint drift by enclosing or covering painting operations.
- Use appropriate application equipment to minimize overspray.
- Immediately clean up spills.
- Collect residue from sand blasting or scraping operations and dispose of this residue properly.
- Paint chips containing lead shall be treated as hazardous waste. Refer to the SM-9 (Hazardous Waste Management) in this manual for more information.
- Clean painting equipment in a sink connected to the sanitary sewer system.
- Mix paints in a covered and contained area when possible.
- Comply with applicable laws and regulations for recycle/disposal of residual paints, solvents, and other materials.
- Provide employee training.
- Properly dispose of material from sand blasting activities. Chips and dust from marine paints or paints containing lead shall be considered hazardous waste. Paint chips and dust from nonhazardous dry stripping and sand blasting shall be swept and disposed of as trash.
- Must comply with applicable Noise Control By-Laws.

Challenges

- Availability of recycled or less hazardous products may be limited.
- Hazardous waste which may not be recycled or reused shall be disposed of by a licensed hazardous waste transporter.

Inspections and Maintenance

Materials and equipment for proper storage and disposal practices shall be readily available.

Topsoil Management - SM-20

Description - Reuse of native soils during re-vegetation activities as part of a soil management plan. Salvaging, stockpiling, and reapplication of native topsoil are important to successful re-vegetation efforts particularly for the reestablishment of native vegetation.

Applications

• Reestablishment of areas where vegetation with native plant species is desirable including sensitive habitat areas, floodplains, wetlands, and stream banks.

Requirements

• Conduct a soil survey of the area prior to soil disturbing activities to assess the location, depth, and amount of soils suitable for salvaging.
• Salvage and stockpile suitable topsoil for future use during re-vegetation of the area.
• Refer to SM-4 (Protection of Stockpiles) in this manual when stockpiling salvaged topsoil.
• Where possible, remove vegetation suitable for reuse (e.g. shrubs) and store with the roots appropriately covered
• Cover or stabilize soil stockpiles with temporary measures such as mulch or temporary vegetation.
• Apply topsoil directly to disturbed areas when practicable.
• Soil replacement depths are determined by factors such as soil depth prior to disturbance, type of vegetation, and physical and/or chemical properties of the material to be covered. A deeper soil layer is required for soils with poor physical and chemical properties. Testing (e.g. nutrients, pH, and toxicity factors) of replacement soils to be covered shall be completed prior to reapplication.
• Consideration of the following items is necessary when developing a topsoil management plan:
  o Quality and amount of native topsoil;
  o Area of surface disturbance to which topsoil will be applied and the required depth of application;
  o Methodology for salvaging topsoil;
  o Stockpile location, duration of storage, and required erosion control measures to protect stockpile;
  o Feasibility of direct application of salvaged soils; and
  o Availability of other growth media to supplement topsoil reclamation.
• Contractor should consult District Soil Removal and Deposit Regulation By-Law 2011 No. 0127 prior to moving soil stockpiles >$50m^3$ on or off site. Soil volumes < $50m^3$ are exempt.

Challenges

• Native soil stockpiles may limit the area available for construction activity.
• Runoff from stockpiles may adversely impact water quality.

Inspections and Maintenance

• Regularly inspect stockpiles for erosion and stabilize as necessary.
• Inspect stockpile covers to ensure adequate protection from wind and rain.
• Adequately water plantings until they are established.

Chapter A2 - Erosion Control

Erosion Control (EC) BMPs are devices installed on a construction site that reduce the erosion potential as a result of land disturbing activities. Erosion Control BMPs serve as prevention measures by stabilizing soil. They are the primary measures of reducing the negative impact of construction activities by preventing storm water pollution.

In this chapter:

- Control construction activities;
- Stabilize soil;
- Minimize disturbed area and protect natural vegetations, streams and soil;
- Control storm water flowing onto and through the project;
- Protect slopes.

Construction Road Stabilization - EC-1

Description - Stabilization and maintenance of temporary roads after grading to minimize erosion and dust from construction traffic.

Applications

- Access roads.
- Subdivision roads.
- Parking areas.
- Areas where mud tracking may be a problem during wet weather.
- Areas where dust may be a problem during dry weather.
- Areas adjacent to receiving waters.
- Along steep grades or areas where additional traction is necessary.

Requirements

- Roadway to be graded to follow topographic contours where possible in order to reduce erosion.
- Roadway grade should not exceed 15 percent.
- Gravel roads should be a minimum of 100mm thick. The base should consist of 50mm to 75mm coarse aggregate and should be applied immediately after grading.
- Remove or convert to permanent roadway upon completion of construction.

Challenges

- Whenever possible avoid chemicals stabilization methods which may contribute to soil pollution.
- In some cases, construction traffic may be subject to air quality control measures.

Inspections and Maintenance

- Properly maintain all BMP features. Inspect, and make repairs to BMP measures as needed or at the following intervals:
    - Inspect weekly during dry periods.
    - Within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour periods.
    - Daily during periods of prolonged rainfall.
    - When existing erosion control measures are damaged or not operating properly as required by site specific BMP.

      • Add additional aggregate on gravel roads as required.

      • During the dry periods, active dirt construction roads shall be watered three or more times per day.

Stabilized Construction Entrance and Exit - EC-2

Description - Stabilized construction entrances/exits are designated areas for entry to or exit from a construction site and are designed to reduce the amount of sediment tracked off-site by construction vehicles.

Applications - Stabilized construction entrances/exits shall be used where access is from a paved surface.

Requirements

- Construct stabilized entrance/exit on level ground where possible.
- Grade the stabilized entrance/exit to prevent runoff from discharging off-site or direct runoff to a sediment trap or basin prior to discharge.
- Provide ample vehicle turning radii.
- Crushed aggregate should be free of fine material and should be 75mm to 150mm in size. The use of crushed asphalt concrete (AC) is not allowed.
- Depth of aggregate shall be 300mm thick underlain by a geotextile or as recommended by the geotechnical engineer. Contractor is responsible to design stabilized construction entrances/exit to support heaviest vehicles and equipment that will use it.
- Dimensions shall be a minimum of 20m L x 10m W. If project site layout will not accommodate minimum dimensions identify additional BMPs to minimize tire tracking.

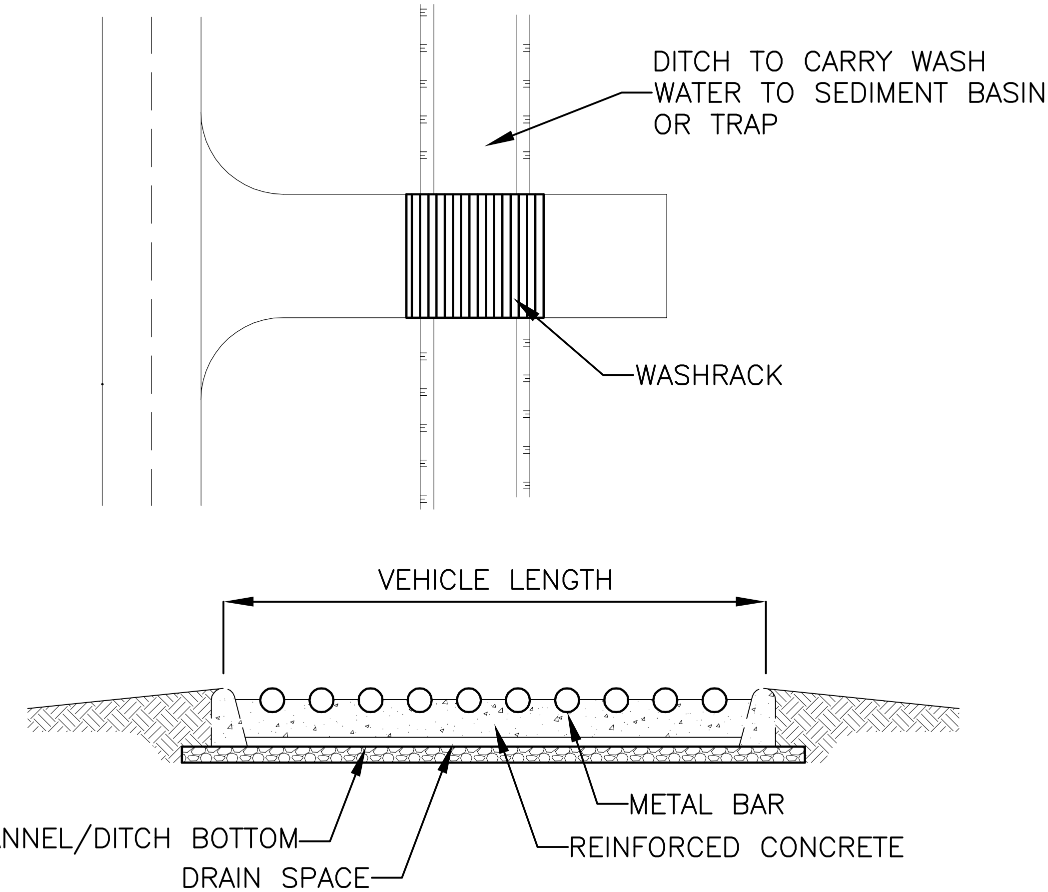
Challenges

- Surface aggregate will need to be periodically replenished.
- A sediment trapping device will be required if a wash rack is used.
- If sediment is being tracked onto the pavement, then street sweeping will be required. If possible increasing the dimensions of the entrance, or the installation of a wheel wash should be considered. The pavement shall not be cleaned by washing down the street, except when permitted. If it is necessary to wash the streets, the construction of a small sump shall be considered. The sediment would then be washed into the sump where it can be controlled. Use BMPs for adjacent drainage structures.

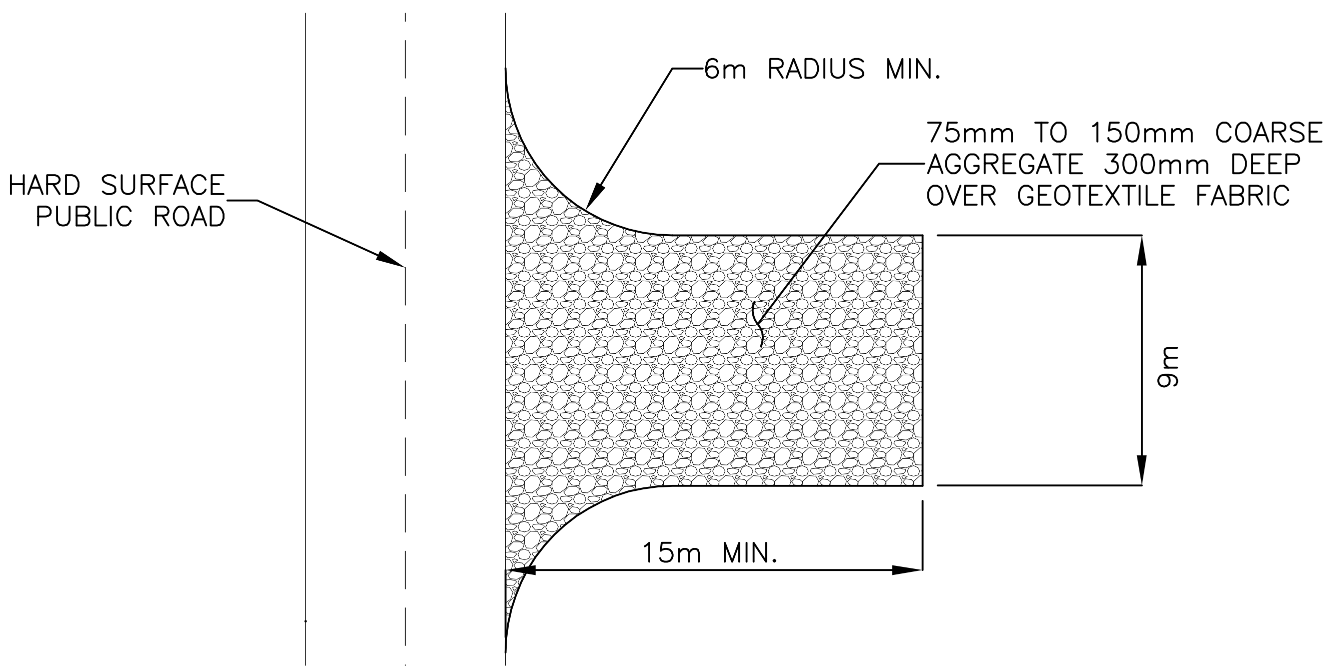
Inspections and Maintenance

- Inspect construction entrance/exit weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall for damage.
- Remove deposited sediment from adjacent roadways or paved areas within 24 hours.
- Replenish surface aggregate as required.
- Upon project completion, all construction entrances/exits shall be removed by the contractor and restore the area to the condition approved by the Owner.

See Figure EC-2



WASH RACK (SCHEMATIC)



STABILIZED CONSTRUCTION ENTRANCE

N.T.S.

STABILIZED CONSTRUCTION ENTRANCE/EXIT

EC-2

Flared Culvert End Sections - EC-3

Description – A flared culvert end section is a device placed at the inlet or outlet of pipes and channels to enhance hydraulic operation while minimizing scour and erosion.

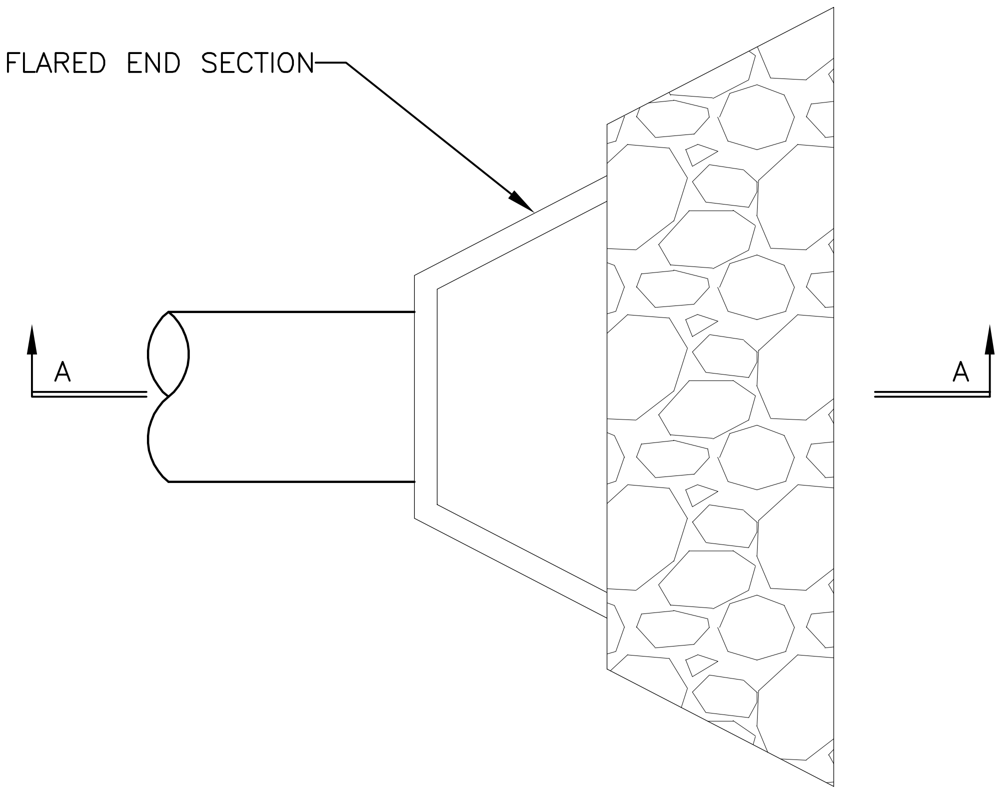
Applications - Flared culvert end sections can be placed at inlets and outlets of slope drains and culverts.

Requirements
• Supplement with other outlet protection.
• Construct on level ground where possible.
• Protect the transition to the flared end section at inlets to prevent scouring.
• Obtain guidance from the District Engineer

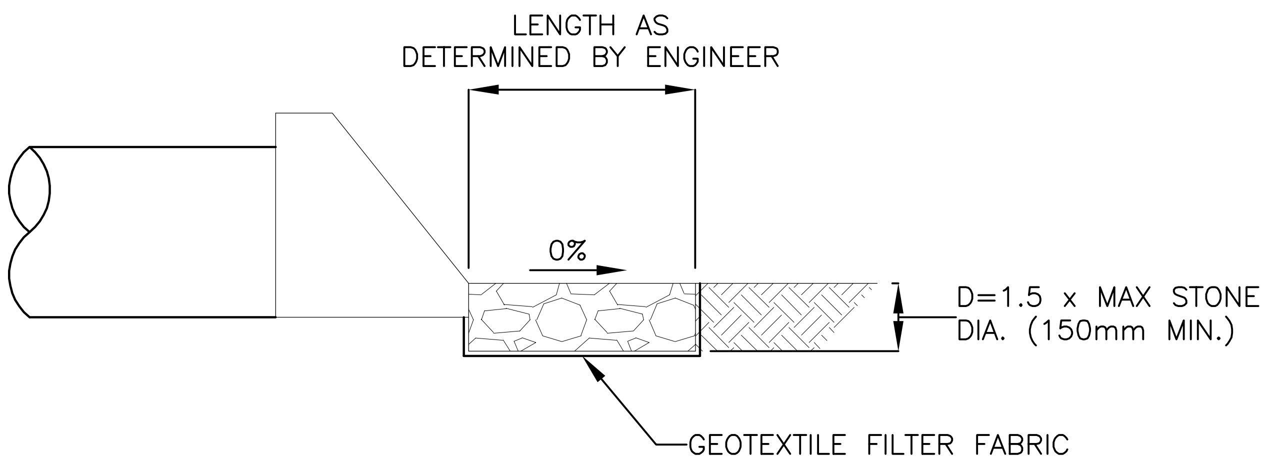
Challenges
Limited use as an erosion control measure since primarily used to increase hydraulic efficiency.

Inspections and Maintenance
• Routine inspections required.
• Monitor accumulation of debris and sediment and remove as required
• Inspect end sections for scour and repair as required.

See Figure EC-3



PLAN



SECTION A–A

N.T.S.

FLARED CULVERT END SECTION	EC–3

Seeding and Planting - EC-4

Description - Seeding and planting of vegetation (e.g. trees, vines, shrubs, grasses) for temporary or permanent stabilization of soil.

Applications
Soil stabilization during or after the construction applies to the following:
• Graded/cleared areas without on-going construction activity;
• Open space and fill areas;
• Steep slopes;
• Stockpile of material;
• Vegetated swales;
• Landscape corridors; and
• Stream banks (outside riparian zone).

Requirements
Requirements for each seeding/planting application shall be considered and include:
• Type of vegetation;
• Site preparation;
• Seasonal planting times;
• Fertilization; and
• Watering requirements.
• Must comply with applicable Noxious Weed and Grass Control By-Laws.

Grasses
• Ground preparation may require fertilization and stabilization of the soil.
• Short-term temperature extremes and waterlogged soil conditions are tolerable.
• Appropriate soil conditions include a shallow soil base, good drainage, and 2:1 or flatter slope.
• Vigorous grass growth dependent on mowing, irrigating, and fertilizing.

Trees and Shrubs
• Selection dependent on vigor, species, size, shape, and potential wildlife food source.
• Consider wind/exposure and irrigation requirements.
• Use indigenous species where possible.

Vines and Ground Cover
• Lime and fertilizer required for ground preparation.
• Use appropriate seeding rates.
• Consider requirements for drainage, acidity, and ground slope.
• Use indigenous species where possible.
• Avoid species which require irrigation.

Challenges
• During dry periods without irrigation, permanent and temporary vegetation may not be appropriate.
• Improper application of fertilizer may contribute to storm water pollution.

Inspections and Maintenance
Monitor vegetation growth and water, fertilize, mow, and/or prune the grasses/plants as needed.

Mulching - EC-5

Description – Mulching involves the application of loose bulky materials to stabilize disturbed or bare soils, increasing infiltration, and reducing runoff. Materials used for mulching can include green materials, vegetable fibres (hay or straw), wood/bark chips, hydraulic mulches of shredded paper or wood fibre, and hydraulic matrices.

Applications
• Temporary ground cover on exposed soil until permanent vegetation has been established.
• Depending on the method used, can act to enhance plant growth.
• Can help maintain soil moisture.

Requirements

GREEN MATERIAL
• Consists of vegetation trimmings such as grass and shredded shrubs and trees applied by hand.
• Acts as temporary ground cover with or without seeding.
• Material should be evenly distributed on soil surface, with depth shall not exceed 100mm.
• Anchor with a tackifier or netting on steep slopes or for areas with anticipated overland sheet flow. Matting could also be considered rather than mulch on steep slopes.

VEGETABLE FIBRES (HAY OR STRAW)
• Loose hay or straw which may be used in combination with seeding. Mulching usually follows seeding and the process is described in the following:
  o Apply seed and fertilizer to bare soil;
  o Apply loose hay or straw over top of seed and fertilizer prior to seed germination. Apply at a rate of approximately 500 kg / Ha by machine or hand distribution;
  o Evenly distribute mulch on the soil surface to cover the ground (80% to 90%);
  o Maintain maximum fibre length. Average fibre length shall be greater than 150mm;
  o Use a tackifier, netting, or mechanical “punching” method to anchor mulch. Method depends on slope steepness, accessibility, soil conditions, and longevity; and
  o “Punching” straw or hay into soil is the preferred method of anchoring mulch for the following conditions:
  - Use a spade or shovel on small areas,
  - Use a knife-blade roller or straight bladed coulter (“crimper”) on slopes with soil, which can support construction equipment without undesirable compaction or instability,
  - Use plastic netting or jute on small areas and/or steep slopes. Geotextile pins, wooden stakes, or 11 gauge wire staples shall secure netting in place. This condition warrants consideration of the use of matting rather than mulch, and
  - Use tackifiers on steep slopes unable to support construction equipment or large application areas where use of nettings, straw, or hay is not cost-effective. Tackifiers glue vegetable fibres together and to the soil surface until the establishment of permanent vegetation.

WOOD/BARK CHIPS
• Suitable for areas such as around trees, shrubs, and landscape plantings which will not be mowed.
• Prior to application, add a minimum of 5 kg of nitrogen per 1,000 kg of mulch to counteract the effect of decomposing wood-based materials, which extract nitrogen from soil. Use a balanced, slow-release fertilizer or an organic source such as compost.

• Evenly distribute wood/bark chips on soil surface by hand and maintain a mulch depth of 50mm to tree basins and 100mm to shrub beds.

HYDRAULIC MULCHES OF RECYCLED PAPER

• Consists of recycled paper sources.
• May be applied with or without tackifiers.
• Mix mulch in a hydraulic application machine (hydroseeder) and apply as a liquid slurry.
• May be sprayed from a cannon up to 50m or from a hose up to 500m away from the application area.
• Mix mulch with seed and fertilizer as specified by the manufacturer. Apply mulch at the manufacturer's recommended rate to ensure uniform, effective coverage.

HYDRAULIC MULCHES OF WOOD FIBRE

• Consists of wood waste.
• May be manufactured with or without a tackifier.
• Hydraulic mulch should comply with the following requirements:
    o 100% wood fibre;
    o Maximum moisture content (total weight basis) shall not exceed 12% ±3%;
    o Minimum organic matter content (oven dry weight basis) of 99.3%;
    o Maximum inorganic matter (ash) content (oven dried basis) of 0.7%;
    o pH of 4.9±10% for a 3% water slurry; and
    o Minimum water holding capacity (oven dried basis) of 10 L / kg of fibre.
• Mix mulch in a hydraulic application machine (hydroseeder) and apply as a liquid slurry.
• Mix mulch with seed and fertilizer as specified by the manufacturer and apply at the manufacturer's recommended rate.

HYDRAULIC MATRICES

• Hydraulic slurries consisting of wood or paper fibres, or a combination of wood and paper fibre mixed with a binder system.
• Can exceed erosion control performance of blankets due to close contact with soil.
• Applied as an aqueous slurry (with seed) using standard hydroseeding equipment.
• Applications rates vary for different combinations of conditions and products.
• A typical mixture based on one Ha of treated area includes the following:
    o 550 kg of wood fibre mulch;
    o 1,100 kg of recycled paper mulch; and
    o 520 L of acrylic copolymer with a minimum solids content of 55%.
• Bonded Fibre Matrix (BFM) consists of premixed fibre and binders.
    o After application and upon drying, BFM shall adhere to soil and form a 100% cover. The cover shall be biodegradable, promote vegetation, and prevent soil erosion.
    o Composed of long strand, thermally produced wood fibres (>88% of total volume by weight), held together by organic tackifiers (10%) and mineral bonding agents (<2%), which become insoluble and non-dispersible upon drying. Composition of BFM varies based on supplier.
    o Perform a free liquid quality control test on the liquid slurry.
    o Binder shall not dissolve or disperse upon watering.
    o Upon application to the soil, holes in the matrix shall not exceed 1mm in size.
    o There shall not be any gaps between the matrix and the soil.
    o Minimum water holding capacity of the matrix shall be 10L / kg matrix.
    o The matrix shall be free of germination or growth inhibiting factors and shall not form a water resistant crust.
    o Materials used for the matrix shall be both biodegradable and beneficial to plant growth.

o Testing and evaluation of the matrix by an independent research laboratory shall have been conducted to verify reported erosion control performance.

o A trained and manufacturer certified applicator with knowledge of proper mixing and product application shall install the BFM.

o Typical BFM application rates range from 3,400 to 9,000 kg / Ha per recommendations from various manufacturers.

o BFM shall not be applied immediately before, during, or after a rainfall event to ensure a drying time of 24 hours after installation.

• Mulch used as temporary ground cover shall be reapplied as needed until permanent vegetation has been established.
• Avoid spraying mulch onto sidewalk, lined drainage channels, travelways, and existing vegetation.

Challenges

GREEN MATERIAL
• Limited commercial availability.
• Variable quality.
• Weeds or undesirable plant material may be introduced to the mulched area.
• Application primarily uses manual labour.
• Unpredictable effectiveness as an erosion control measure. Requires overspray with a tackifying agent to increase effectiveness.
• Application of fertilizer may be required.
• Limit use to non-critical steep slopes and areas where alternative erosion control measures may be readily applied.

VEGETABLE FIBRES (HAY OR STRAW)
• Require three-step machinery.
• Labour intensive installation.
• Weed seeds and undesirable plant material may be introduced to sensitive areas.
• For applications using straw blowers, the applicable area must be located adjacent to a road or surface capable of supporting loads from large vehicles. If both hay and straw are available, it is preferable to use straw.

WOOD/BARK CHIPS
• Poor erosion control effectiveness.
• Anchoring of chips onto steep slopes is difficult due to potential movement from high winds.
• Subject to displacement from storm water runoff.
• Use of a fertilizer with high nitrogen content is required to prevent nutrient deficiency in plants due to decomposing woodbased materials. Improper fertilizer use may contribute to water quality pollution.
• Limit use to non-critical steep slopes and areas where alternative erosion control measures may be readily applied.

HYDRAULIC MULCHES OF RECYCLED PAPER
• Limited erosion control effectiveness due to short fibre length and absence of a tackifier.
• Limited moisture and soil temperature moderation.
• Residual chemicals within mulches may be undesirable in environmentally sensitive areas.
• Significant decrease in longevity compared with wood fibre mulch.
• Produce is impacted due price changes for recycled paper products.

HYDRAULIC MULCHES OF WOOD FIBRE

• Limited erosion control effectiveness.
• Short-term use of one growing season.

HYDRAULIC MATRICES

• Avoid application of mulch immediately before, during, or after a rainfall event.
• Requires drying time of 24 hours.

Inspections and Maintenance

• Mulches applied to seeded areas may be disturbed due to wind or runoff. Recover exposed areas until permanent vegetation has been established.
• Mulches applied to areas, which will be re-graded and re-vegetated, should be inspected weekly.
• Replace ornamental and landscape mulches of bark or wood chips if soil is visible in more than 75% of the designated area.

Geotextiles and Mats - EC-6

Description - Natural or synthetic mats to be used for temporary or permanent soil stabilization.

Applications
• Drainage ditches, channels, stream banks and steep slopes.

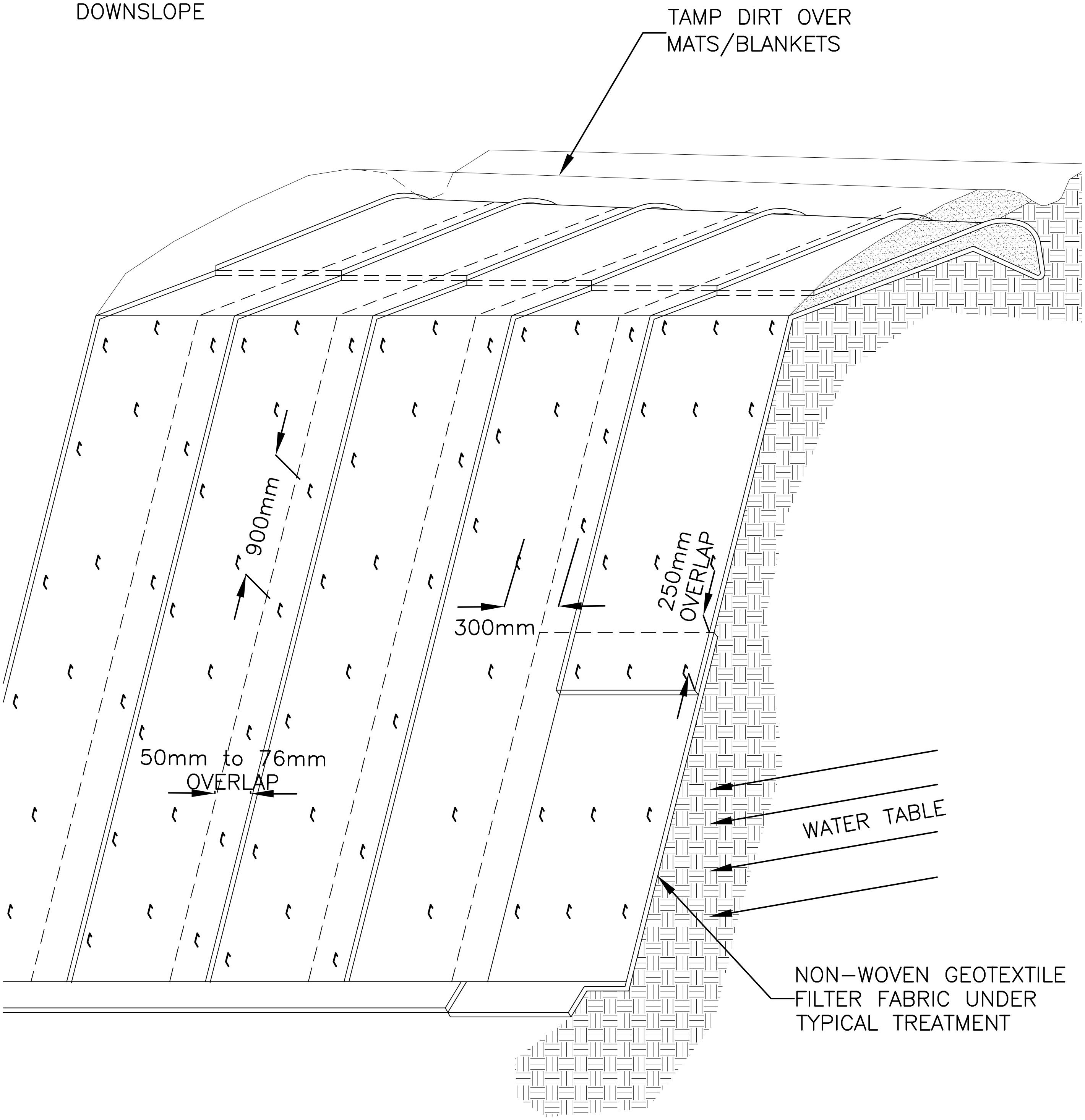
Requirements
• Apply geotextile/matting to disturbed soils and/or areas where vegetation has been removed.
• Organic matting provides can provide temporary protection until: permanent vegetation has been established, optimal weather conditions occur, or construction delays are resolved.
Organic matting materials can include jute matting or straw matting.
• Synthetic matting can provide temporary or post-construction soil stabilization in both vegetated and non-vegetated areas. Synthetic matting materials include the following:
  o Glass fibre matting;
  o Staples; and
  o Mulch netting.
• Other proprietary products may be used and shall be installed per manufacturer's recommendations.

Challenges
• Minimize use of matting to areas where other erosion control measures are not applicable such as channels or steep slopes since matting is more costly compared to other erosion control measures.
• Seed germination may be delayed due to decreased soil temperature.
• An experienced is required during installation.

Inspections and Maintenance
Periodically inspect matting after installation.

See Figure EC-6

MATS/BLANKETS SHOULD BE INSTALLED VERTICALLY DOWNSLOPE



WET SLOPE LINING

N.T.S.

GEOTEXTILES AND MATS INSTALLATION DETAIL	EC-6

Run-on Diversion - EC-7

Description – A drainage structure to intercept, divert, and convey off-site surface runoff around or away from the project site to prevent site erosion. Storm water entering the site (run-on) diversion structures include dikes, swales, and slope drains.

Applications

• Parallel to paved surfaces to intercept runoff.

• Upslope from a project site to prevent erosion of disturbed areas on-site.

• Downslope of project site to convey runoff to a sediment control device such as a sediment trap or basin.

• Located around material storage areas, maintenance and fueling areas, or areas with runoff containing contaminants or pollutants.

• Below steep grades to intercept concentrated runoff.

• Located around adjacent property and buildings, diversion devices can provide protection from storm water runoff.

Requirements

• Size diversion devices appropriately.

• Immediately stabilize earth dikes and swales. Refer to SC-6 (Earth Dike) and SC-7 (Temporary Drains and Swales) in this manual for more information.

• Refer to SC-10 (Slope Drains and Subsurface Drains) in this manual for more information.

Challenges

• Sediment is not removed from runoff.

• Ditches and swales may require check dams or lining to prevent erosion.

• Inspect weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall.

• Inspect channels embankments, and ditch beds for erosion, washout, and accumulated sediment and debris.

• Remove accumulated sediment and debris and repair damages as necessary.

Slope Roughening, Terracing, and Rounding - EC-8

Description – Slope roughening, terracing and rounding are methods of slope grading which can reduce potential erosion by decreasing runoff velocities, trapping sediment, shortening slope length, and increasing infiltration into the soil.

Applications

• Areas where seeding, planting, and mulching erosion control measures may be enhanced by roughening of the soil surface.
• Graded areas with smooth, hard surfaces.
• Areas requiring terracing to shorten the slope length.

Requirements

CUT SLOPE ROUGHENING

• Cut slopes steeper than 3:1 (H:V) should use stair-step grading or furrows.
• Use stair-step grading on soft soils that may be ripped by a bulldozer. Stair-step grading is particularly suitable for slopes consisting of soft rock with some subsoil.
• The vertical cut distance shall be less than the horizontal distance. The "step" shall drain towards the slope.
• Avoid individual vertical cuts greater than 600mm high in soft materials or greater than 900mm high in rocky materials.
• Create ridges and depressions along the slope contours using machinery.

FILL SLOPE ROUGHENING

• Fill slopes steeper than 3:1 (H:V) shall be placed in lifts not exceeding 230mm. Each lift shall be properly compacted.
• Slope faces shall consist of 100 to 150mm of loose and un-compacted soil.
• Grooving or tracking shall be used to roughen slope faces as necessary.
• Apply seed, fertilizer, and mulch. Track or punch in the mulch. Refer to EC-6 (Mulching) and EC-5 (Seeding and Planting) in this manual for additional information.
• The final slope face shall not be bladed or scraped.

CUTS, FILLS, AND GRADED AREAS

• Slopes that will be maintained by mowing shall be no steeper than 3:1 (H:V).
• Create shallow grooves by normal tilling, disking, harrowing, or use of a cultivator-seeder. Final pass of tillage shall be along the contour. Spacing between grooves shall be 250mm or less. Groove depth shall be a minimum of 25mm.

ROUGHENING WITH TRACKED MACHINERY

• Roughening with tracked machinery is only applicable to sandy soils. Other types of soil may be over-compacted by tracked machinery.
• Leave horizontal depressions in the soil by operating tracked machinery up and down the slope. During the final grading operation, do not back blade.
• Roughened areas shall be seeded and mulched for optimum seed germination and growth.

TERRACING

• Slope grades of 5:1 (H:V) shall include terraces or benches when slope heights exceed 9m. Steeper slope or highly erosive soil conditions may warrant terraces or benches for slope heights of 4.5m or higher.

• Runoff collected along terraces and benches shall be routed to lined diversion ditches. Install lined diversion ditches at the intersection of the terrace and slope.

ROUNDING

• All slopes shall be rounded with no sharp breaks in plan or profile.

Challenges

• Since terracing is permanent, design and approval shall be under the direction of a qualified soils engineer.

• Design of terraces shall provide adequate drainage and stabilized outlets.

• Roughening may result in increased grading costs and sloughing in soil.

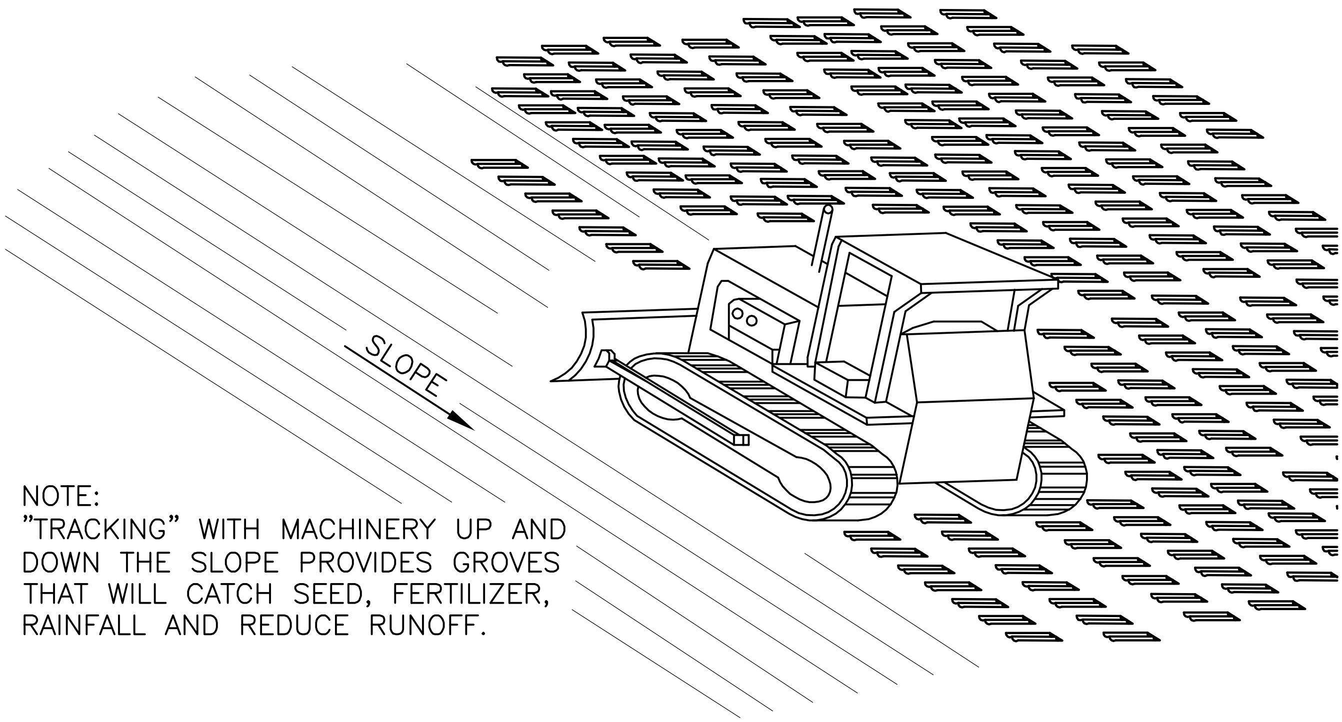
• Stair-step grading may not be applicable to sandy, steep, or shallow soils.

• During intense rainfall events, roughening may not be an effective temporary erosion control measure.

Inspections and Maintenance

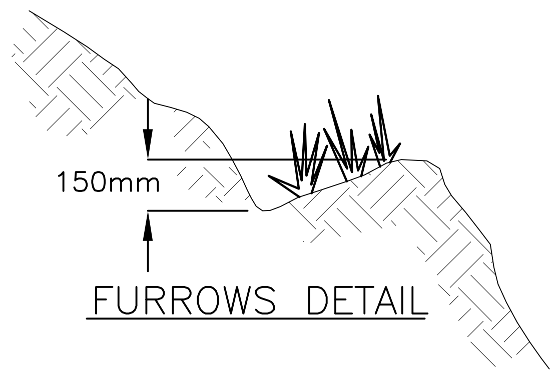
Inspect seeded and planted slopes for rills and gullies weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall.

See Figures EC-8-1, EC-8-2 and EC-8-3.

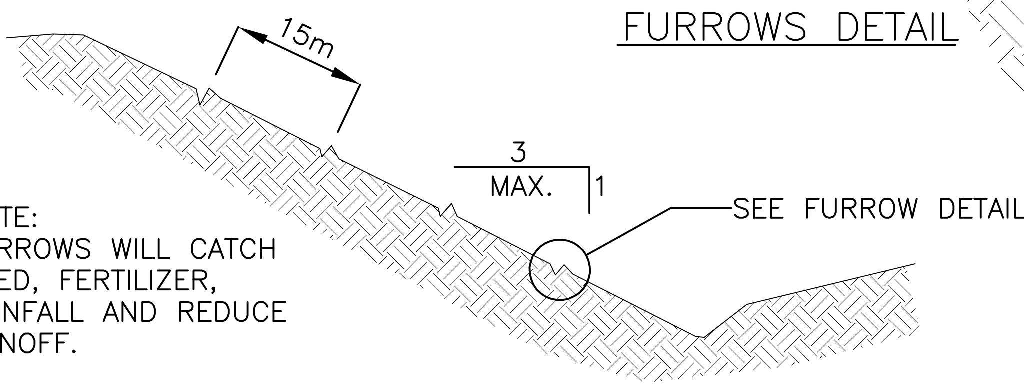


NOTE:
"TRACKING" WITH MACHINERY UP AND DOWN THE SLOPE PROVIDES GROVES THAT WILL CATCH SEED, FERTILIZER, RAINFALL AND REDUCE RUNOFF.

TRACKING



FURROWS DETAIL

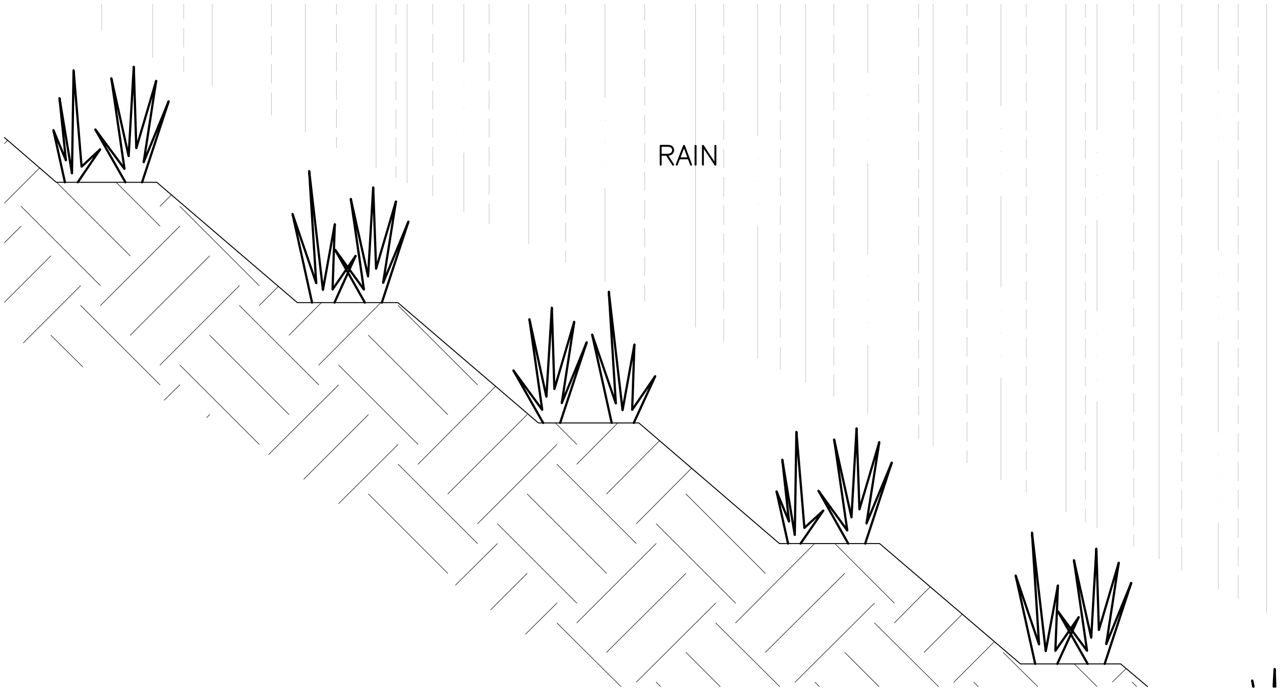


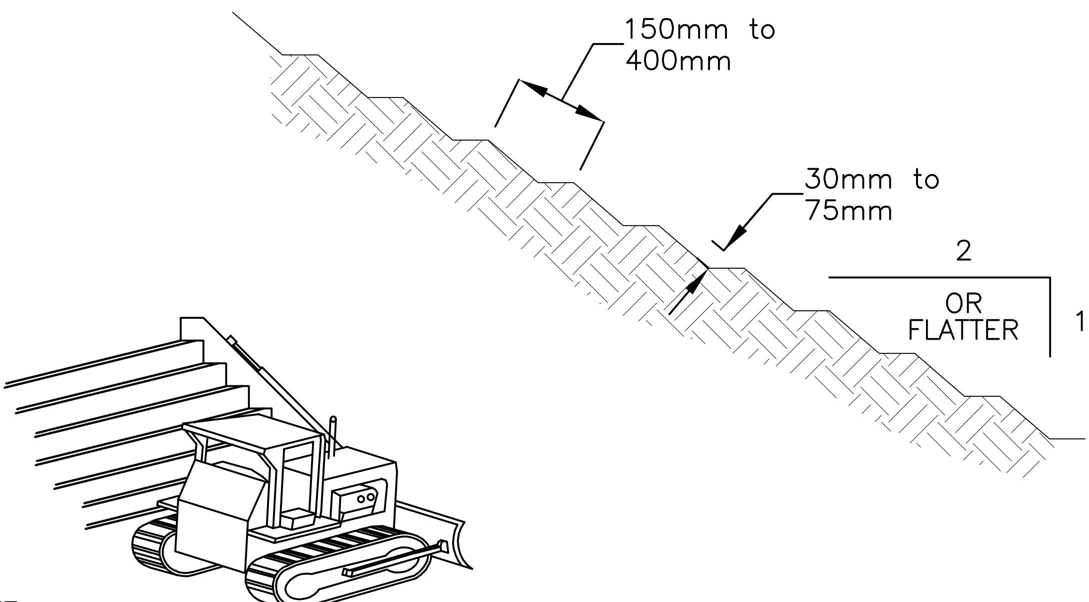
NOTE:
FURROWS WILL CATCH SEED, FERTILIZER, RAINFALL AND REDUCE RUNOFF.

CONTOUR FURROWS

N.T.S.

SLOPE ROUGHENING TERRACING & ROUNDING	EC-8-1



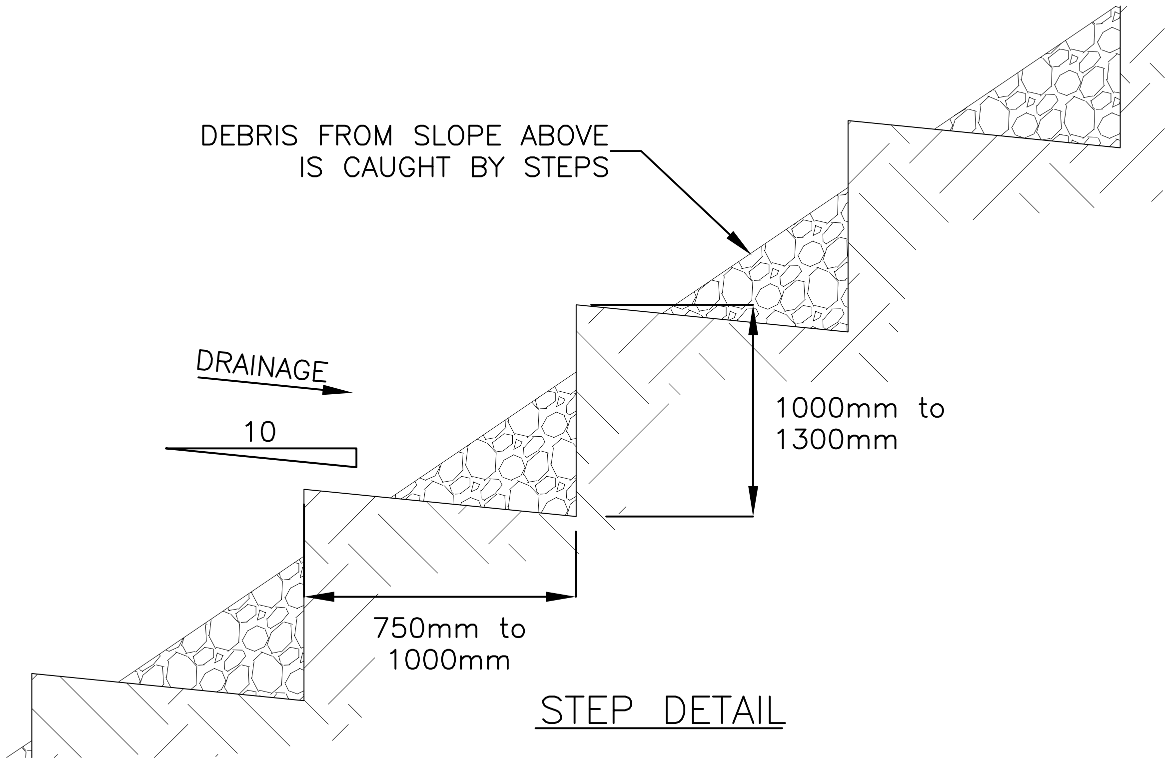


NOTE:
GROOVE BY CUTTING SERRATIONS ALONG CONTOUR. IRREGULARITIES IN THE SOIL SURFACE CATCH RAINWATER SEEDS MULCH AND FERTILIZER.

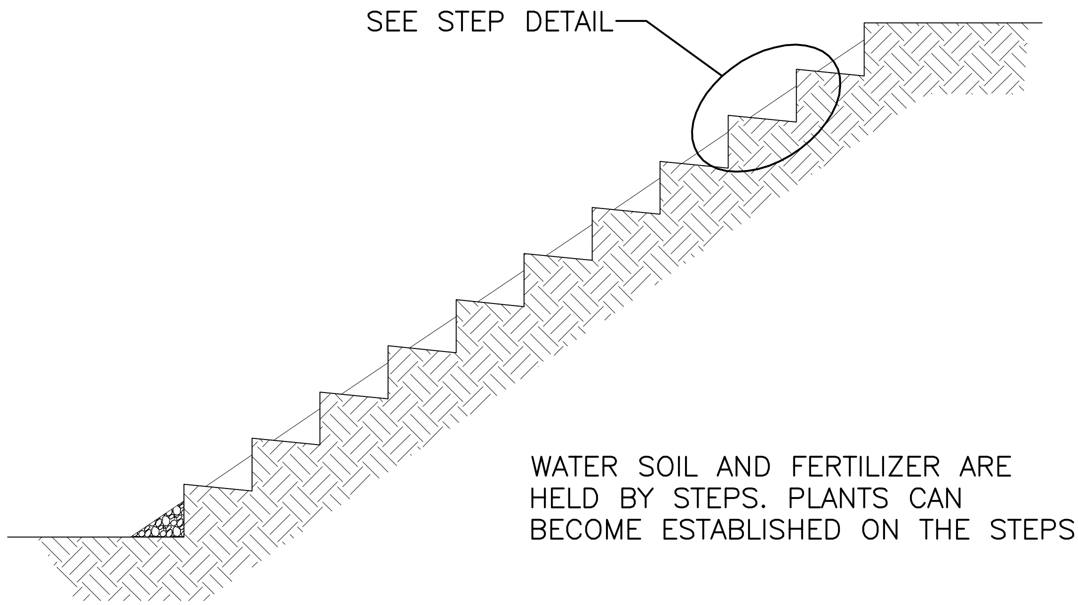
SERRATED SLOPE

N.T.S.

SLOPE ROUGHENING TERRACING & ROUNDING	EC-8-2



STEP DETAIL



N.T.S.

STAIR STEPPING CUT SLOPES

EC–8–3

Chapter A3 - Sediment Control

Sediment Control (SC) BMPs are controls implemented for a construction site that limit the amount of sediment from being transported and deposited off-site. Sediment control BMPs are used to detain sediment-laden storm water runoff on-site and promote infiltration and/or sedimentation. Sediment Control BMPs therefore serve as treatment measures by providing a second line of defense.

In this chapter the following controls are described:

- Retention of sediment on-site;
- Protection of storm drain inlets;
- Establishment of perimeter controls;
- Control of dewatering practices.

Silt Fence or Filter Fabric Fence - SC-1

Description – A silt fence or filter fabric fence is a sediment barrier composed of permeable geotextile filter fabric attached to supporting posts. Wire fencing may be required to provide additional support. The silt fence intercepts the flow of sediment laden runoff, and traps the sediment on the upstream side of the fence.

Applications

A silt fence or filter fabric fence can be used in the following locations:

- Along site perimeters.
- Around temporary stockpiles.
- Along streams and channels.
- Below the toe of cleared or erodible slopes.
- Downslope of exposed soil areas.

Requirements

- Install silt fence along or parallel to contours where sheet flow occurs.
- Ends of silt fence shall be turned uphill and the geotextiles should be overlapped.
- Silt fence posts shall be driven at least 350mm into the trench (see silt fence detail) and the geotextile filter fabric shall be embedded a minimum of 150mm vertically into the ground or according to manufacturer's recommendation.

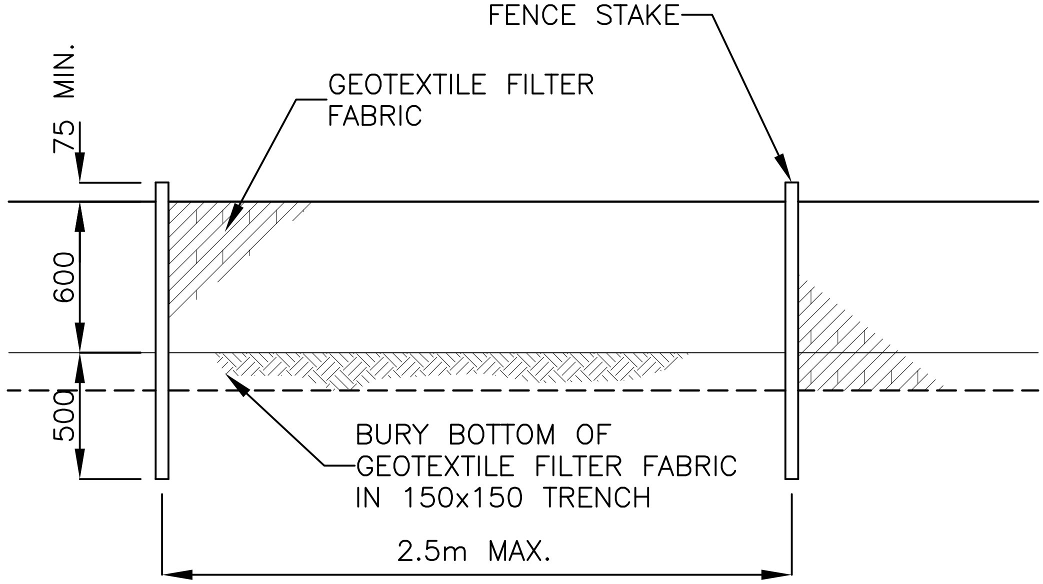
Challenges

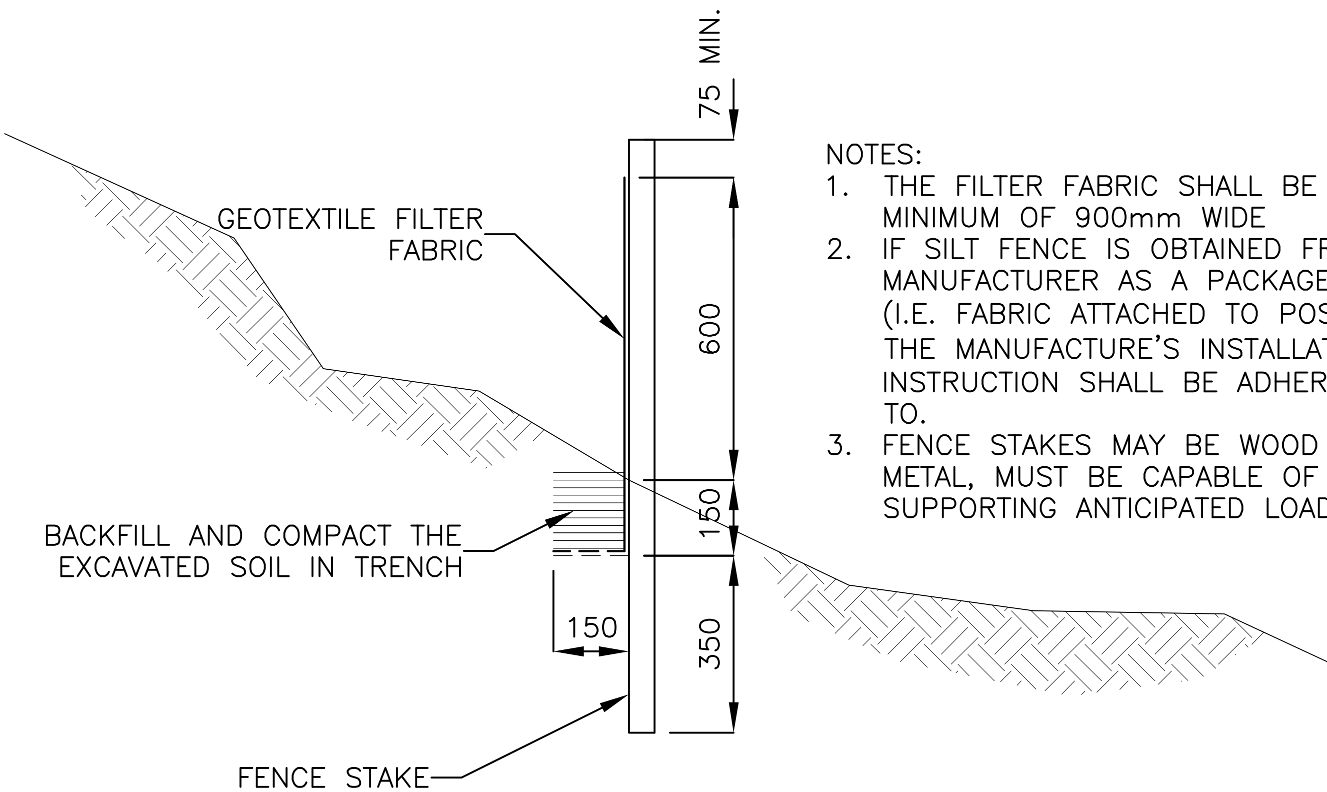
- If silt fence is placed on slope, fence posts may need to be driven deeper.
- Should not be installed in streams, channels, or areas of storm runoff.
- Cannot be used to divert flow.

Inspections and Maintenance

- Inspect weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall.
- Repair or replace damaged fence or posts.
- Remove accumulated sediment when depth reaches approximately 1/3 of the barrier height.

See Figure SC-1





NOTES:
1. THE FILTER FABRIC SHALL BE A MINIMUM OF 900mm WIDE
2. IF SILT FENCE IS OBTAINED FROM MANUFACTURER AS A PACKAGE (I.E. FABRIC ATTACHED TO POST) THE MANUFACTURE'S INSTALLATION INSTRUCTION SHALL BE ADHERED TO.
3. FENCE STAKES MAY BE WOOD OR METAL, MUST BE CAPABLE OF SUPPORTING ANTICIPATED LOADS.

N.T.S.

SILT FENCE	SC–1

Storm Drain Inlet Protection - SC-2

Description - Devices installed at storm drain inlets to detain and/or filter sediment-laden runoff and prevent sediment from entering into the storm drain system.

Applications - Every storm drain inlet that may intercept sediment-laden runoff shall be covered or protected.

Requirements

- Five types of common inlet protection are described below.
  - o Geotextile Filter Fabric Fence: Applicable to drainage basins less than 0.5 Ha and with less than a 5% slope.
  - o Block and Stone Filter: Applicable to flows exceeding 15 L/s.
  - o Stone and Wire Mesh Filter: Applicable for curb or drop inlets subjected to traffic from construction equipment.
  - o Sandbag Barrier: Applicable to sloped, paved streets; creates a small sediment trap upstream of inlets.
  - o Excavated Drop Inlet Sediment Trap: Applicable to areas requiring overflow capability due to expected high flows; an excavated area around the inlet which detains runoff and allows sediment to settle.
- In addition to the methods of inlet protection described above, there are other proprietary devices which can be considered.
- Limit to drainage areas less than 0.5 ha, unless a sediment trap intercepts the runoff prior to the inlet protection device.
- Provide an area for water to pond around inlet without flooding nearby structures and property.

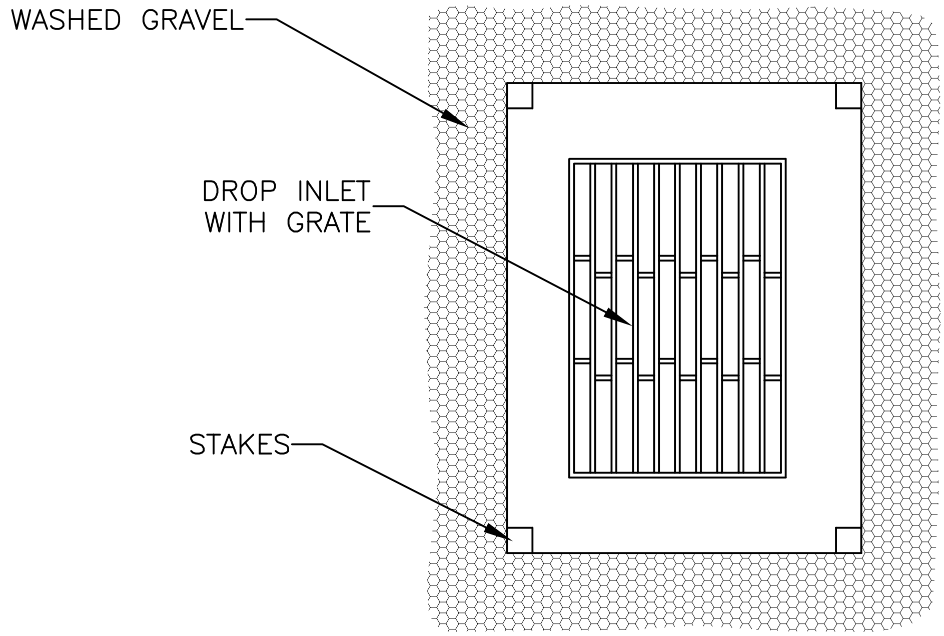
Challenges

- Short-term flooding at a protected inlet can occur.
- Drainage area should be limited to 0.5 ha or less.
- Straw bales should not be used for inlet protection.
- Runoff on slopes may bypass protected inlets

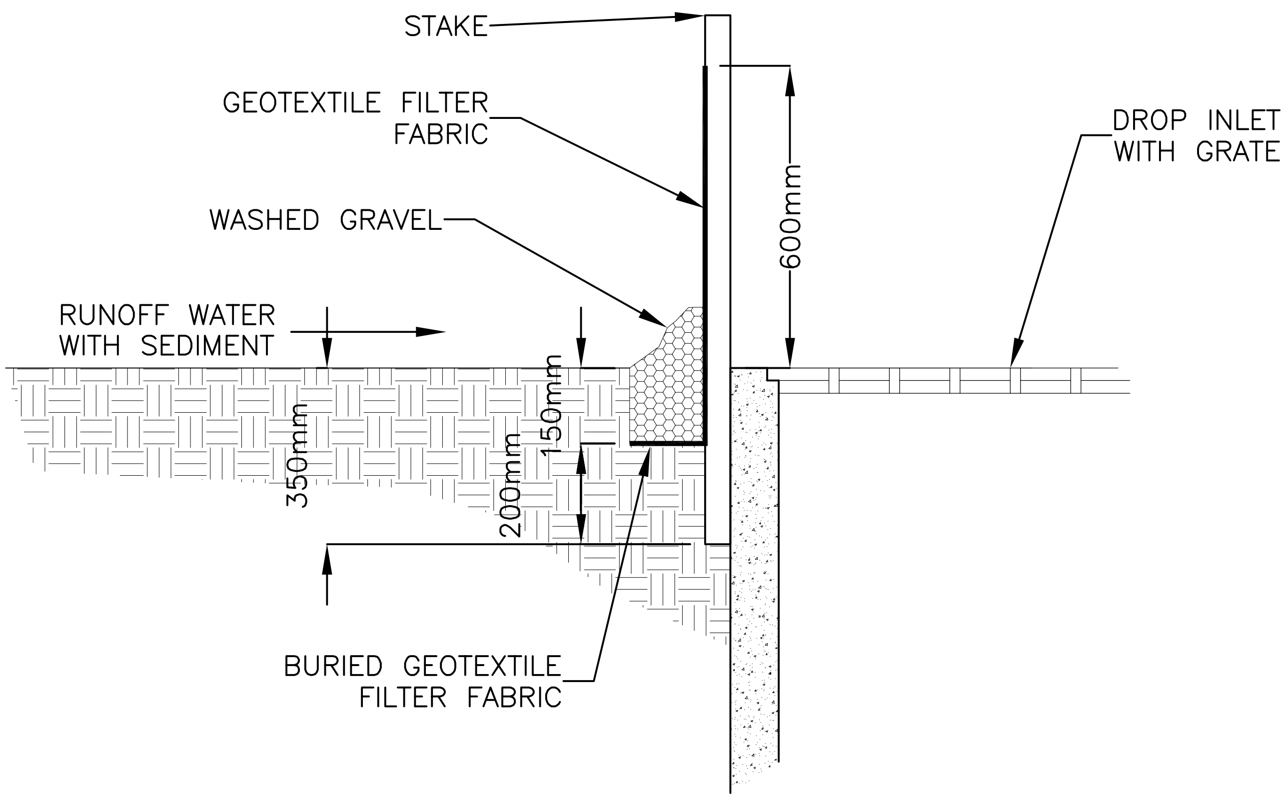
Inspections and Maintenance

- Inspect weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall.
- Immediately replace clogged geotextile filter fabric or stone filters.
- Remove accumulated sediment when depth reaches half of the filter height or half of the sediment trap depth.
- Remove inlet protection after stabilization of upstream soils and sweeping of streets is completed. Properly dispose of trapped sediment.

See Figures SC-2-1,2-2, 2-3, 2-4, 2-5.



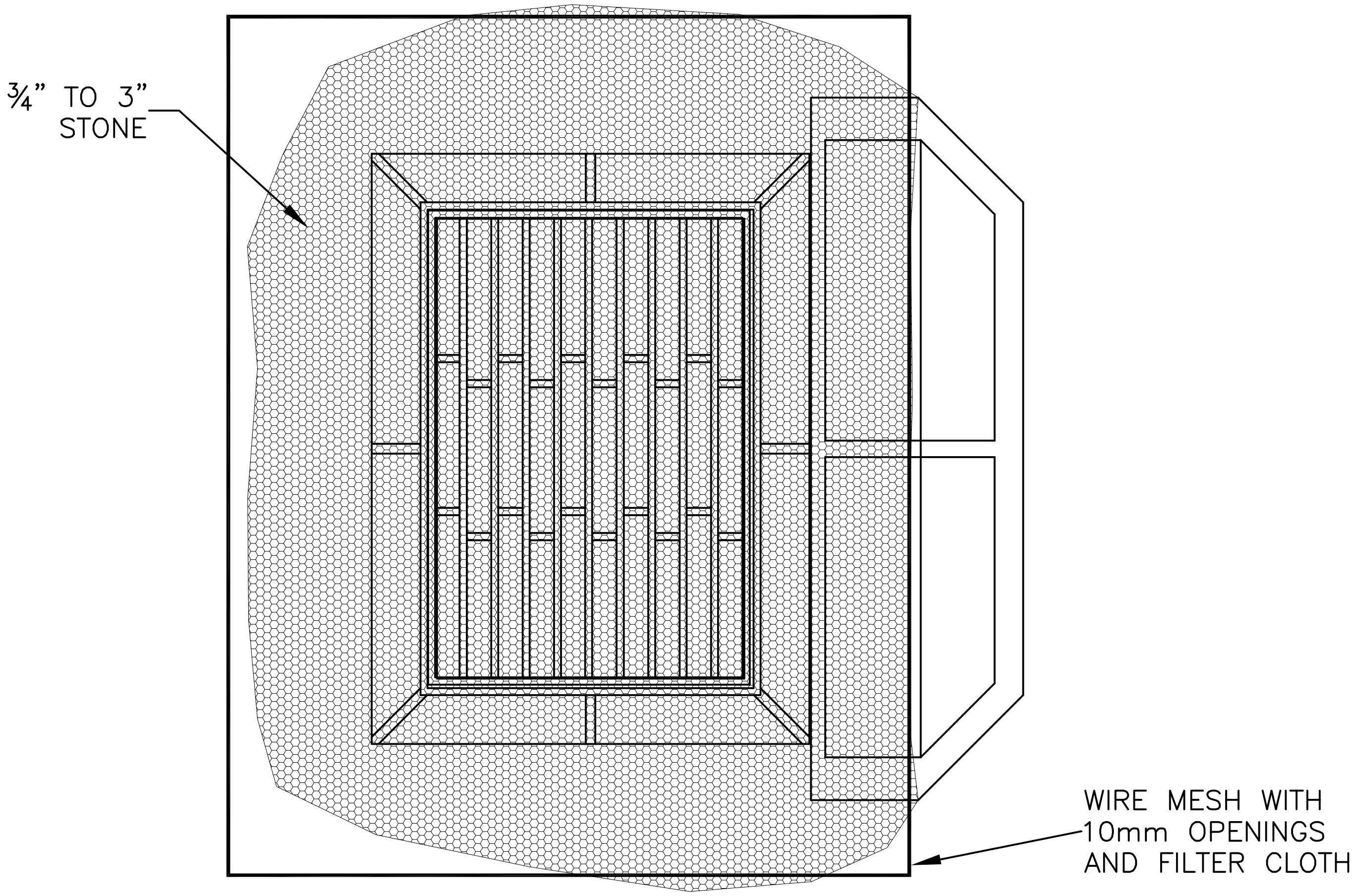
PLAN



SECTION

N.T.S.

GEOTEXTILE FILTER FABRIC FENCE FOR DROP INLET FILTER	SC−2−1



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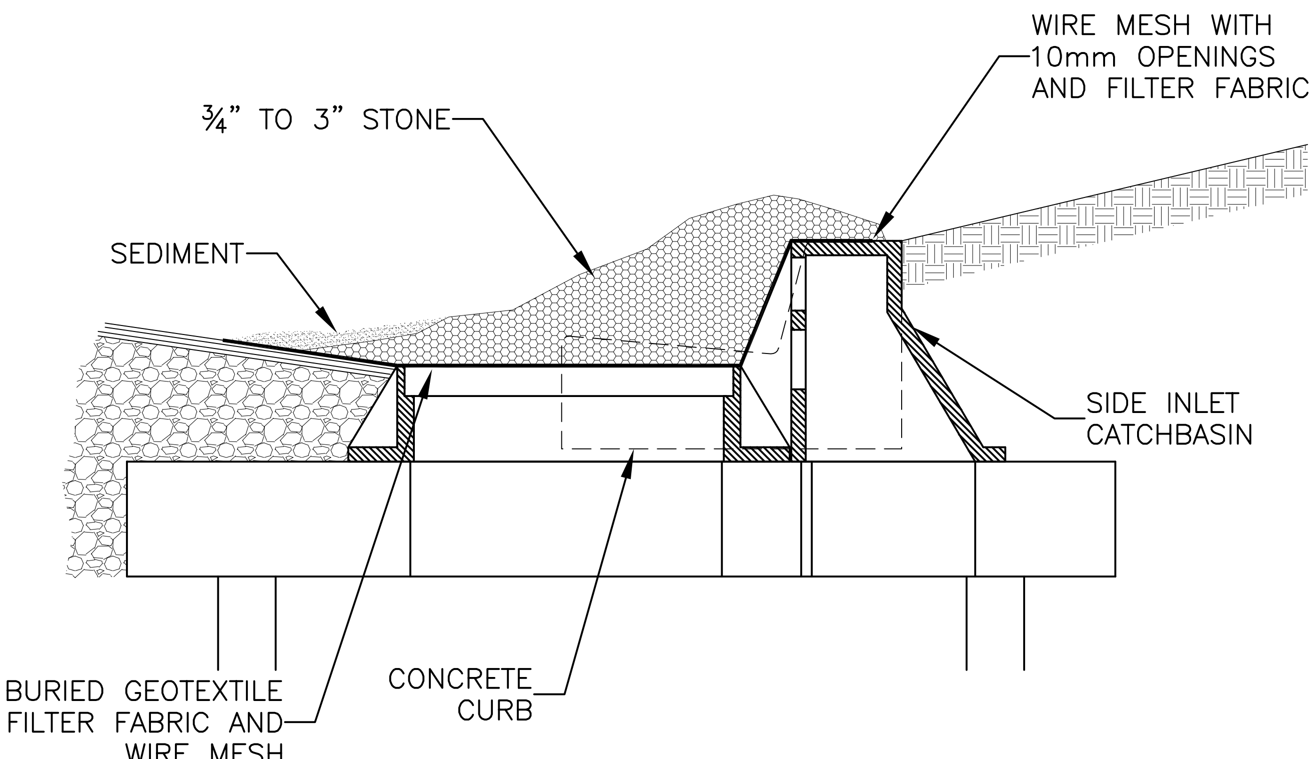
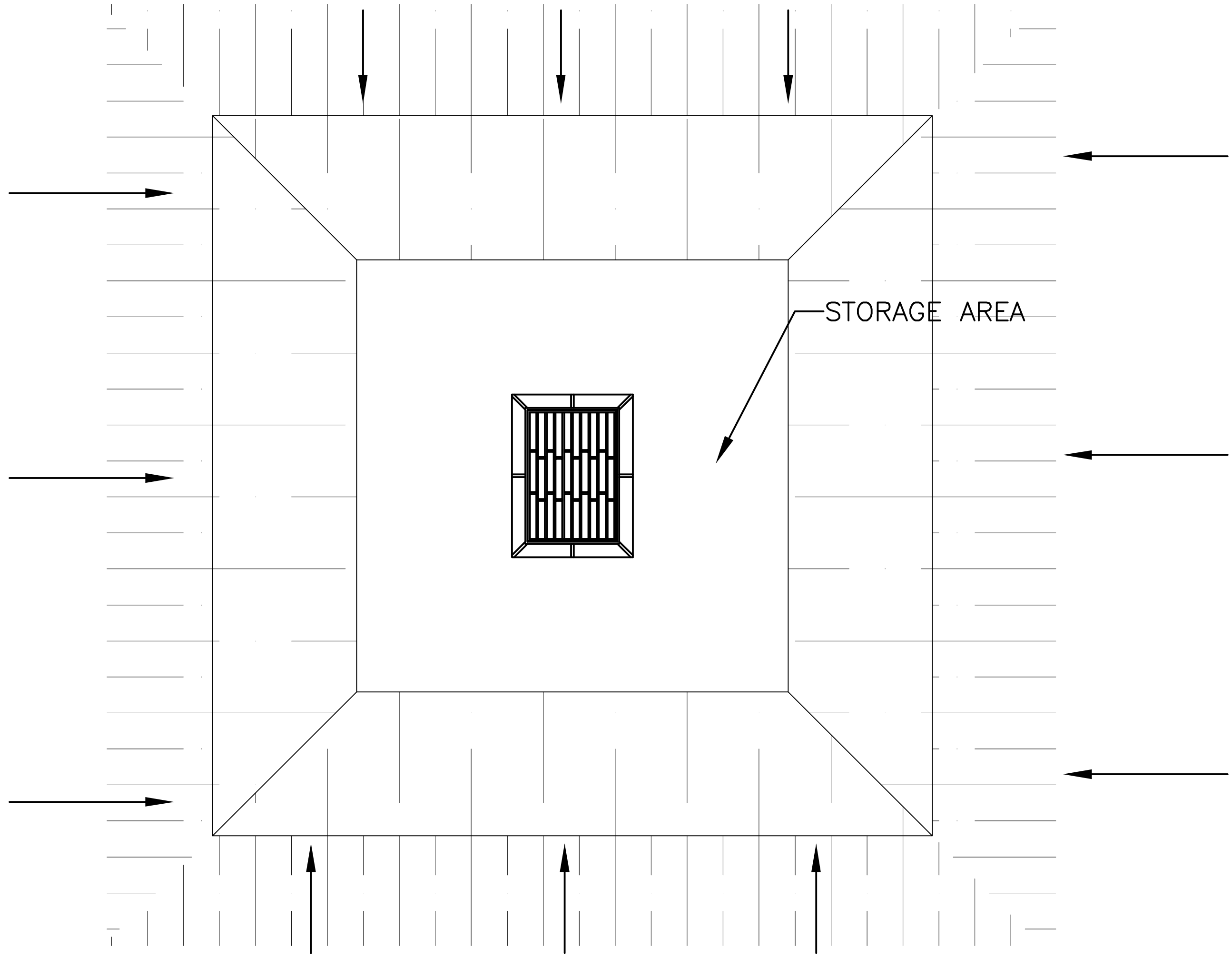


SECTION

N.T.S.

STONE AND WIRE MESH FILTER FOR CURB INLET

SC-2-2



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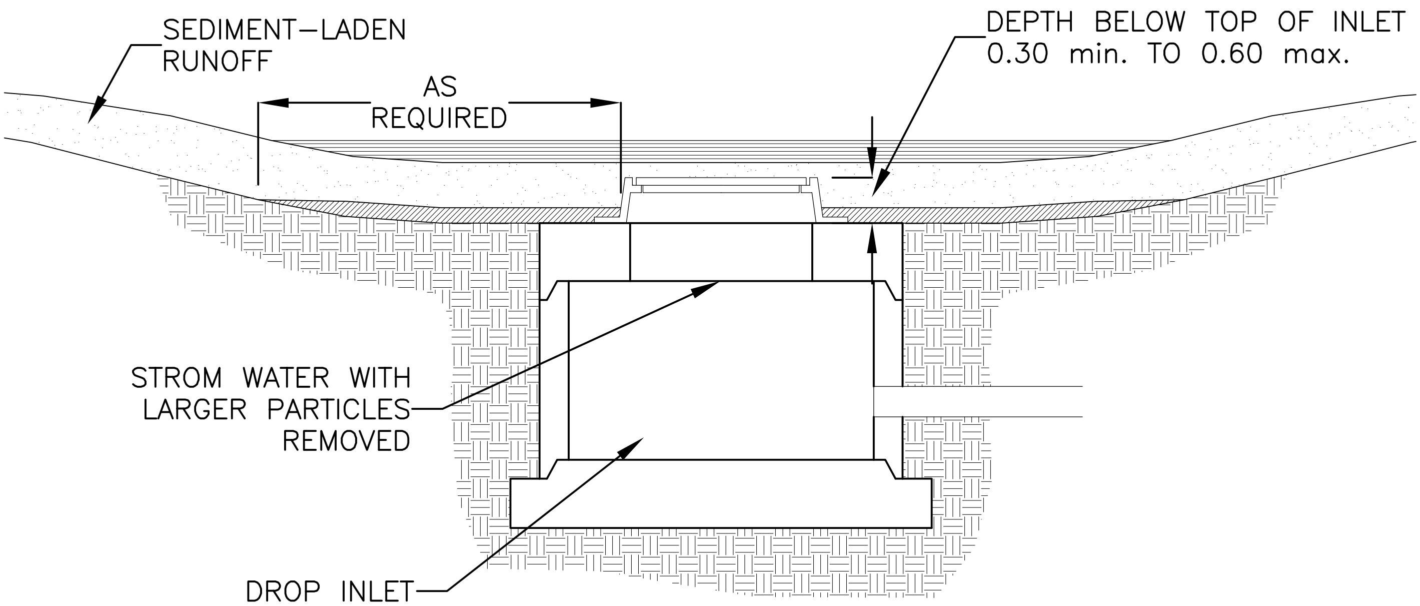
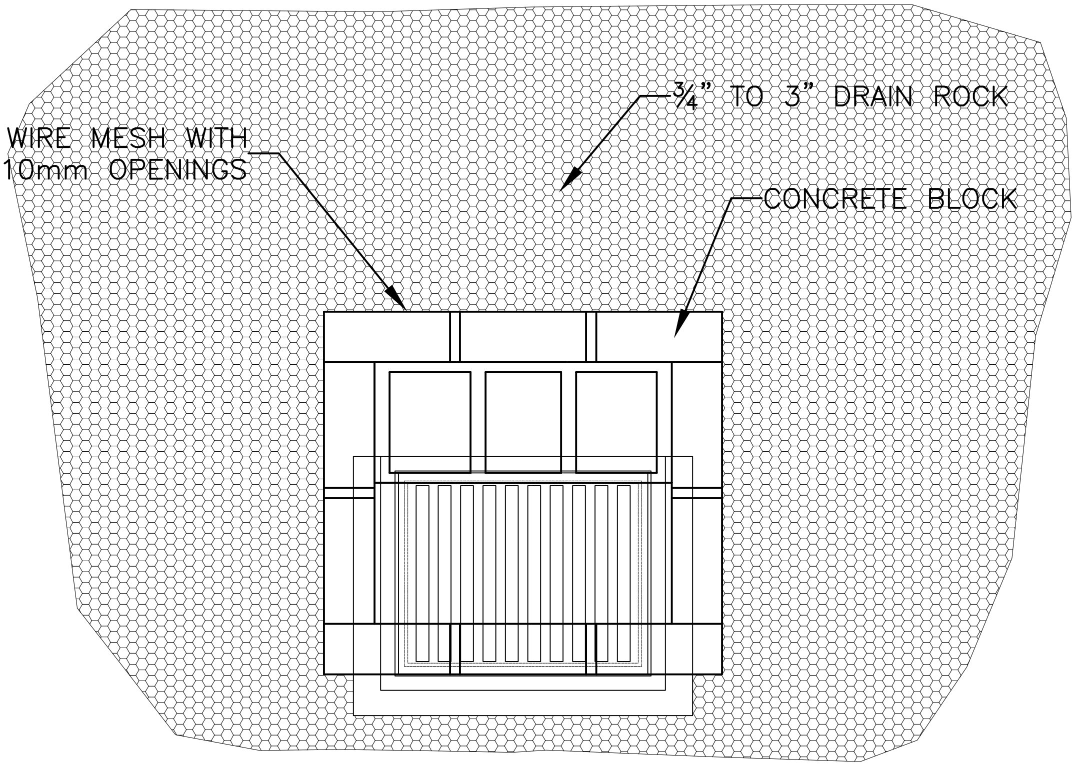


SECTION

N.T.S.

STORM DRAIN INLET PROTECTION

SC–2–3



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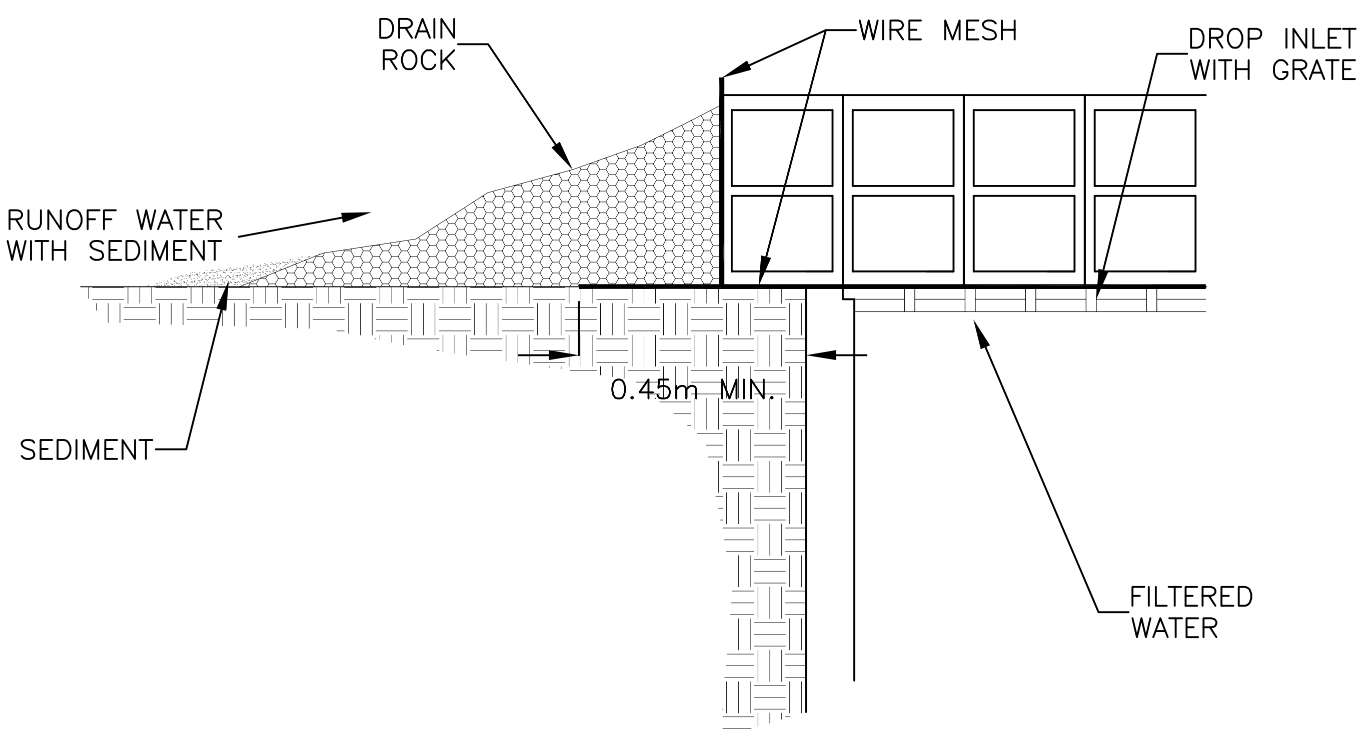
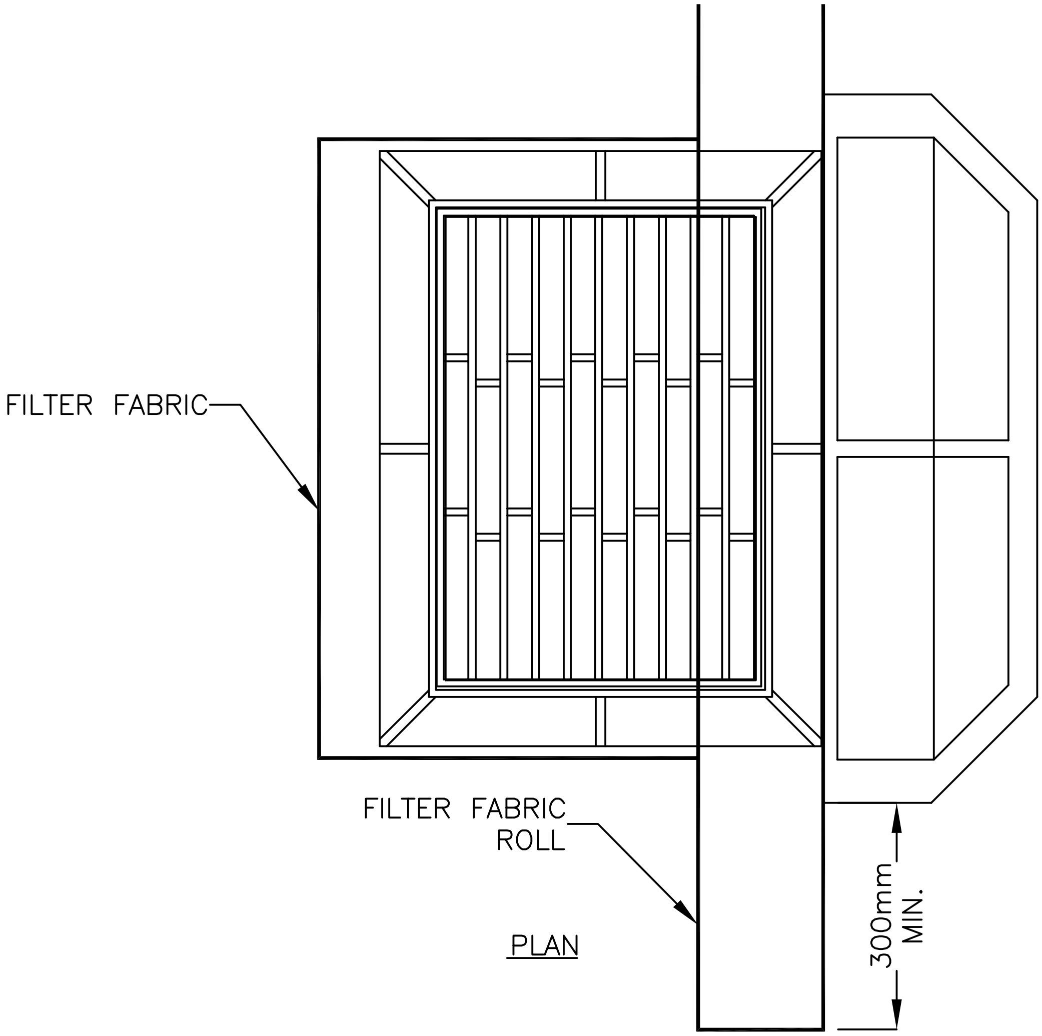


SECTION

N.T.S.

BLOCK AND STONE FILTER AT DROP INLET	SC-2-4



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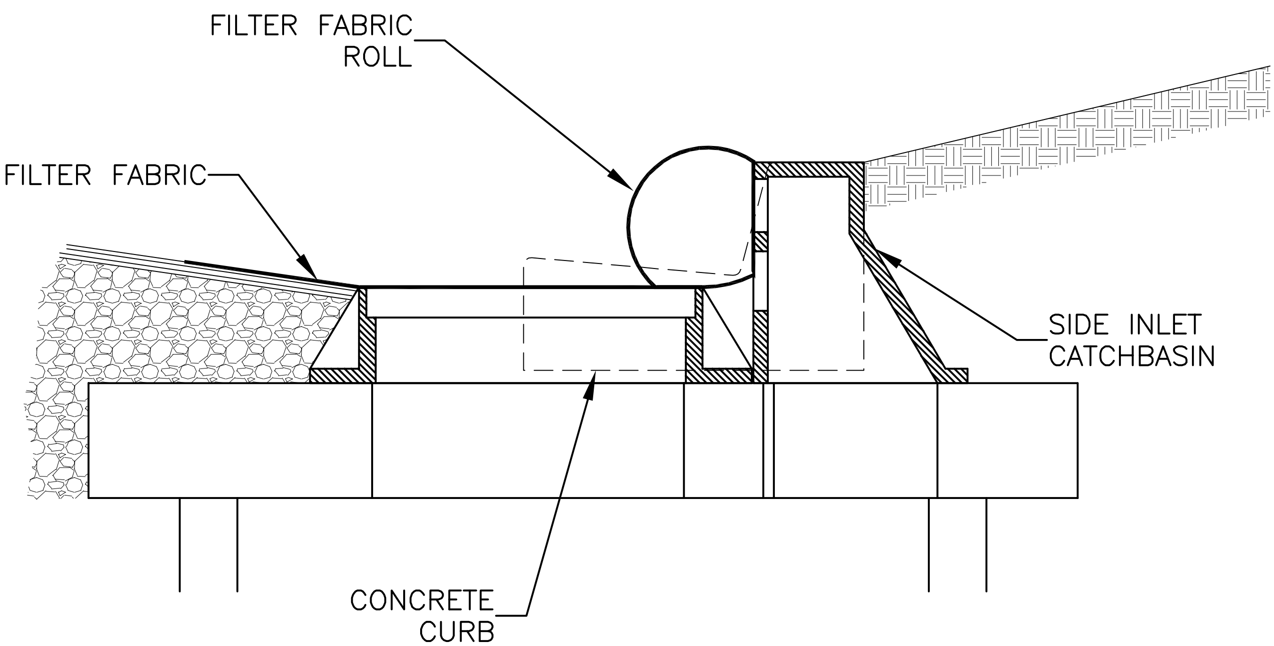


SECTION

N.T.S.

FILTER ROLL WITH SUPPORTS FOR CURB INLET

SC-2-5

Rip-Rap and Gabion Inflow Protection - SC-3

Description – A lined drainage-way to stabilize the flow channel along steep slopes.

Applications
• Use of rip-rap inflow protection applies to slopes between 10:1 and 4:1 (H:V).
• Use of gabion inflow protection applies to slopes exceeding 4:1 (H:V).

Requirements

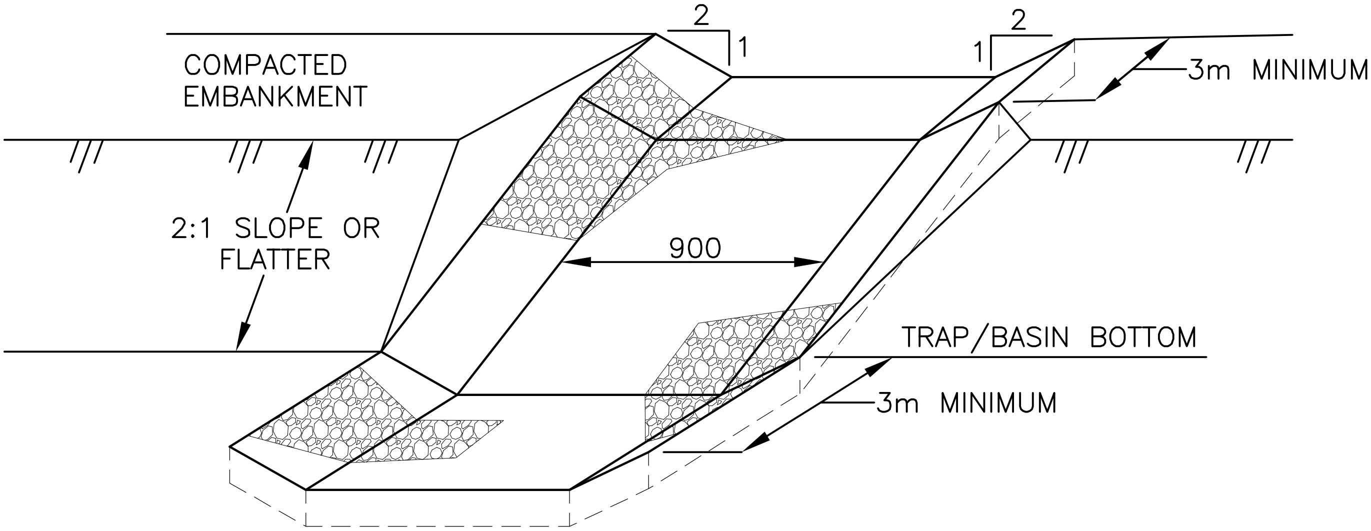
RIP-RAP
• 2:1 (H:V) side slopes, 900mm minimum bottom width, and 300mm minimum depth.
• Line channel with 100 to 300mm rip-rap at a depth of 450mm.
• Install geotextile filter fabric under all rip-rap.
• Blend rip-rap into existing ground.
• Refer to Rip-rap Inflow Protection detail for installation of entrances and exits.
• Gabion inflow protection may be used in lieu of rip-rap inflow protection, see below.

GABION
• Construct 2:1 (H:V) side slopes, 900mm bottom width, and 300mm deep from 230mm x 75mm x 230mm gabion baskets.
• Install geotextile filter fabric under all gabion baskets.
• Fill gabion baskets with 100mm to 180mm stone.
• Install gabions in accordance with manufacturer's recommendations.

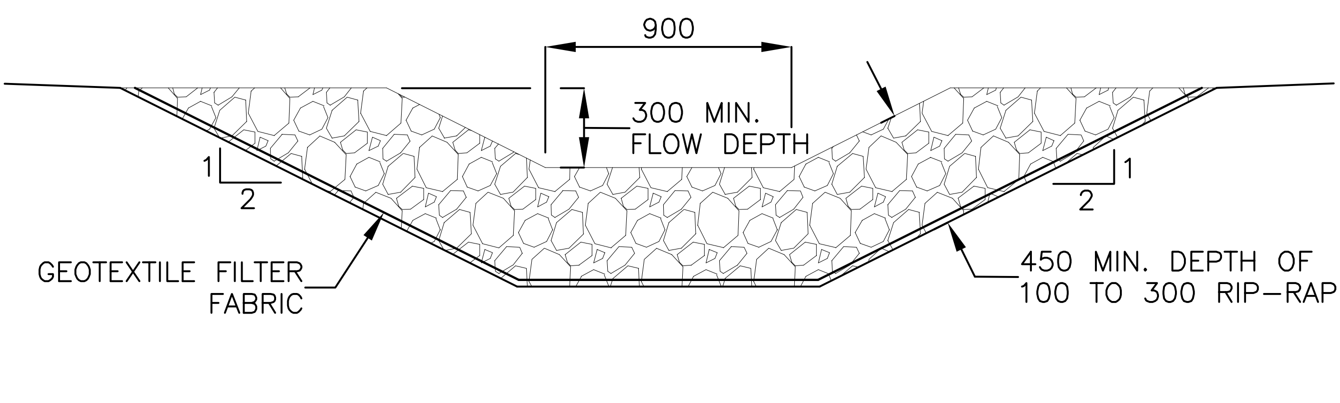
Challenges - None

Inspections and Maintenance
• Inspect weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall.
• Remove accumulated sediment at inlet structure.

See Figure SC-3-1 and SC-3-2.



PERSPECTIVE VIEW

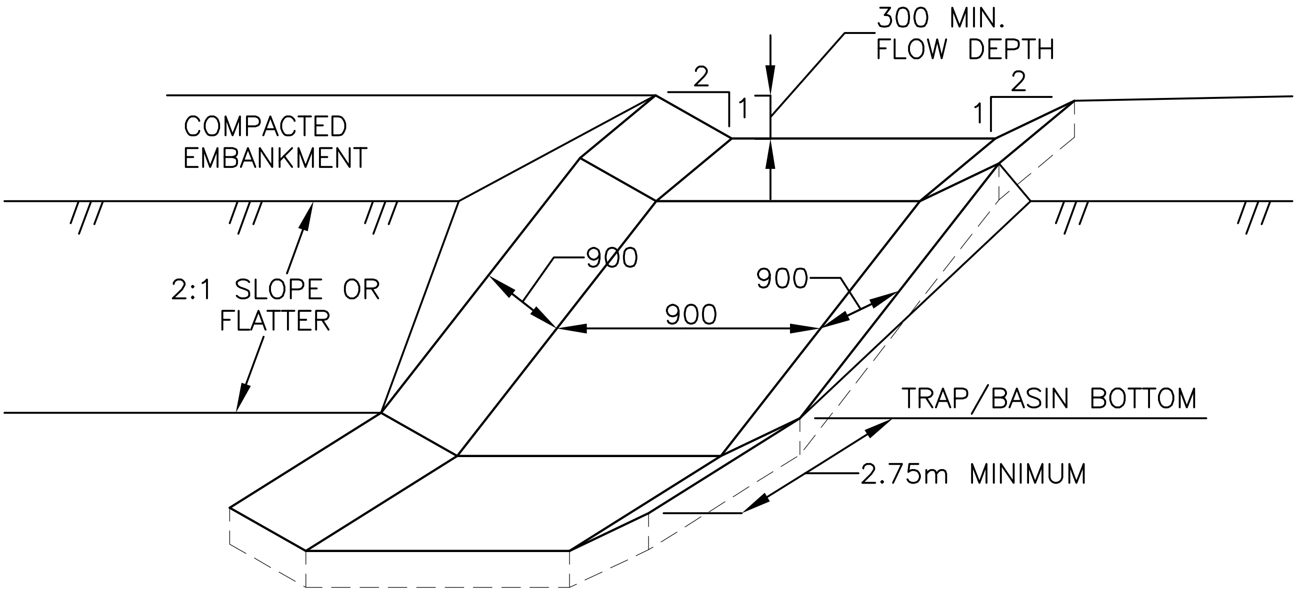


CROSS SECTION

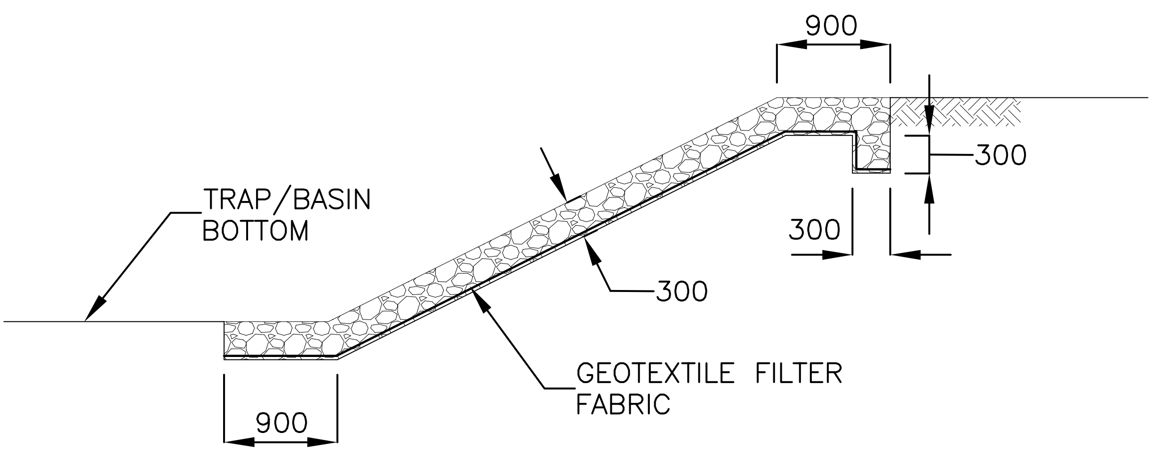
N.T.S.

RIP–RAP GABION INFLOW PROTECTION

SC–3–1



PERSPECTIVE VIEW



PROFILE ALONG CENTRELINE

N.T.S.

RIP-RAP GABION INFLOW PROTECTION

SC-3-2

Outlet Protection and Velocity Dissipation Devices - SC-4

Description - Devices placed at outlets of pipes and channels to prevent or minimize scouring and erosion resulting from high velocity storm water flows.

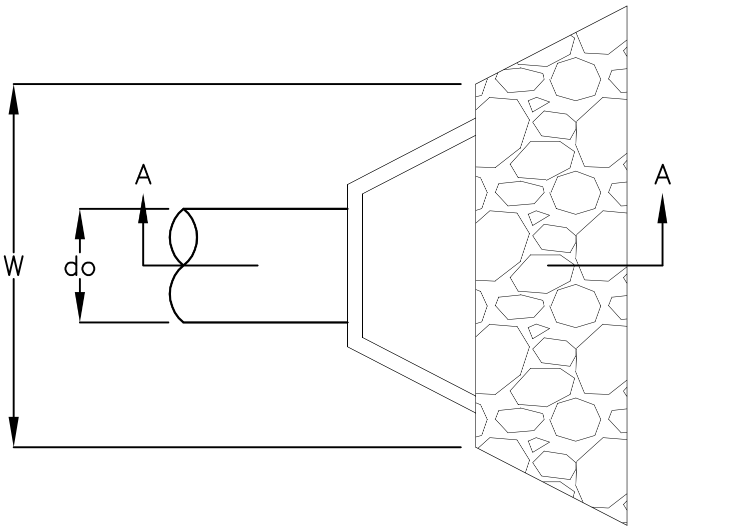
Applications
• Outlets with continuous flows.
• Outlets located at the bottom of slopes.
• Outlets subject to short, intense flows.
• Discharge points from lined conveyances to unlined conveyances.

Requirements
• Align apron with direction of flow and avoid curves in apron. If a curve is necessary, place it in the upper section of the apron.
• Apron length shall be determined by outlet flow rate and tailwater level.
• Protect the underlying geotextile filter fabric with a 100mm minimum rock blanket if the rip-rap is 300mm or larger.

Challenges
• Potential for stones to wash away during high flow periods.
• Break up of grouted rip-rap resulting from hydrostatic pressure caused by water accumulation.

Inspections and Maintenance
• Establish an inspection schedule for all structures.
• Immediately repair damaged slopes or underlying geotextile filter fabric
• Inspect apron for damage to underlying geotextile filter fabric or dislodged rip-rap.

See Figure SC-4



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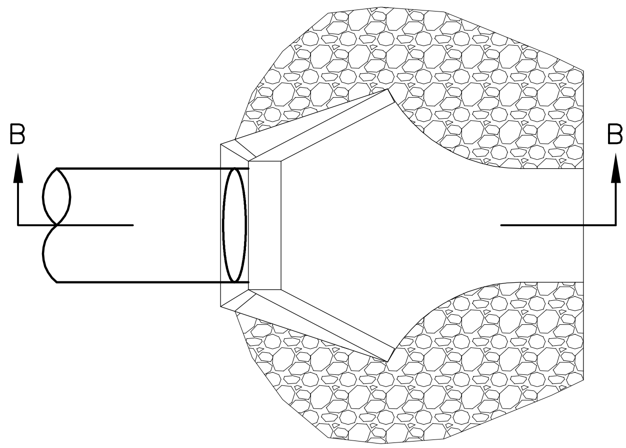

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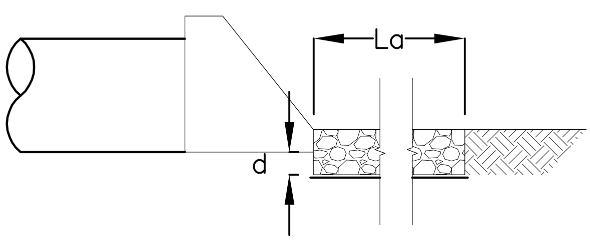
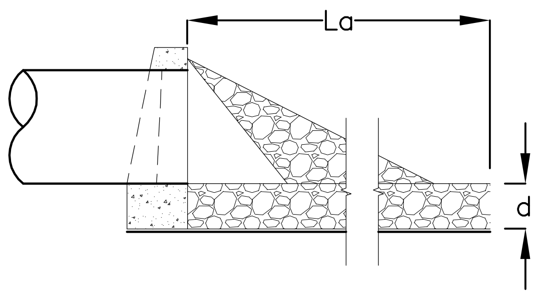


SECTION A–A



SECTION B–B

NOTES:

1. APRON LINING MAY BE RIP–RAP, GROUTED RIP–RAP, OR CONCRETE.
2. PIPE DIAMETER, APRON DIMENSIONS, AND AVERAGE ROCK SIZE FOR RIP–RAP ARE BASED ON THE DESIGN FLOW RATE AND VELOCITY. La AND ROCK SIZE MUST BE SET TO SLOW THE FLOW TO NON–EROSIVE VELOCITITES (eg. LESS THAN 10fps).
3. d=1.5 TIMES THE MAXIMUM ROCK SIZE DIAMETER BUT NOT LESS THAN 150mm

N.T.S.

OUTLET PROTECTION AND VELOCITY DISSIPATION DEVICES	SC–4

Vegetated Buffer Strips and Channels - SC-5

Description - Vegetative buffer strips and channels protect soil from erosion, increase infiltration, and remove sediment from surface runoff entering storm systems and/or receiving waters.

Applications

• Any site which is suitable for establishment of vegetation.
• Uncurbed, paved areas; steep or potentially unstable slopes; and areas adjacent to receiving waters.
• Vegetated channels are appropriate for surface runoff conveyed by channels to downstream inlets or receiving waters.

Requirements

• Refer to SM-15 (Preservation of Existing Vegetation) in this manual if existing vegetation will be used as a buffer strip.
• Installation of a buffer strip with new vegetation should comply with the following:
  - o Prior to cultivation of the buffer strip area, remove and dispose of weeds and debris
  - o During construction, strip and stockpile topsoil for surface preparation purposes prior to planting activities;
  - o Plant the area upon completion of grading in the area;
  - o Grade and roll areas to be planted after cultivating soil and, if applicable, install an irrigation system;
  - o Provide watering or irrigation of vegetation to supplement rainfall as required until vegetation has been established;
  - o Fertilize vegetation in accordance with manufacturers' instructions and grass/soil requirements determined by testing of the soil;
  - o Vehicle traffic passing through vegetated buffer strips or channels shall be avoided
  - o Comply with applicable regulations and manufacturers' instructions when applying fertilizers, pesticides, soil amendments, or chemicals;
  - o Comply with the following during seeding activities:
    - - Add soil amendments such as fertilizer when preparing seedbed. Apply mulch after seeding to protect vegetation during establishment. Select an appropriate seed mixture based on site conditions. Dense grasses are more effective in reducing flow velocities and removing sediment. Thick root structures are necessary for erosion control,
    - - Use proper equipment and methods to ensure uniform distribution and appropriate seed placement, and
    - - Overseed, repair bare spots, and apply additional mulch as necessary
  - o Comply with the following during sodding activities:
    - - Protect sod with tarps or other types of protective covering during delivery and do not allow sod to dry between harvesting and placement,
    - - Any irregular or uneven areas observed prior to or during the plant establishment period shall be restored to a smooth and even appearance,
    - - Areas, which will be planted with sod and are adjacent to paved surfaces such as sidewalks and concrete headers, shall be 40±5 mm below the top grade of the paved surface after grading, rolling, and settlement of the soil.
  - - Ends of adjacent strips of sod shall be staggered a minimum of 600mm,
  - - Edges and ends of sod shall be placed firmly against paved borders,
  - - After placement of the sod, lightly roll sodded area to eliminate air pockets and ensure close contact with the soil,
  - - After rolling, water the sodded area to moisten the soil to a depth of 100mm,

- Do not allow sod to dry,
- Avoid planting sod during extremely hot or wet weather, and
- Sod shall not be placed on slopes steeper than 3:1 (H:V) if the area will be mowed.

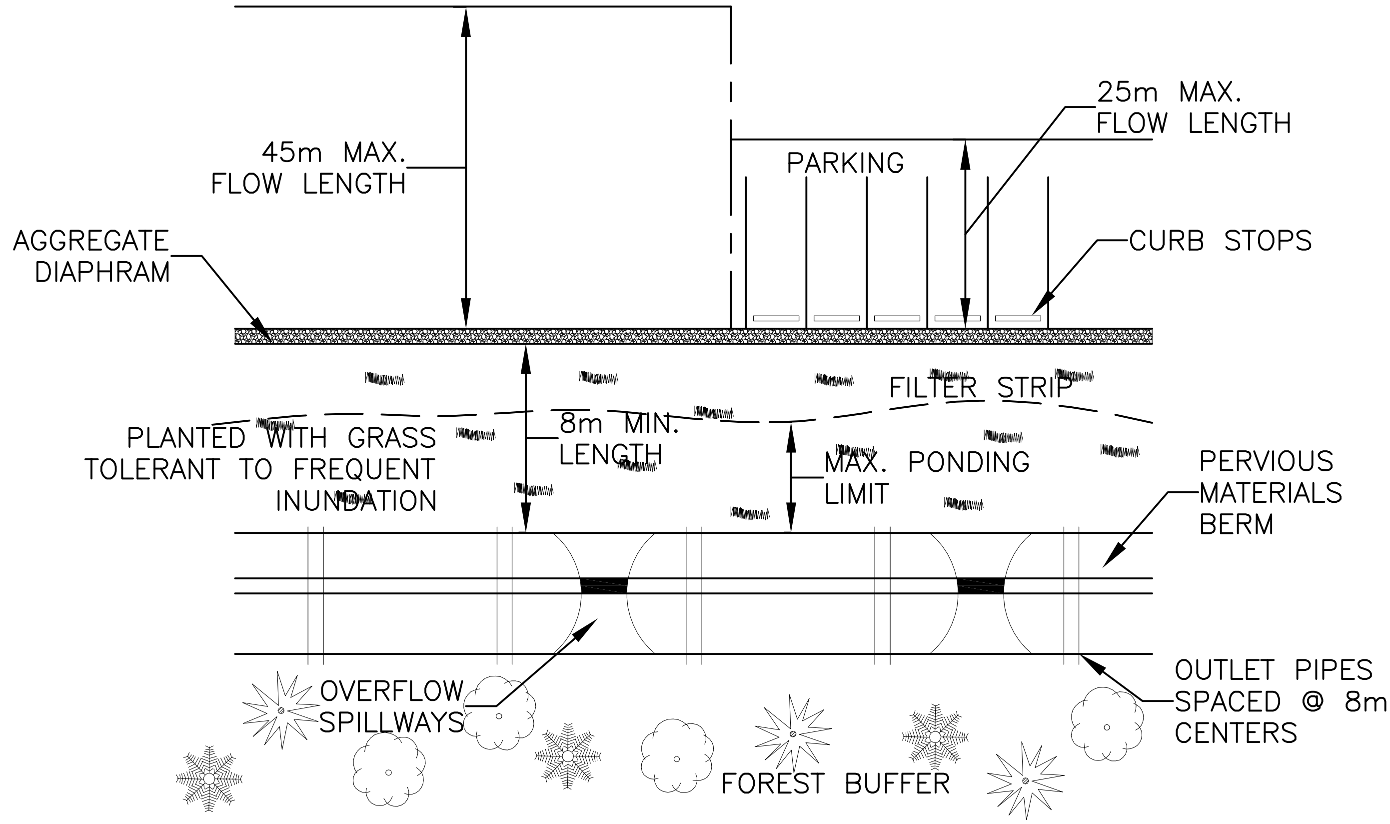
Challenges

• Site conditions such as availability of land.
• Flow depth and vegetative condition determine BMP effectiveness.
• May require irrigation to maintain vegetation.
• Maintenance requirements may exist depending on the design condition of the vegetation.
• Unless existing vegetation is used as a buffer strip, an area will need to be provided specifically for a buffer strip and vegetation will need to be established.
• Maintaining sheet flow in buffer strips may be difficult.
• Vegetated channels require a larger area than lined channels.
• Vegetated channels require gradual slopes since runoff with high flow velocity may flow over grass rather than through it.

Inspections and Maintenance

• Inspect weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall until vegetation is established. Repair eroded or damaged areas as necessary.
• Maintenance activities include mowing, weeding, and verification of a properly operating irrigation system, if applicable.
• Properly remove and dispose of clippings from mowing and trimmings

See Figure SC-5



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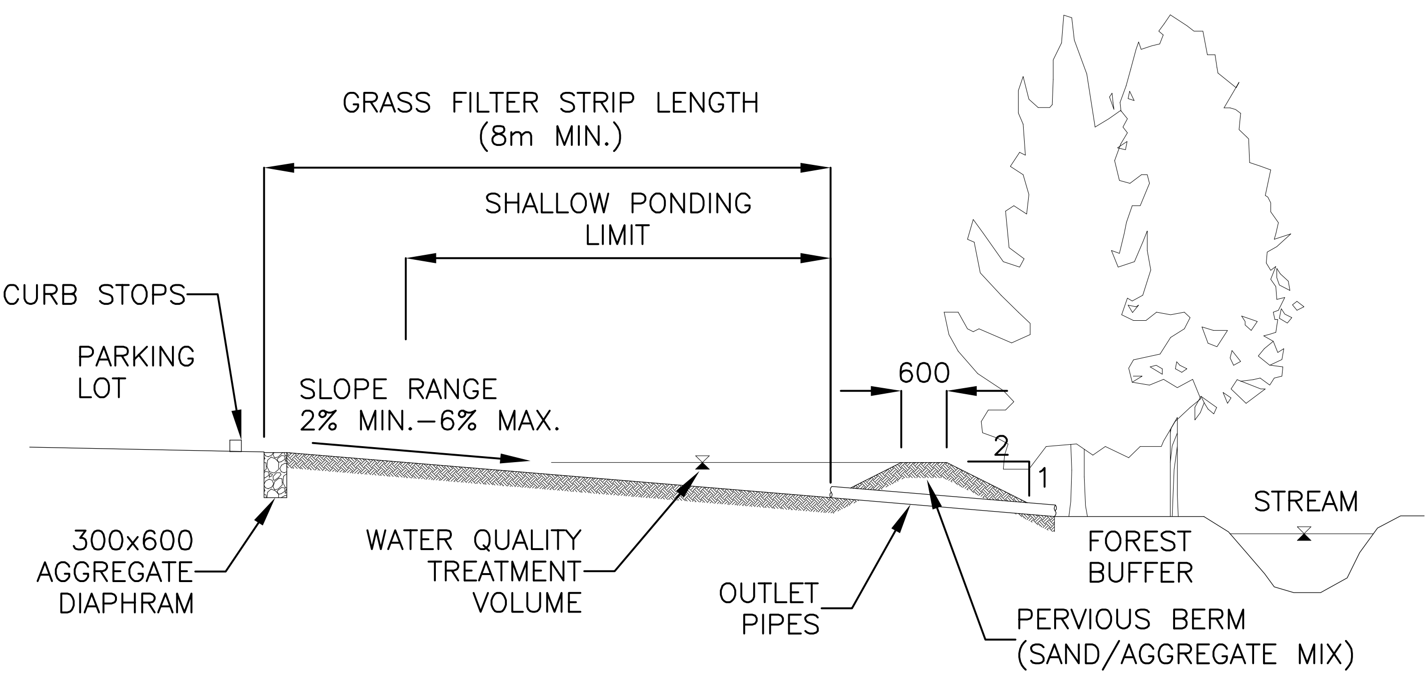


SECTION

N.T.S.

TYPICAL VEGETATED BUFFER STRIP

SC–5

Earth Dike - SC-6

Description – An earth dike is a structure that prevents erosion by intercepting, diverting, and/or conveying surface run-on (storm water entering the site) to a stabilized area or sediment trapping device.

Applications

- Drainage areas smaller than 4 Ha.
- Direct runoff around unstable or disturbed areas to a stabilized water course or channel.
- Divert runoff to sediment basins or sediment traps.
- Intercept and divert runoff to prevent sheet flow over sloped surfaces.
- Convey surface runoff down sloping land.

Requirements

- Firmly compact earthen materials to minimize erosion and prevent unequal settling.
- Drain sediment laden runoff to a stabilized outlet or sediment trapping device.
- Ensure continuous, positive grade along dike to prevent ponding of runoff.
- Stabilize earth dikes with vegetation or other physical devices.
- Conform to predevelopment drainage patterns and capacities.
- Design flow and safety factor shall be determined by an evaluation of risks associated with overtopping, flow backups, or washout of structures.
- Establish minimum flow velocity requiring lining (rip-rap, geotextile filter fabric, vegetation, concrete) for earthen diversion devices
- Incorporate an emergency overflow section or bypass area into the design for storms exceeding the design storm.

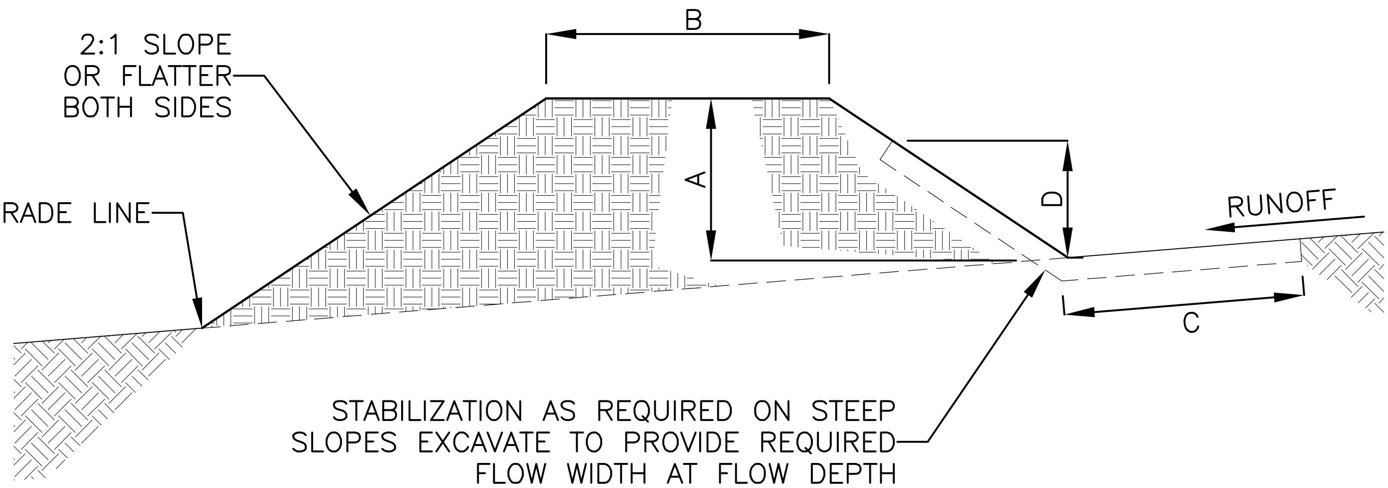
Challenges

- Unsuitable for use as a sediment trapping device.
- Use of additional sediment and erosion control devices may be required to prevent scour and erosion in recently graded dikes.
- Select size and location to prevent consequences such as erosion along steep and unlined ditches and ponding within the roadways or material storage areas.

Inspections and Maintenance

- Remove dikes after stabilization of the surrounding drainage area or completion of construction.
- Inspect dikes weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall. Inspections shall include the following:
    - o Check for erosion and restore all bare areas with the appropriate lining material;
    - o Remove accumulated sediment and debris; and
    - o Inspect dike walls for cracks, washouts, animal habitation, exposed materials, and other signs of potential failure.
- Restore areas with the appropriate materials.

See Figure SC-6



REQUIREMENTS BASED ON UPSTREAM DRAINAGE AREA

	DIKE 1 (2 HECTARES OR LESS)	DIKE 2 (2–4 HECTARES)
A–DIKE HEIGHT	450	900
B–DIKE WIDTH	600	900
C–FLOW WIDTH	100	150
D–FLOW DEPTH	200	400

N.T.S.

EARTH DIKE

SC–6

Temporary Drains and Swales - SC-7

Description – Temporary drains and swales are structures that prevent erosion by intercepting, diverting, and conveying surface run-on (storm water entering the site) to a stabilized area or sediment trapping device.

Applications

- Drainage areas smaller than 2 Ha.
- Direct runoff around unstable or disturbed areas to a water course or channel.
- Divert runoff to sediment basins or traps.
- Intercept runoff.
- Supplement other sediment control measures.
- Intercept and divert runoff to prevent sheet flow over sloped surfaces and/or convey surface runoff down sloping land.

Requirements

- Firmly compact earthen materials to minimize erosion and prevent unequal settling.
- Drain to a stabilized outlet.
- Drain sediment laden runoff to a sediment trapping device.
- Ensure continuous, positive grade along swale or ditch to prevent ponding of runoff.
- Stabilize earth drains or swales with vegetation or other physical devices.
- Conform to predevelopment drainage patterns and capacities.
- Design flow and safety factor shall be determined by an evaluation of risks associated with overtopping, flow backups, or washout of structures.
- Evaluate potential run-on from off-site properties.
- Establish minimum flow velocity requiring lining (rip-rap, geotextile filter fabric, vegetation, concrete) for earthen diversion devices
- Incorporate an emergency overflow section or bypass area into the design for storms exceeding the design storm.

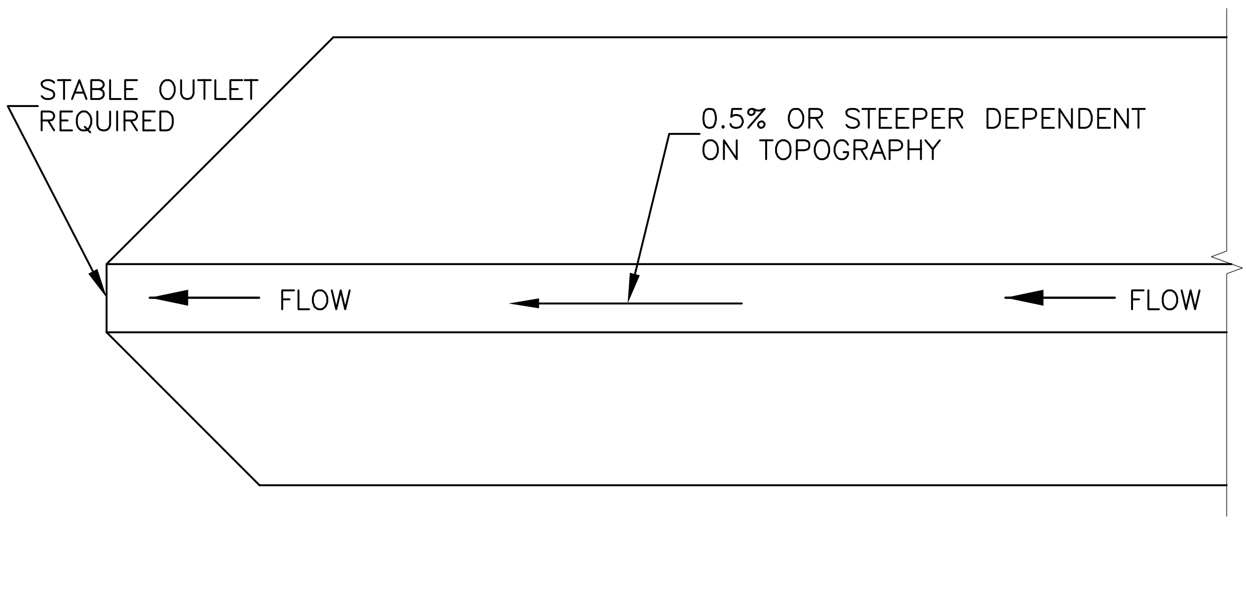
Challenges

- Unsuitable for use as a sediment trapping device.
- Use of additional sediment and erosion control devices may be required to prevent scour and erosion in recently graded swales and ditches.
- Ditches and swales may require check dams or lining to prevent erosion.

Inspections and Maintenance

- Remove temporary swales and ditches after stabilization of the surrounding drainage area or completion of construction.
- Inspect swales and ditches weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall. Inspections shall include the following:
    - o Check for erosion along channel linings, embankments, or beds of ditches and restore all bare areas with the appropriate lining material;
    - o Remove accumulated sediment and debris; and
    - o Inspect embankments, compacted fills, and earthen channel sidewalls for cracks, washouts, animal habitation, exposed materials and other signs of potential failure. Restore areas with the appropriate materials.

See Figure SC-7



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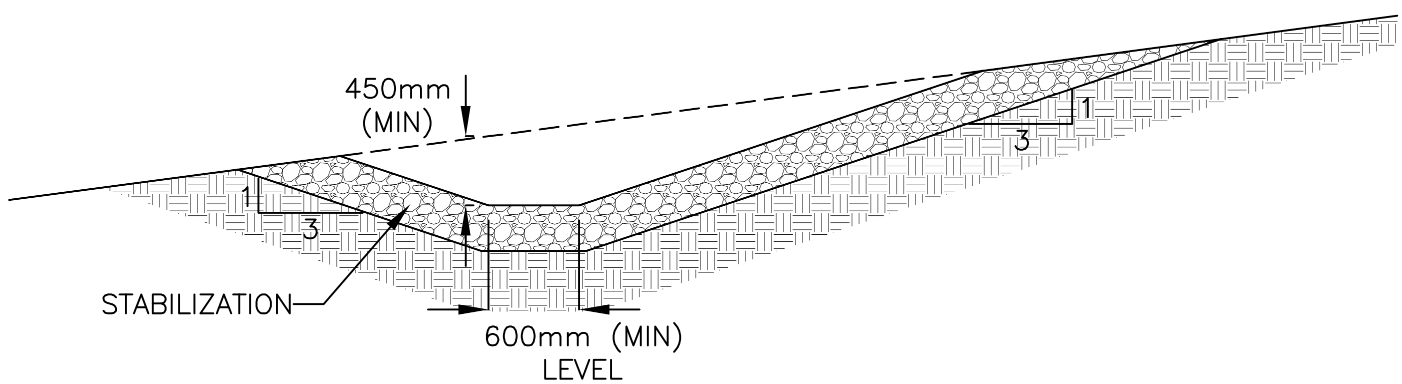


SECTION

TEMPORARY DRAINAGE SWALE

N.T.S.

TEMPORARY DRAINS AND SWALES

SC-7

Compost Filter Berm - SC-8

Description - A dike consisting of composted material (e.g. OgoGrow) and placed perpendicular to runoff to reduce flow velocity and retain sediments.

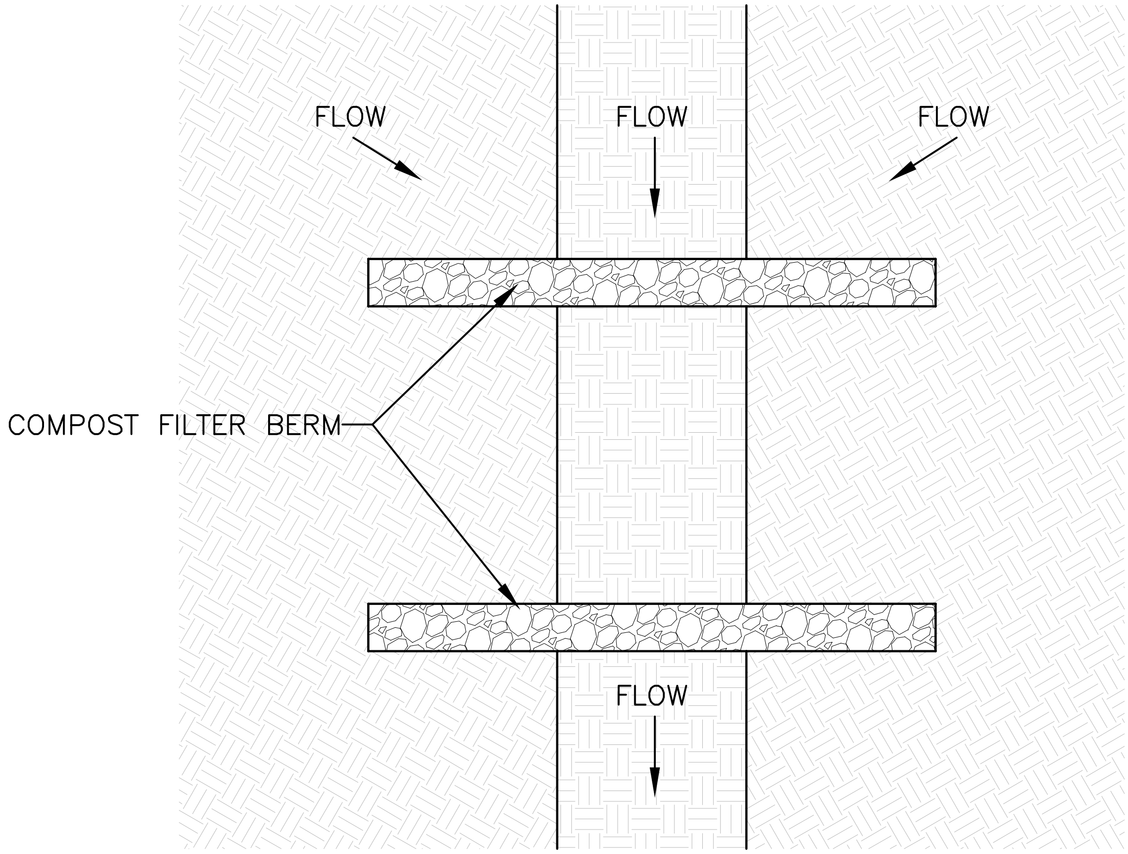
Applications
• Along the site perimeter.
• Along the slope face.
• As a check dam in small drainage ditches.
• As inlet protection for storm drains.
• Appropriate for small drainage areas and low surface velocity flows (less than 30 L/s).
• May be used in combination with other BMPs such as a compost blanket or silt fence for high rainfall areas and steeper or longer slopes.

Installation and Implementation Requirements
• Usually located at the base of slopes as required.
• Berm size is determined by factors such as slope length and grade, soil characteristics, climate, and presence of existing vegetation.
• Berms may remain un-vegetated.
• Compost quality shall comply with all regulatory requirements.
• A compost filter sock may be utilized which consists of a mesh tube filled with composted material, as a type of compost filter berm and should comply with the following:
  o Assemble by tying a knot at one end of the mesh sock, filling the sock with compost, and knotting the other end of the sock. A pneumatic blower may be used to fill the sock with compost;
  o Use a filter sock equivalent to the length of the slope where practicable;
  o When use of multiple socks is required, place socks end-to-end and interlock the ends;
  o Anchor filter socks to ground; and
  o Turn ends of filter sock up slope to prevent flow around ends.
• Material for compost berm may be left at the site and used as a soil amendment.

Challenges
• Unsuitable for areas with high runoff unless a low flow rate and small drainage area warrants use of a filter berm.
• Heavy vegetation must be removed to ensure close contact of compost with the ground surface.

Inspections and Maintenance
• Inspect weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall.
• Remove sediment which has accumulated to within 1/3 of the berm height.
• Replace disturbed or damaged areas of the berm.
• Significant washout may indicate a larger berm or additional BMPs such as a compost blanket or silt fence are required.

See Figures SC-8-1, SC-8-2, and SC-8-3.



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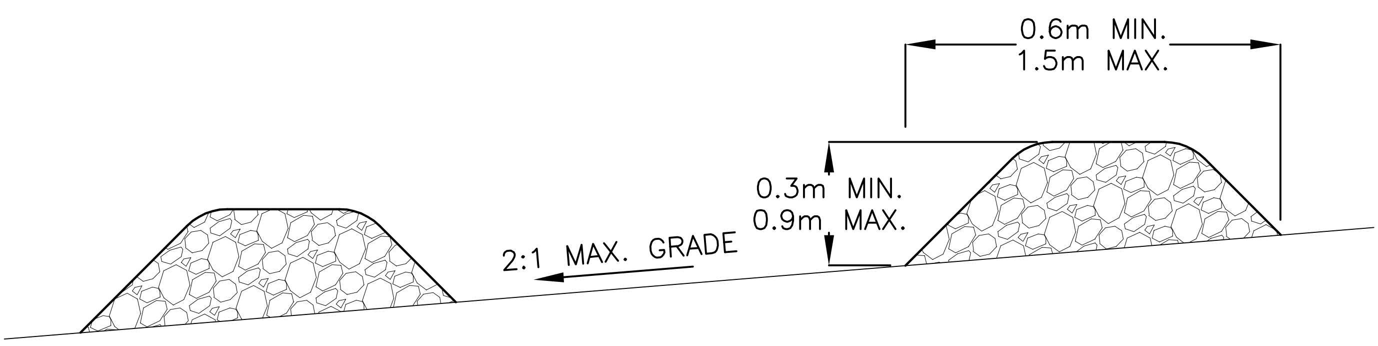
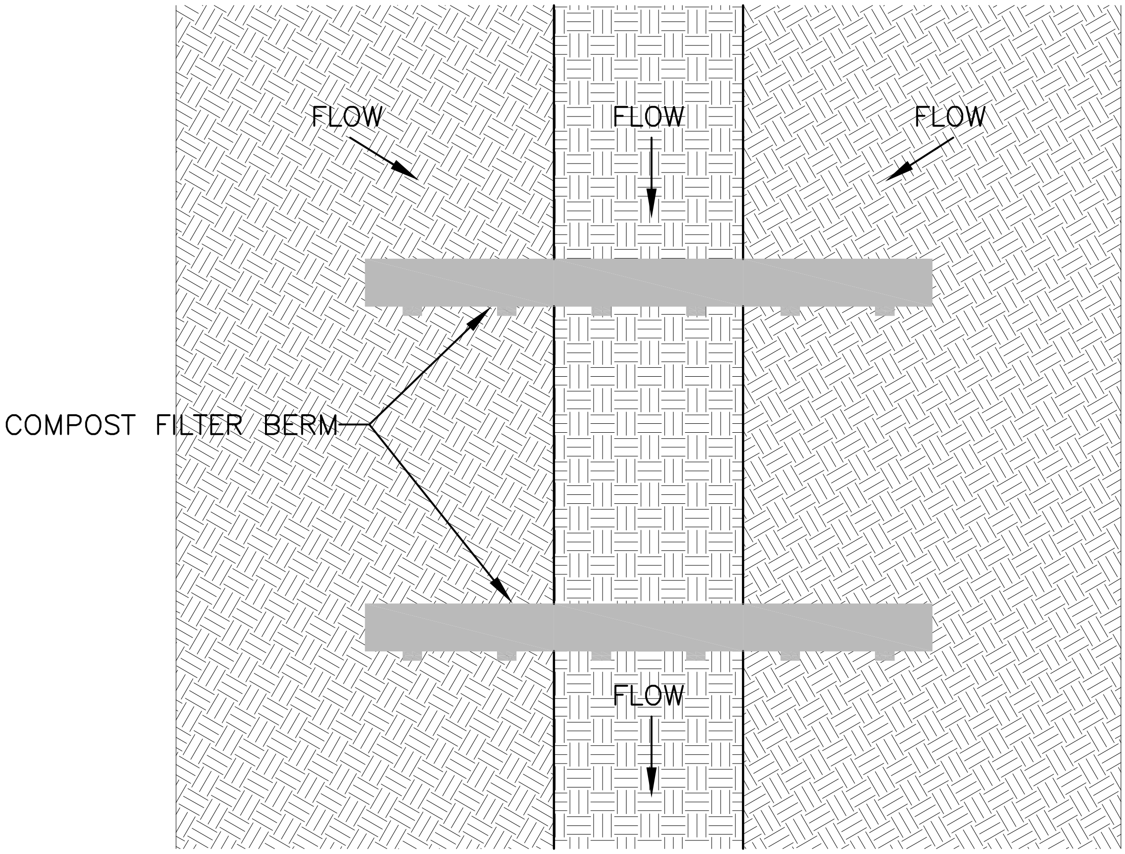


SECTION

N.T.S.

COMPOST FILTER BERM

SC-8-1



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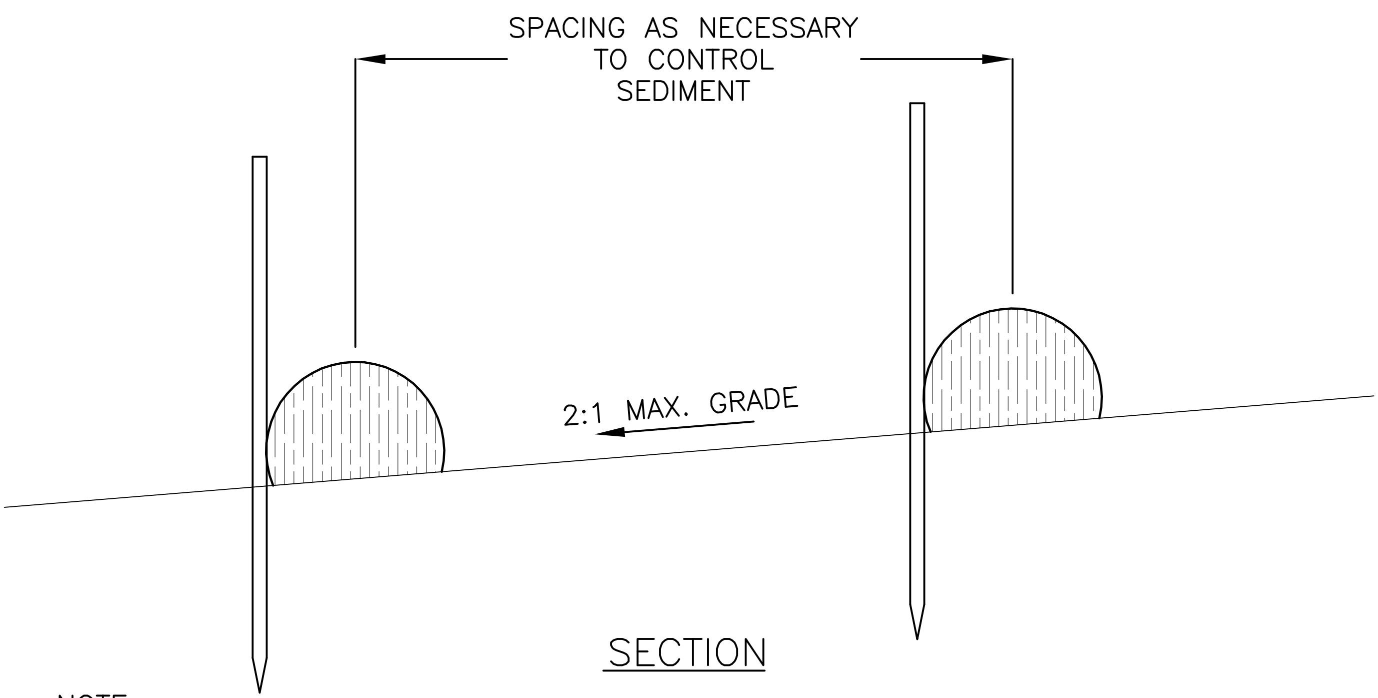
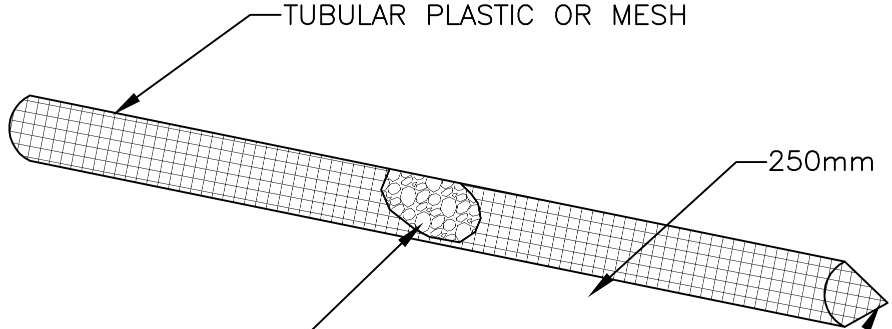


SECTION

NOTE:
STAKE FILTER SOCK AS PER MANUFACTURER'S REQUIREMENTS

N.T.S.

COMPOST FILTER BERM (FILTER SOCK)	SC-8-2



PLAN

N.T.S.

COMPOST FILTER BERM (FILTER SOCK)

SC-8-3

Check Dams - SC-9

Description – A check dam is a temporary structure placed across channels or ditches to reduce scour and erosion by reducing flow velocity and promoting sedimentation.

Applications

- Appropriate for small open channels conveying runoff from 4 Ha or less.
- Steep channels with runoff velocities exceeding 0.6m/s.
- Temporary ditches which do not require installation of erosion-resistant linings due to expected short-term use.

Installation and Implementation Requirements

- Distance between check dams and height of each device promotes the formation of small pools between adjacent devices.
- Backwater from the downstream check dam shall reach the toe of the upstream check dam.
- Major flows (i.e. 2 year storm or larger) shall flow over the check dam without increasing upstream flooding or damaging the check dam.
- Remove check dams and accumulated sediment upon establishment of vegetative lining.
- Stone check dams shall consist of stones ranging from approximately 200 to 300mm in size. Stones shall be placed by hand or by other mechanical means. Stone material shall completely span the channel or ditch to prevent washout of the check dam.
- Log check dams shall consist of logs ranging from approximately 100 to 150mm in diameter. Logs shall be embedded a minimum of 450mm into the soil.
- Upon establishment of grass used for stabilization of the ditch or channel, the check dams can be removed unless the slope of the swale exceeds 4%.

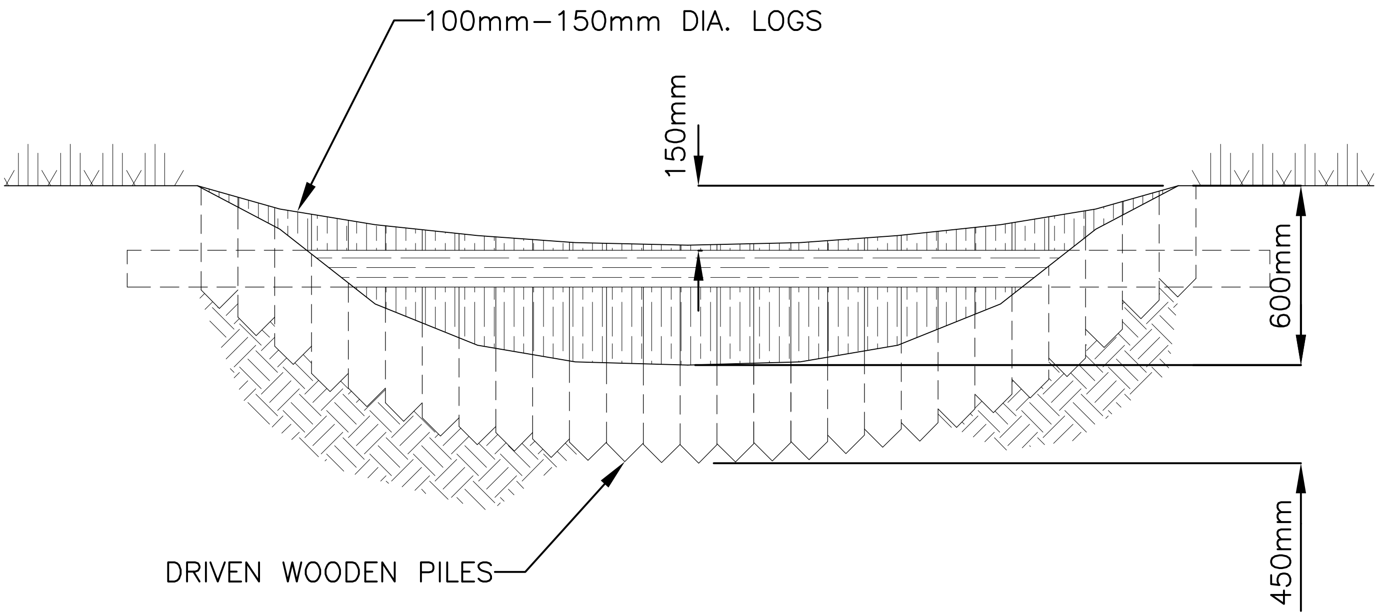
Challenges

- Drainage area discharging to open channels shall not exceed 4 Ha.
- Not applicable for streams.
- High velocity flows will require additional maintenance.
- Subsequent storms or removal of the check dam may re-suspend trapped sediment.

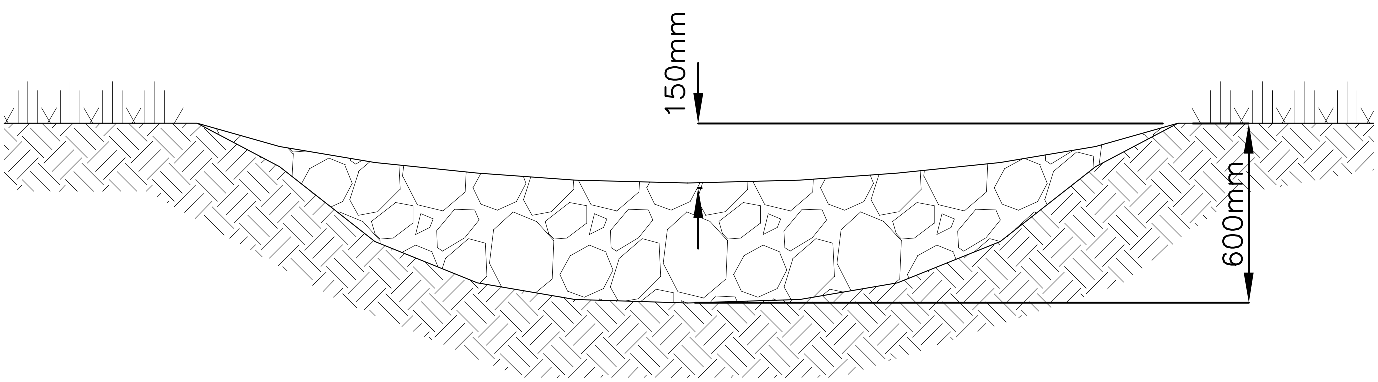
Inspections and Maintenance

- Inspect check dams for sediment accumulation and erosion weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall.
- Remove accumulated sediment when depth reaches one-half the sump depth.
- Prior to permanent seeding or soil stabilization, remove accumulated sediment and check dams.

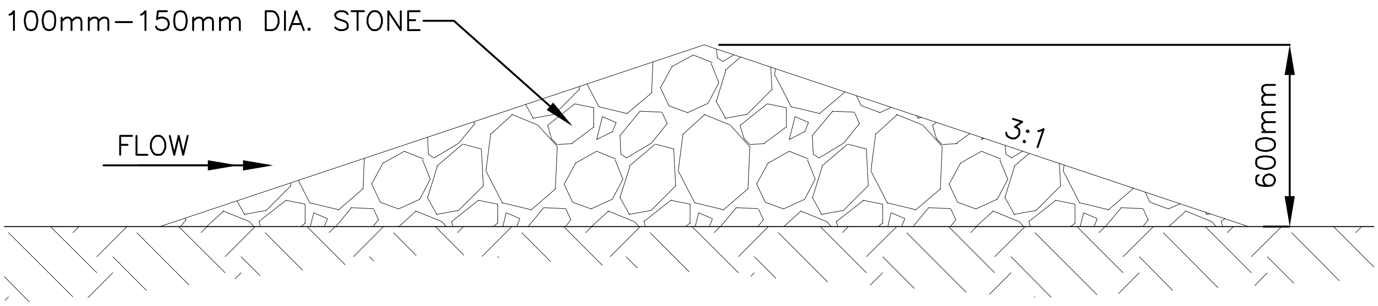
See Figure SC-9-1 and SC-9-2.



LOG CHECK DAM ELEVATION



STONE CHECK DAM ELEVATION

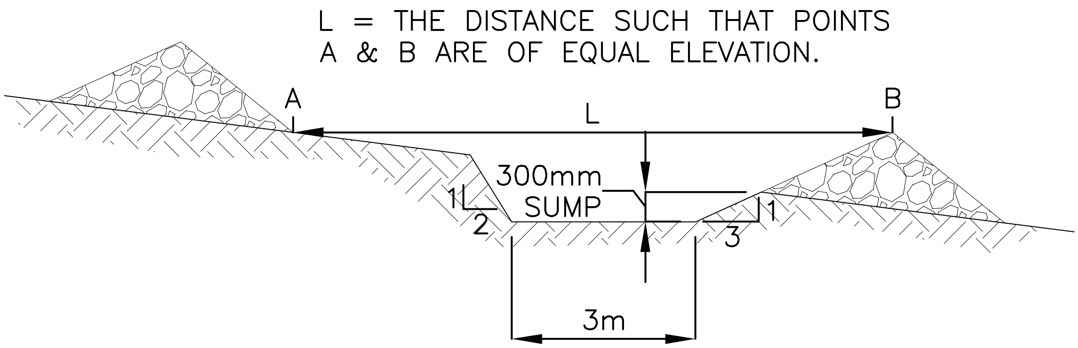


STONE CHECK DAM SECTION

N.T.S.

CHECK DAMS

SC–9–1



SPACING BETWEEN STONE CHECK DAMS

N.T.S.

CHECK DAMS

SC–9–2

Slope Drains and Subsurface Drains - SC-10

Description - Pipes which reduce erosion along slopes by intercepting and conveying runoff or groundwater from the top of the slope to a discharge point at the bottom of the slope. Slope drains are primarily used to convey runoff down cut or fill slopes. Subsurface drains are used to remove water from the soil in sloped areas.

Applications

- The use of slope drains is applicable to the following:
  - o Drainage of runoff from within swales or behind dikes located at the top of slopes; and
  - o Drainage of surface runoff to prevent erosion along the slope.
- Emergency spillways for sediment basins.
- Use of subsurface drains applicable to areas where water must be removed from the soil to lower the groundwater table or to prevent soil saturation.

Requirements

- Design of slope drains shall consider the following:
  - o Consult with a hydro-geologist or qualified engineer regarding design flows;
  - o Limit drainage area discharging to slope drain to less than 2 Ha;
  - o Direct surface runoff into slope drain using interceptor dikes at the top of slope. Refer to SC-6 (Earth Dike) and SC-7 (Temporary Drains and Swales) in this manual for more information;
  - o Pipe slope drains exceeding 300mm in diameter require a standard flared end section or headwall constructed at the inlet and outlet;
  - o Install a lining such as a vegetation or geotextile filter fabric to protect the area around the inlet;
  - o Install rip-rap or other energy dissipation device at outlets;
  - o Compact soil under and around inlet, outlet, and along the pipe;
  - o Slope drains may either be installed above ground or buried beneath the slope surface;
  - o Above ground installation shall utilize pipe anchors to secure pipe to ground;
  - o Align slope drain perpendicular to contours of slope;
  - o Generally limit maximum slope to 2:1 (H:V). For slopes exceeding 2:1 (H:V), velocity dissipation is required at the pipe outlet; and
  - o Direct sediment-laden storm water to a sediment trap or sediment basin.

Challenges

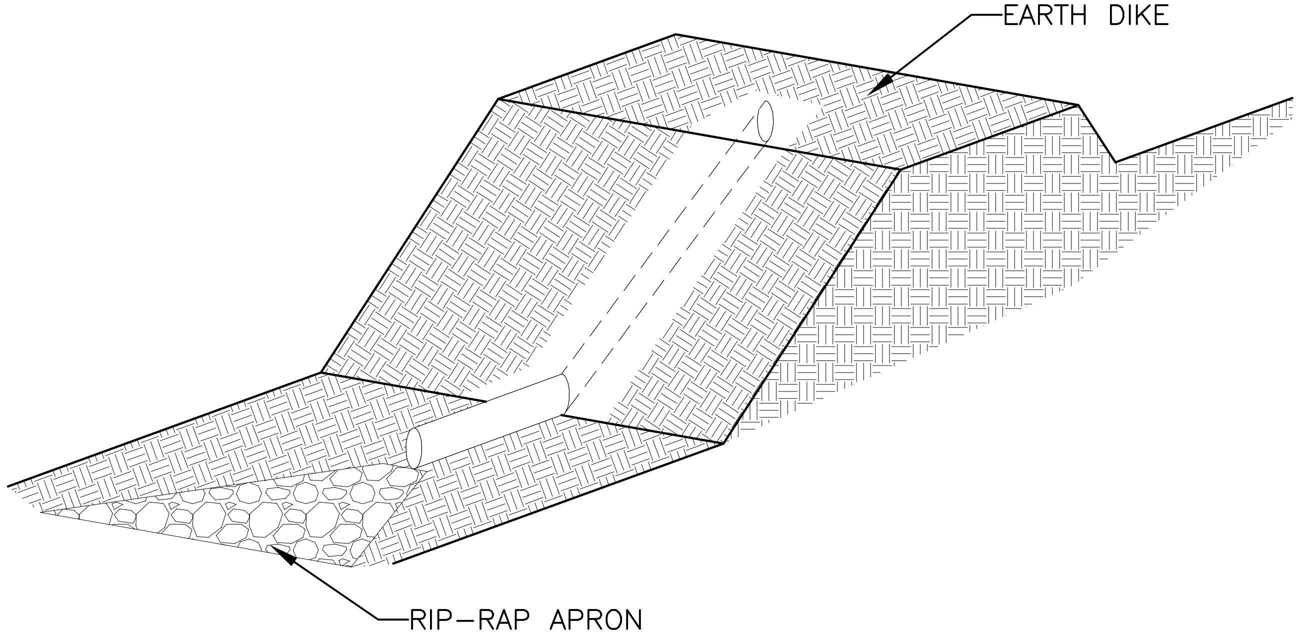
- Drainage area discharging to slope drains shall not exceed 2 Ha. For larger areas, use multiple pipes, paved chute, or rock lined channel.
- Clogged slope drains direct runoff around pipe which may result in erosion along the slope.
- High flow velocities at the pipe outlet require implementation of velocity dissipation devices to prevent downstream erosion.
- Severe flooding and erosion may result from failure of slope drains.

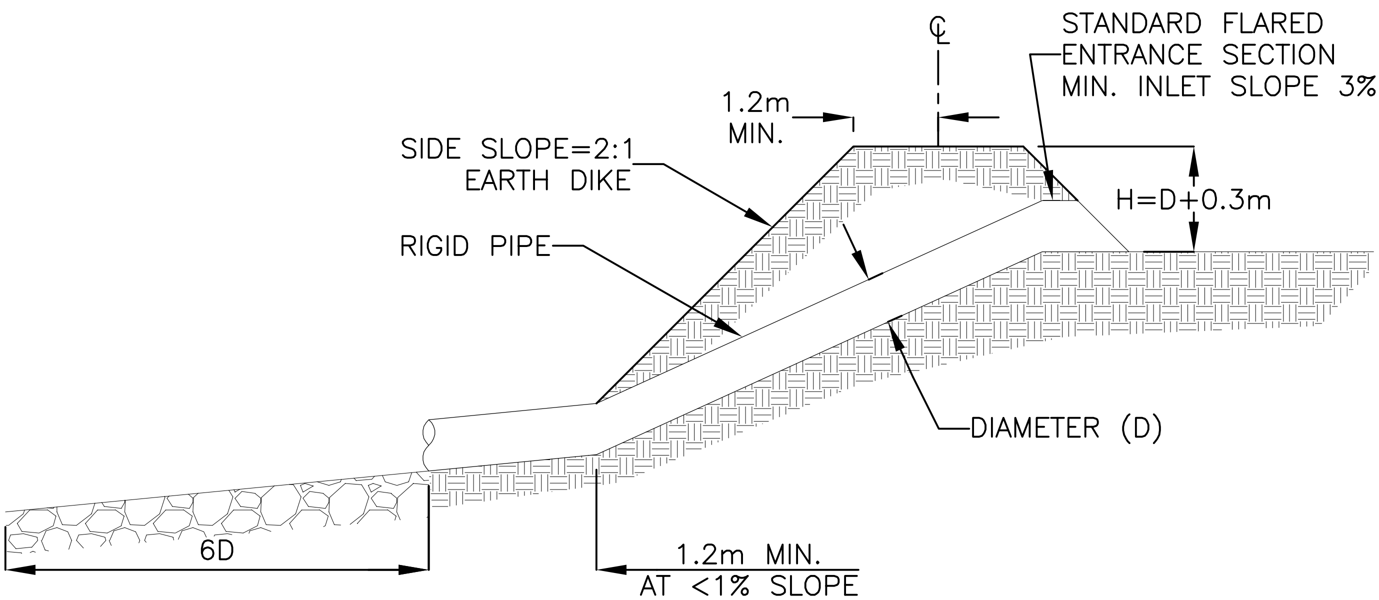
Inspections and Maintenance

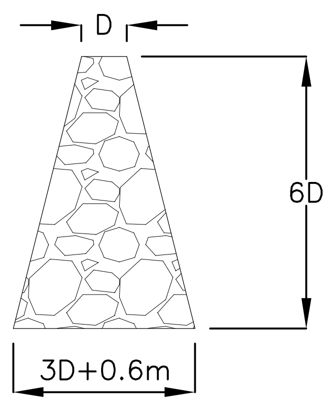
- Inspect weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall for erosion at outlet and downstream scour. Repair damage and install energy dissipation devices as necessary.
- Inspect slope drains for debris and sediment accumulation. Remove sediment and debris from entrances, outlets, and within drains.
- Inspect pipe anchors to ensure pipe remains anchored to slope.

• Verify ponding does not occur in areas such as roadways and stockpiles.

See Figure SC-10-1 and SC-10-2.







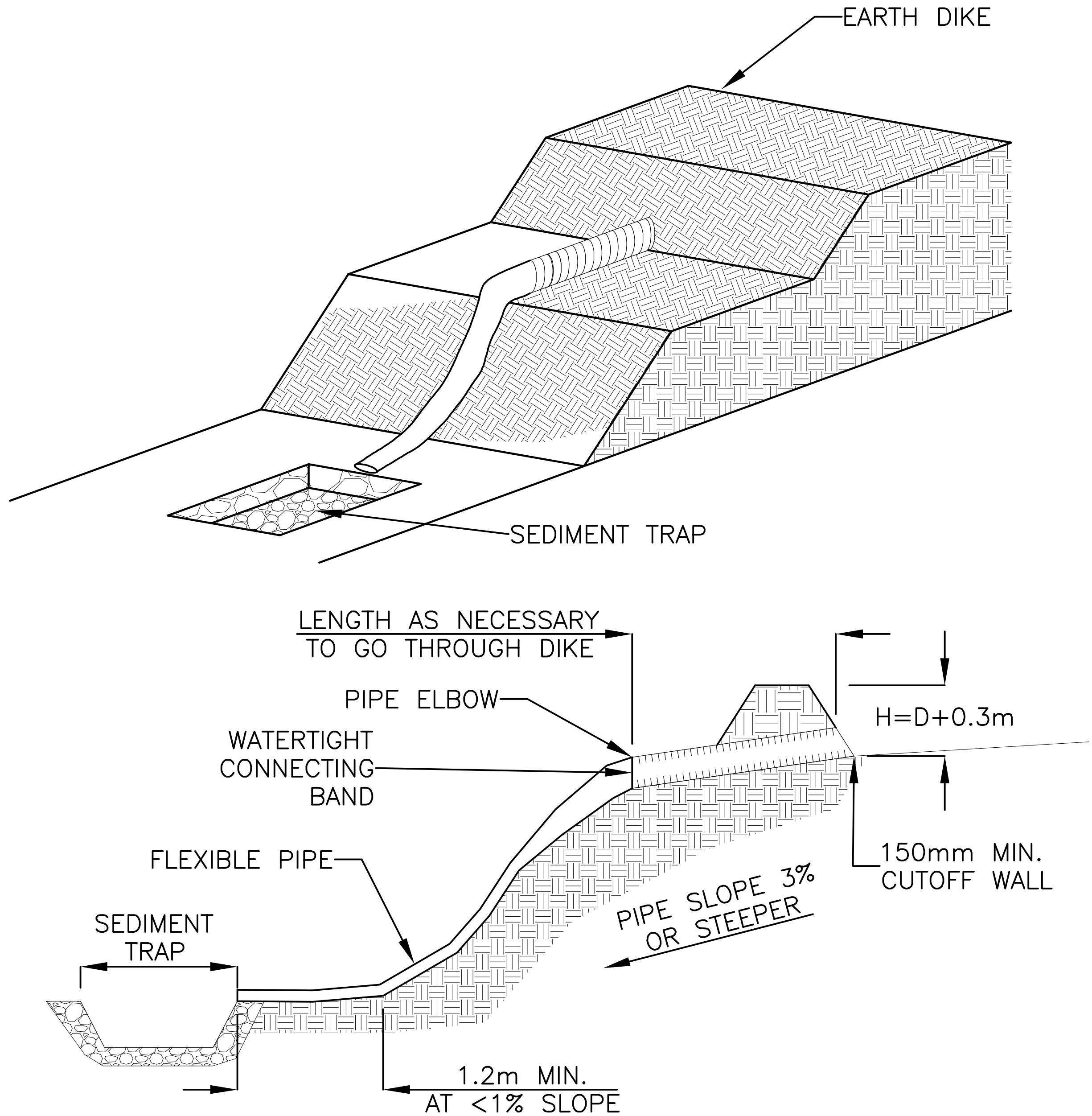
NOTE:
RIP-RAP SHOULD CONSIST OF 150mm DIAMETER STONE PLACED AS SHOWN AND SHOULD BE A MINIMUM OF 300mm IN THICKNESS.

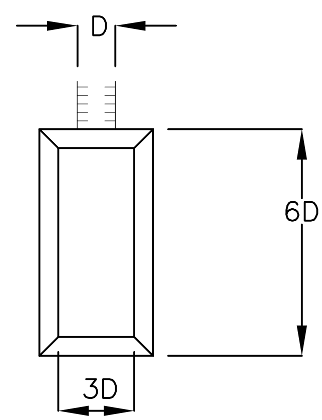
PIPE SLOPE DRAIN (RIGID)

N.T.S.

SLOPE DRAINS AND SUBSURFACE DRAINS

SC-10-1





NOTE:
RIP–RAP SHOULD CONSIST OF 150mm DIAMETER STONE PLACED AS SHOWN. DEPTH OF SEDIMENT TRAP SHOULD EQUAL PIPE DIAMETER AND SHOULD BE A MINIMUM OF 300mm IN THICKNESS.

PIPE SLOPE DRAIN (FLEXIBLE)

N.T.S.

SLOPE DRAINS AND SUBSURFACE DRAINS	SC–10–2

Top and Toe of Slope Diversion Ditches and Berms - SC-11

Description - Devices used to minimize sheet flow over slopes and reduce erosion by intercepting and conveying runoff to sediment removing structures or a protected drainage system.

Applications
- Areas which must be protected from runoff flowing down slopes.
- Areas where runoff must be intercepted at bottom of slope.

Requirements
- Design flows and safety factors should be determined by consideration of risks associated with; erosion, overtopping, flow backups, or structure washouts.
- Line or stabilize ditches prone to high flow velocities.
- Direct flows at top of slopes to slope drains. Refer to SC-10 (Slope Drains and Subsurface Drains) in this manual for more information.
- Protect outlets from erosion.

Challenges • Additional sediment trapping BMP devices may be necessary for sediment-laden runoff.

Inspections and Maintenance
- Inspect weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall.
- Inspect ditches/berms for washouts. Repair requirements shall include replacement of rip-rap, damaged lining, or soil stabilizers and compaction and re-vegetation of fill berms and ditches.
- Inspect structures for accumulated sediment and debris and remove as necessary.

Sandbag Barrier - SC-12

Description - Stacked sandbags can intercept sediment-laden runoff and allow sediment to settle prior to discharge off-site.

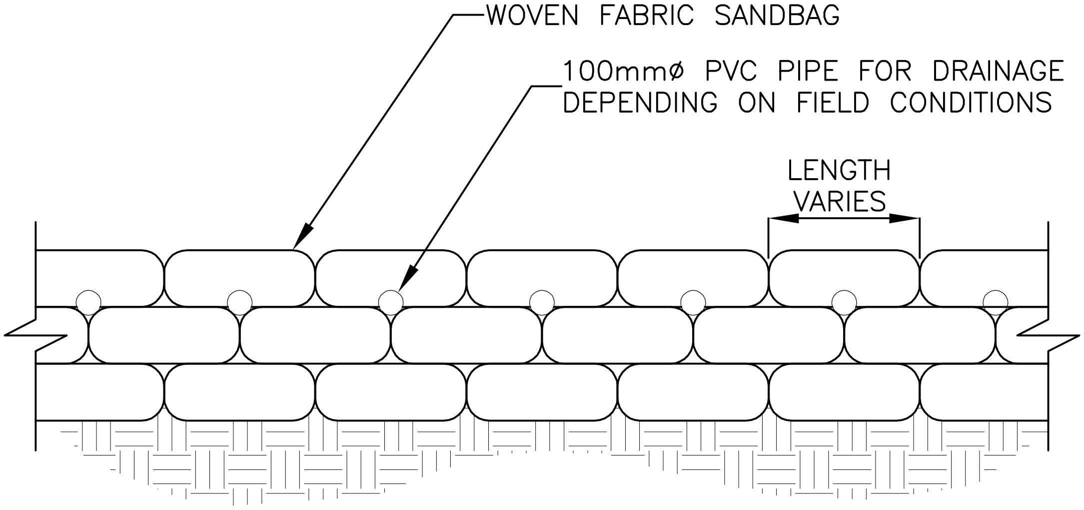
Applications – Numerous applications include the following:
• Along site perimeters.
• Along streams and channels banks (outside of riparian zone).
• Utility trench barriers in channels.
• Across swales with small catchments.
• Diversion dikes or berm.
• Below the toe of exposed slopes.
• Temporary sediment traps.
• Around stockpiles.

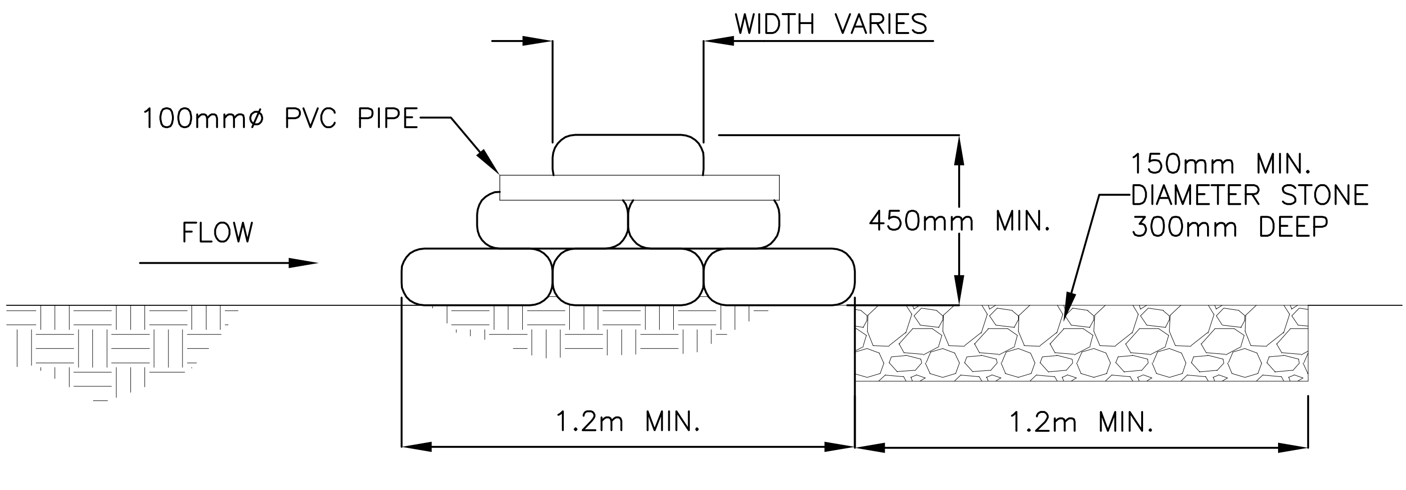
Requirements
• Install bags end-to-end along a level contour.
• Turn ends of sandbag barrier up slope to prevent flow around ends.
• May be used in combination with soil stabilization controls up slope.
• Materials for sandbag barrier shall comply with the following:
    o Sandbag shall be woven polypropylene or polyamide fabric with ultraviolet protection to avoid rapid deterioration of fabric.
    o Bag dimensions can vary but must be able to withstand anticipated flows.
    o Fill material shall consist of non-cohesive, permeable material free from clay and deleterious material.

Challenges
• Drainage area shall not exceed 2 Ha.
• Avoid installing at locations which may compromise traffic safety.
• Burlap material can be used when woven polypropylene or polyamide fabric bags are not available. The burlap should be treated to prevent mould or mildew.

Inspections and Maintenance
• Inspect weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall.
• Reshape or replace sandbags as necessary.
• Remove and properly dispose of sediment, which has accumulated to a depth of 150mm.

See Figure SC-12





N.T.S.

SANDBAG BARRIER

SC–12

Brush or Rock Filter - SC-13

Description - A brush or rock filter is a berm composed of rock or brush placed across an area where sheet flow may occur. Sedimentation will occur as runoff intercepted by the berm is detained.

Applications

- Check dams across construction roads with mild slopes.
- Below the toe of slopes.
- Along the site perimeter, streams, or channels.
- Around temporary spoil areas.
- Downstream of small cleared areas.
- Sediment traps at culvert or pipe outlets.

Requirements

- Use stones between 20 to 75 mm in diameter or brush wrapped in geotextile filter fabric. Brush from site clearing may be used.
- Place across areas of sheet flow.
- If stones are used across an area of concentrated flow, use larger stones placed in staked and woven wire sheathing.
- Construct along a level contour.
- Provide an area behind the berm for detention and sedimentation.

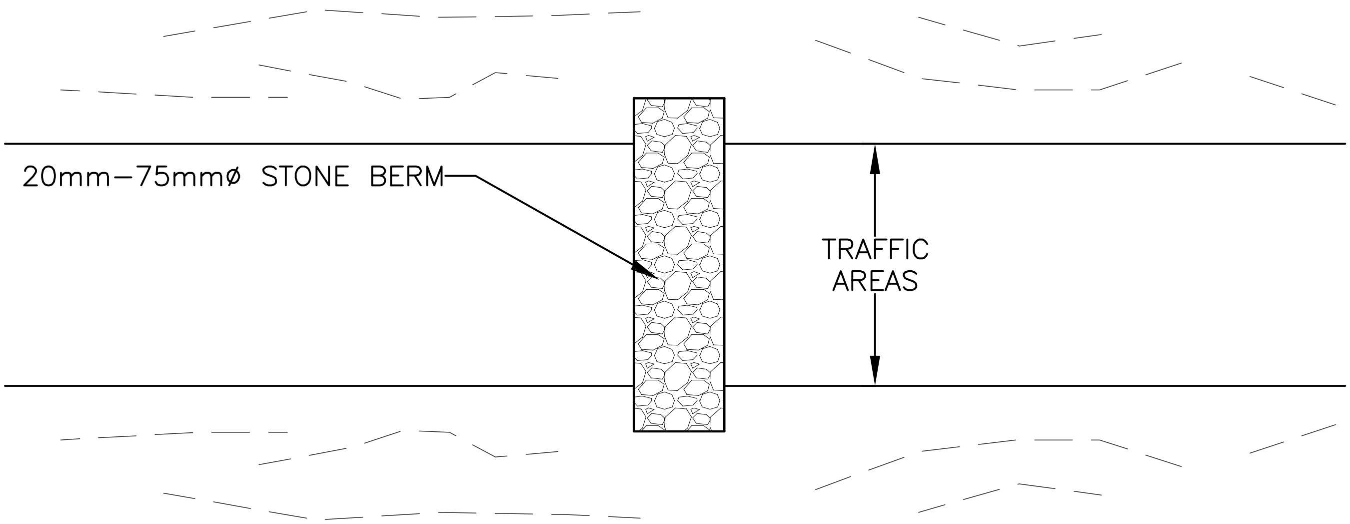
Challenges

- Adequate detention area behind berm is necessary to prevent flooding upstream.
- Drainage area shall not exceed 2 Ha.
- Removal of stone berms may be difficult resulting in limited usefulness in landscaped areas.

Inspections and Maintenance

- Inspect weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall.
- Reshape berm and replace any missing or dislodged stone or brush.
- Remove and dispose of sediment on upstream side of filter upon reaching a depth of 150mm.

See Figure SC-13



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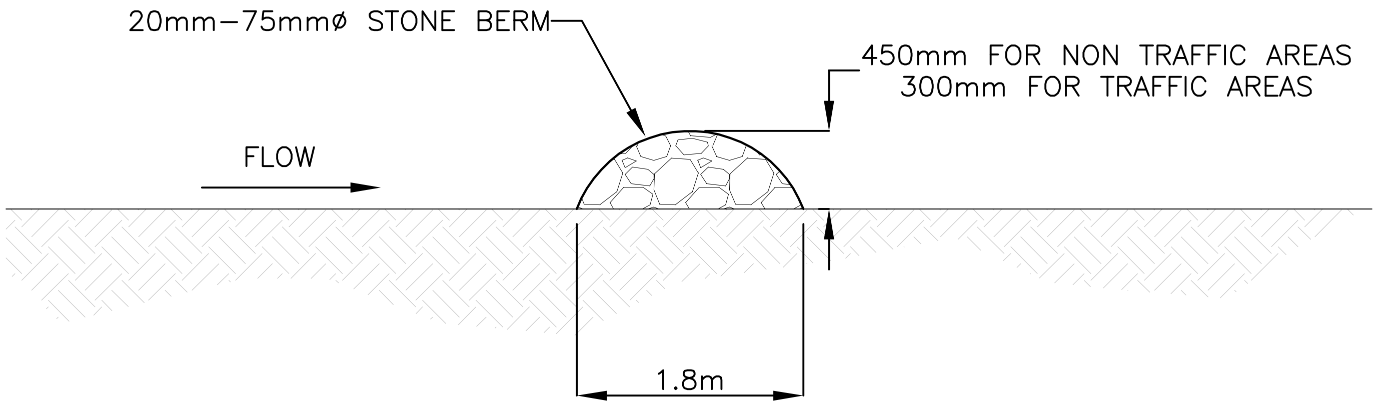


SECTION

N.T.S.

BRUSH OR ROCK FILTER

SC–13

Sediment Trap - SC-14

Description – A sediment trap is a temporary runoff containment device, which promotes sedimentation prior to discharge of the runoff to a storm system or receiving water.

Applications

- Drainage areas less than 2 Ha.
- Areas along the perimeter of the site where sediment-laden runoff is discharged off-site.
- Areas requiring additional sediment containment measures such as discharge to a storm system or receiving water.

Requirements

- Construct sediment trap prior to engaging in site earth works.
- Location of the sediment trap shall be based on the following:
    - o Area where a low embankment may be constructed across a swale;
    - o Area where failure of sediment trap will not cause property damage or personal injury; and
    - o Area where maintenance crew may easily access sediment trap.
- Sediment trap size shall be based on the following:
    - o Minimum trap settling volume of 250 m^3 / Ha;
    - o Minimum trap sediment storage volume of 62.5 m^3 / Ha;
    - o Trap width shall be less than half of the trap length; and
    - o Flood volume which may contain a major flood without damage to upstream areas or overtopping the embankment.
- Construct sediment trap by excavating ground or constructing an earthen embankment to create a containment area.
- Area under embankment shall be cleared, grubbed, and stripped of vegetation and root mat.
- Fill material for embankment shall be free of roots, woody vegetation, over-sized stones, rocks, organic material, or other objectionable material. Compact embankment by traversing with construction equipment.
- Stabilize trap outlet with stone or vegetation.
- Install fencing to prevent unauthorized entry and for safety purposes.
- All pipe joints shall be watertight when a riser is used.
- The top 2/3 of the riser shall be perforated with holes 25 to 100mmm in diameter. The holes shall be vertically spaced at 200mm intervals and horizontally spaced at 250 to 300mm intervals.
- Outlet crest elevation of an earth or stone outlet shall be a minimum of 300mm below the top of the embankment.

Challenges

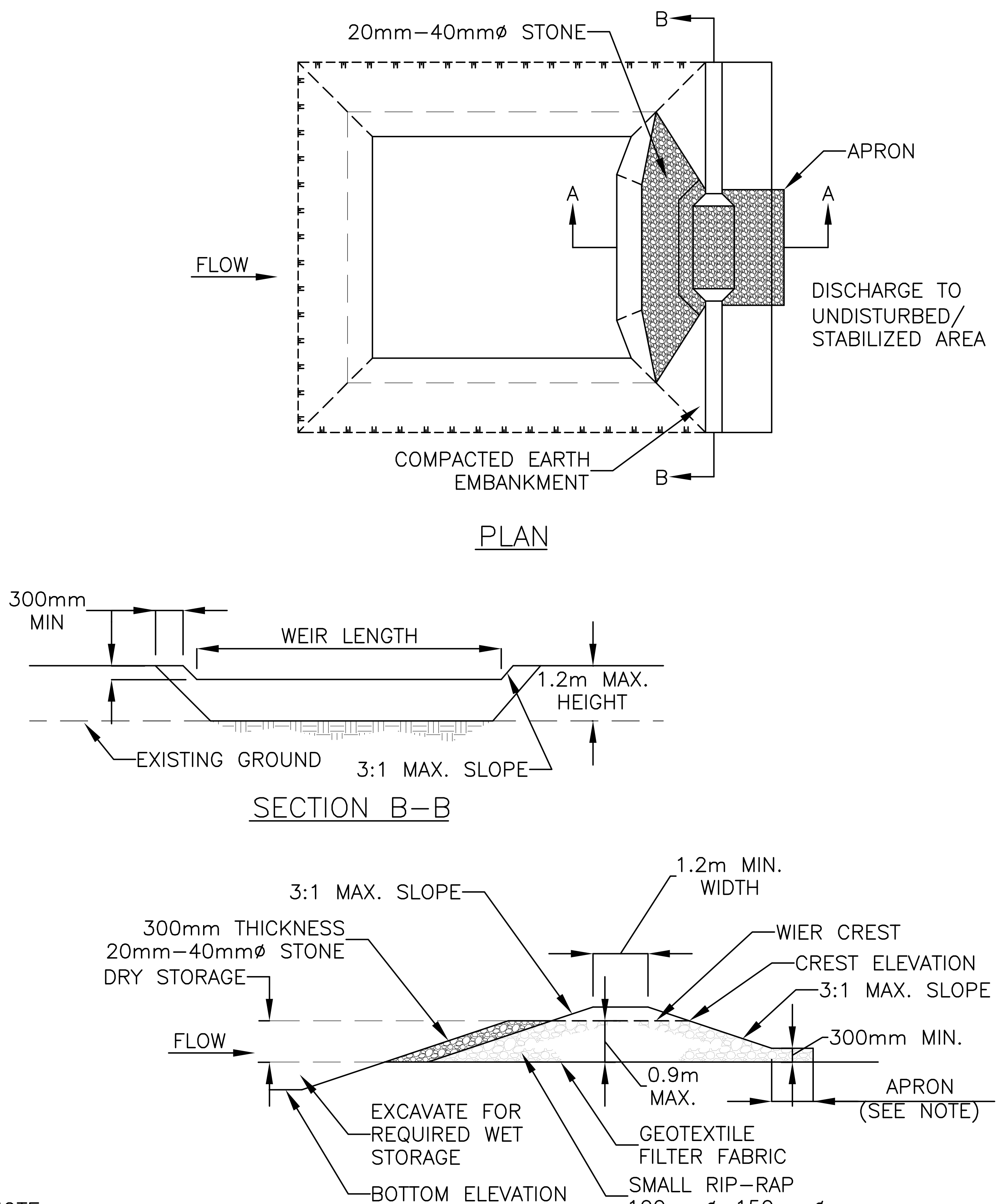
- Applies to maximum drainage area of 2 Ha. Drainage areas exceeding 2 Ha shall implement Sediment Basins. Refer to SC- 15 (Sediment Basin) in this manual for more information.
- Only removes large and medium size particles.
- Requires protective fencing.
- Cannot be installed in streams.
- Availability of right-of-way may limit size of sediment trap.

Inspections and Maintenance

- Inspect weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall.

- Inspect spillway and outlet for obstructions or damage. Remove obstructions and repair damage as necessary.
- Inspect outlet for erosion and stabilize as necessary.
- Inspect fencing for damage and repair as necessary.
- Remove sediment which has accumulated to within 300mm of the top of the dry storage volume.
- Properly dispose of sediment and debris removed from sediment trap.

See Figure SC-14-1 and SC-14-2.

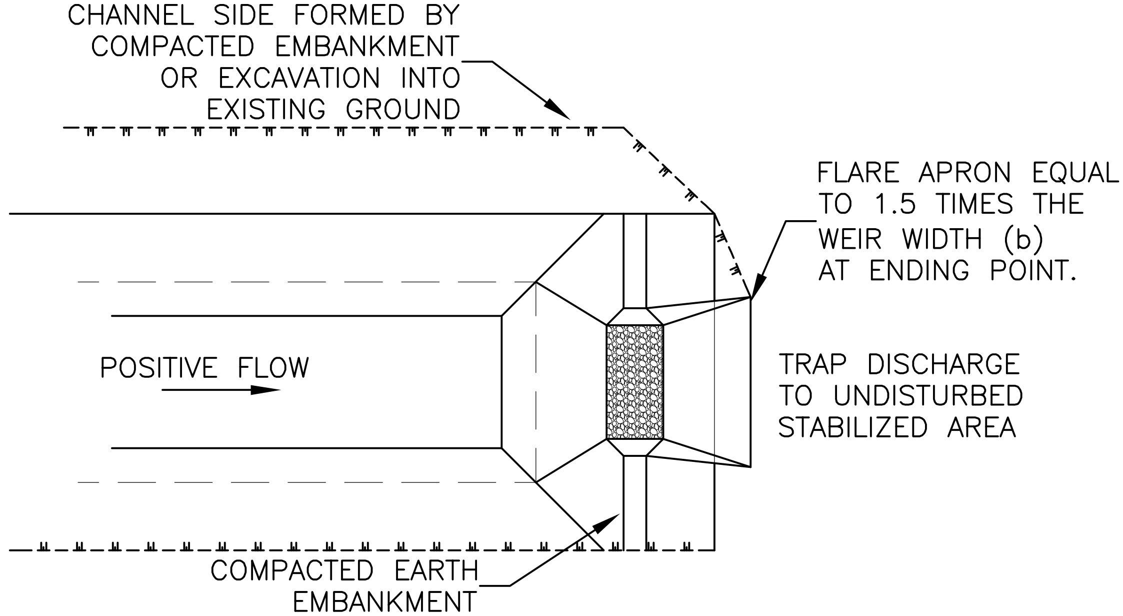


NOTE:
MAXIMUM DRAINAGE AREA=2 HECTARES

STONE OUTLET SEDIMENT TRAP

N.T.S.

SEDIMENT TRAP	SC–14–1



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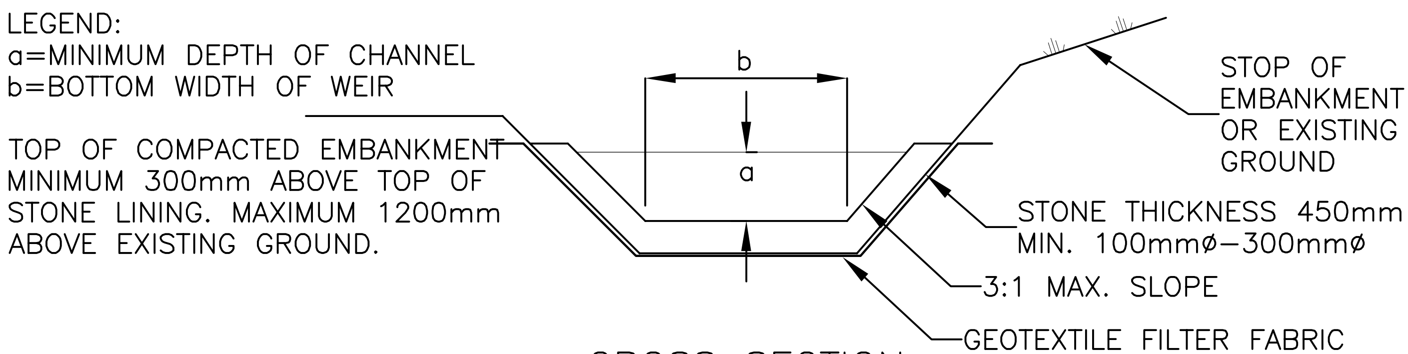
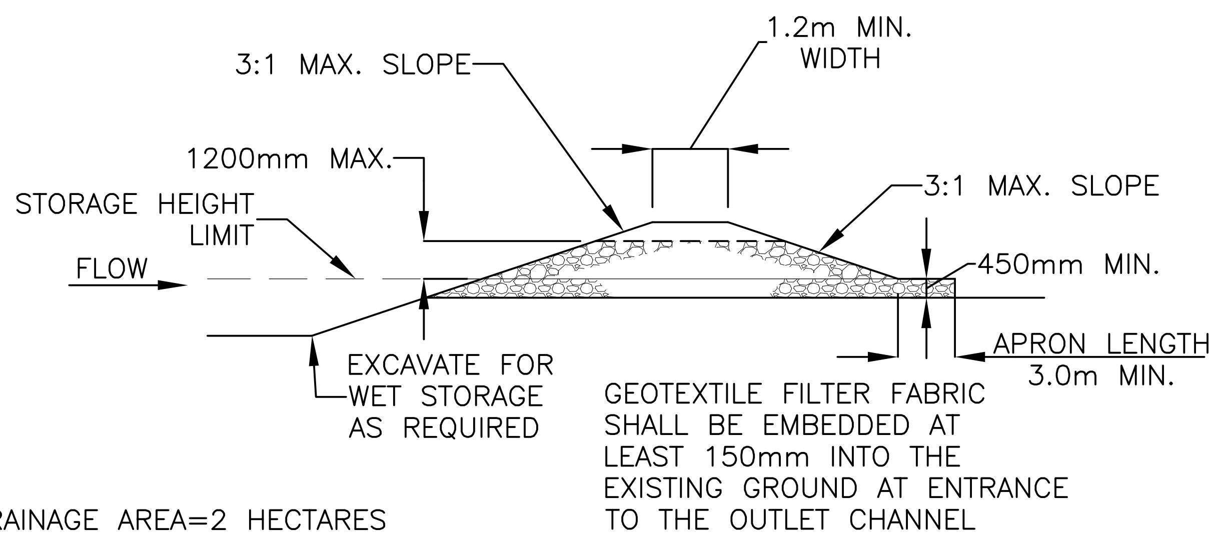


CROSS SECTION



NOTE:
MAXIMUM DRAINAGE AREA=2 HECTARES

PROFILE

RIP–RAP SEDIMENT TRAP

N.T.S.

SEDIMENT TRAP

SC–14–2

Sediment Basin - SC-15

Description – A sediment basin is a temporary basin which intercepts sediment-laden runoff and allows sediment to settle prior to discharge of the runoff to the storm system or receiving waters.

Applications

• Drainage areas larger than 2Ha.
• Areas where sediment-laden runoff is discharged to the drainage system or receiving water.

Requirements

• Construct sediment basins prior to clearing, grubbing, or grading activities.
• Location of a sediment basin shall be based on the following:
  o Area where terrain forms a natural basin;
  o Area which minimizes construction interference;
  o Area where maximum benefit may be achieved from the existing terrain to minimize earth works
  o Area where failure of sediment basin will not cause property damage or personal injury;
  o Area where maintenance crew may easily access sediment basin; and
  o Area where permanent detention basin will be constructed.
• Sediment basin shall be designed to allow 70 to 80 % of the sediment to settle during a 24 to 40 hour detention time.
• The sediment basin is divided into two zones:
  o Sediment storage zone with a minimum of 300mm in depth and
  o Settling zone with a minimum of 600mm in depth
• Sediment basin design shall be based on the following requirements:
  o Settling zone volume shall be determined by the following equation:
  V=1.2(SD)Q/VSED

Where:

V =Settling zone volume

SD =Settling depth, which shall be a minimum of 600mm and greater than the average distance from inlet to outlet of the basin divided by 200

VSED=Settling velocity of the design soil particle (medium silt). The settling velocity of a medium silt soil particle is 0.3mm/s

Q =CIA

Where:

Q =Discharge rate measured in m^3/s

C =Runoff coefficient

I =Precipitation intensity for the 10 year, 1 hour rain event

A =Area draining into the sediment basin in Ha;

- Basin geometry for the sediment storage zone shall be determined by a minimum depth of 300mm and 3:1or flatter side slopes extending from the bottom of the basin. Basin bottom shall be level;
- Provide an emergency spillway with the top of the riser pipe 300mm below the crest elevation;
- Sediment basin length to settling depth ratio (L/SD) shall not exceed 200; and
- Sediment basin length to width ratio shall not be less than 6:1 or baffles shall be installed.
- Anti-seep collar shall be securely anchored and installed on the outlet pipe/riser.

- Construct sediment basin by excavating ground or constructing an embankment of compacted soil.
- Sediment basin may have more than one inflow point.
- Stabilize inlet, outlet, and slopes of basin with rock or vegetation.
- Install fencing to prevent unauthorized entry and for safety purposes.

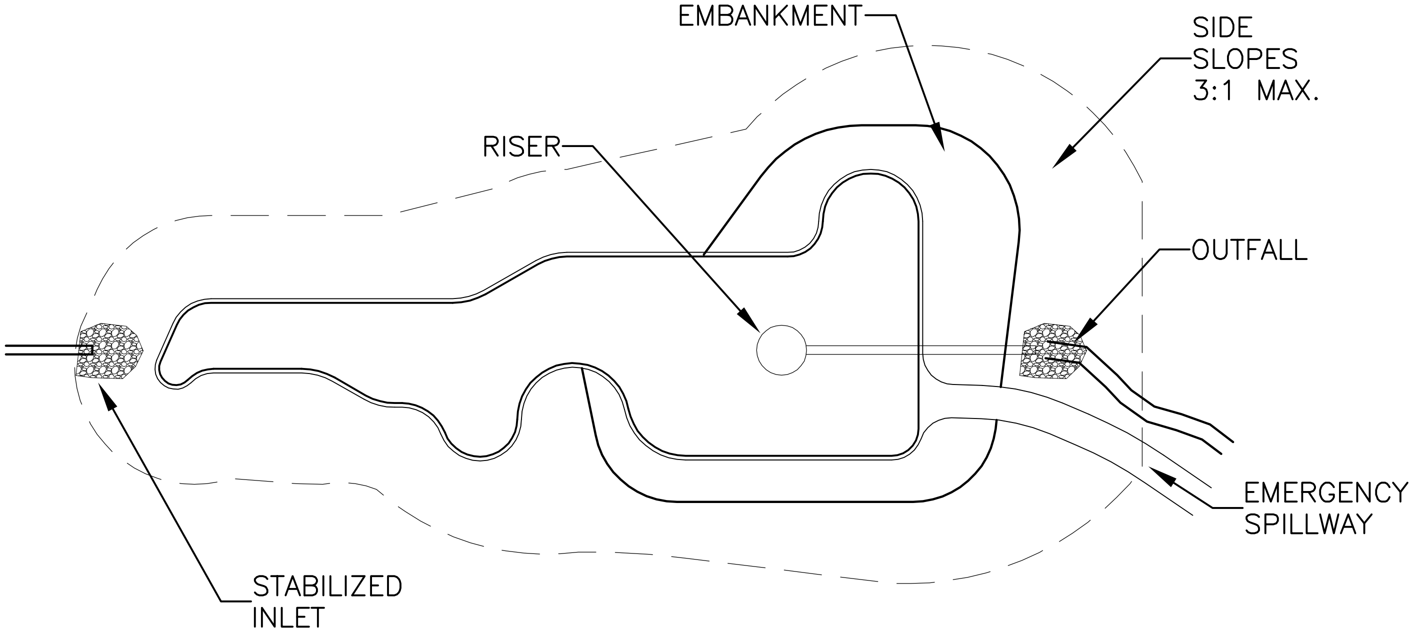
Challenges

• Limited design life of 12 to 18 months.
• Sediment basin removes medium size particles.
• Additional BMPs such as seeding, mulching, and diversion dikes may be used to reduce the amount of sediment intercepted by the basin.
• Requires protective fencing for safety.
• Inappropriate for installation in streams.
• Availability of right-of-way may limit size of sediment basin.
• Large basins may be subject to provincial requirements for dam safety.

Inspections and Maintenance

• Inspect weekly during dry periods as well as within 24 hours of any rainfall of 10mm or greater which occurs in a 24-hour period and daily during periods of prolonged rainfall.
• Inspect inlet and outlet for obstructions or damage. Remove obstructions and repair damage as necessary.
• Inspect outlet for erosion and stabilize as necessary.
• Inspect fencing for damage and repair as necessary
• Remove sediment when the sediment storage volume is half full.
• Properly dispose of sediment and debris removed from sediment basin.

See Figure SC-15



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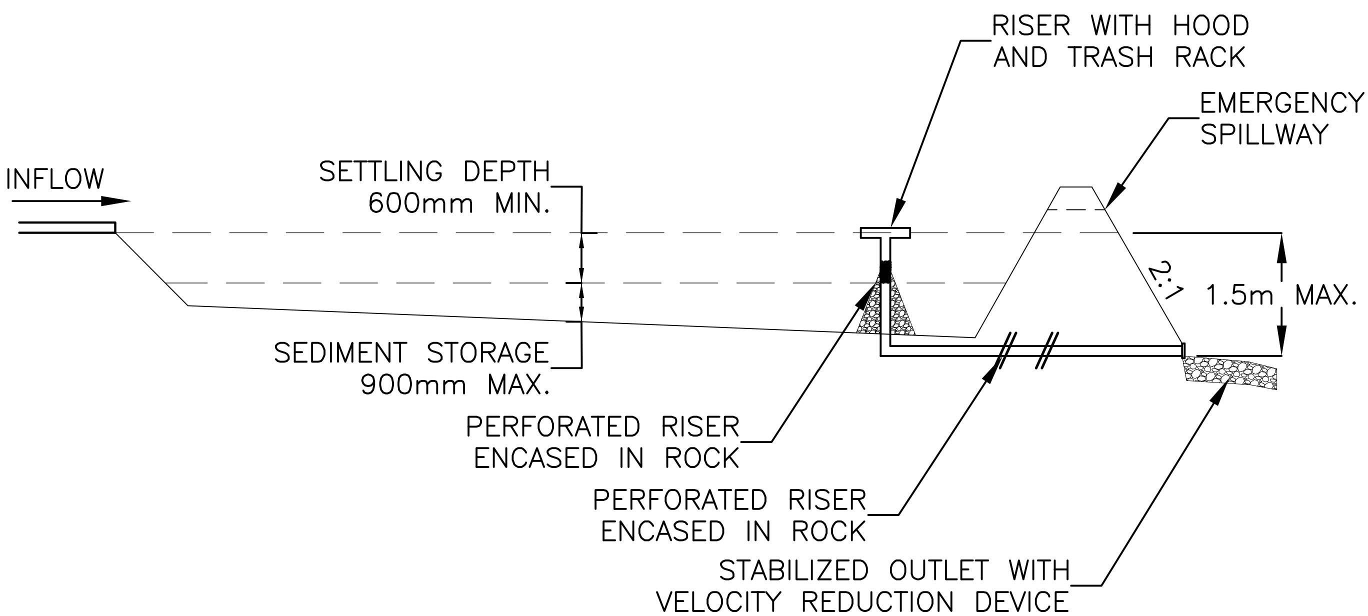


SECTION

N.T.S.

SEDIMENT BASIN

SC–15

PART B - PERMANENT BEST MANAGEMENT PRACTICES

Chapter B1 - Background

1.1 Environmental Background

Urban development has a profound influence on the quality of water on the watershed within the Okanagan. Site developments result in land use and land cover changes thereby altering the hydrologic cycle. The ability of the ground to absorb rainfall diminishes as pervious surfaces become impervious and ultimately rainfall yields storm water runoff.

Impervious surfaces accumulate pollutants deposited from the atmosphere, leaked from vehicles or windblown from adjacent areas. During storm events, these pollutants are washed off impervious surfaces and discharged to receiving waters via surface runoff. Common pollutants contained in urban storm water runoff include nutrients (e.g. phosphorus and nitrogen), suspended solids, organic carbon and hydrocarbons, bacteria, metals, pesticides, and trash and debris. These pollutants reduce water quality. In addition, groundwater recharge, which functions as a natural pollution filter diminishes as impervious surfaces increase. Impervious surfaces also increase the rate and velocity of storm water runoff, which may potentially cause flooding problems, increase the soil erosion in the receiving channel, and alter the geomorphic balance of the streams. Geomorphic instability causes streams to widen and down cut rapidly thereby causing unbalanced channel erosion, which ultimately results in the degradation of stream habitats.

1.2 Introduction to this Chapter

The District of West Kelowna operates a municipal storm drainage system within the District boundaries. The operation and discharge of this system is designed to project local surface and groundwater resources. Direct outfalls into Lake Okanagan are authorized and governed by the Province of British Columbia and are subject to permit requirements issued by the BC Ministry of Environment.

To fulfill its objectives and to address storm water pollution associated with runoff, the District implements Permanent Best Management Practices (BMPs) that apply to applicable new developments and significant redevelopment projects.

The purpose of this Chapter is to provide procedures and guidelines to ensure that permanent BMPs are being considered and implemented throughout all phases of site development, including planning, design, construction, and maintenance.

1.3 Scope

All projects are subject to District review to determine if storm water permanent BMPs are required. If applicable, the storm water permanent best management practices and measures shall be designed consistent with this manual and constructed according to the project plans approved by the District.

1.4 Design Criteria

The BMP(s) required shall be designed and installed in accordance with the criteria, guidelines, and design standards described in this manual. The permanent BMP(s) shall be maintained in its perpetuity unless the original purpose of the project no longer exists. The permanent BMPs are intended to reduce storm water pollution typically associated with the increased impervious surfaces. Typical pollutants contained in the storm water runoff may include, but are not limited to, phosphorus, nitrogen, sediment, heavy metals, oil and grease. Unlike construction activities BMPs, the storm water permanent BMPs are designed to remain part of the project features after the site grading operation is completed.

The type and size of the permanent BMPs is dependent on the water quality and water quantity a project is required to control and should be designed in accordance to the sizing guidelines outlines in this manual.

1.5 Redevelopment

New development and redevelopment projects are subject to the same criteria as described in this manual. Where conditions prevent impervious area reduction or on-site storm water management (quality or quantity), practical alternatives may be considered. Alternatives are subject to District approval and include but are not limited to:

- Stream restoration (length of restoration subject to BC Ministry of Environment approval);
- Retrofitting an existing BMP; and
- Other practices approved by the District

Special Conditions

Projects with special conditions may be subject to the rules and criteria contained in this manual regardless of area of the new impervious surface. Special conditions are determined by the District and may include District projects which drain to sensitive receiving waters.

Chapter B2 - Permanent BMP Consideration in Planning and Design Phase

2.1 Introduction

As the District implements a proactive storm water management program and applies unified criteria for all new development and significant redevelopment projects, it is important for District personnel, private consultants, and contractors to consider permanent BMPs throughout every phase of a project, including planning, conceptual engineering, and final design. Early consideration of permanent BMPs will help identify sufficient rights-of-way needs and costs, potential community impacts, and design conflict. All of these factors may lead to poor design and project delays. As detailed in various chapters of this manual, the District emphasizes the consideration of permanent BMPs throughout the 'Life Cycle" of a project, from the planning phase to the maintenance phase.

2.2 BMP Concepts in Project Planning Phase

Purpose

Storm water permanent BMPs should be considered in determining impacts to receiving surface waters and groundwater. In certain situations, permanent BMPs can be difficult to accomplish and may affect the feasibility of the project options and alternatives being evaluated. The requirements and rights-of-way demands of permanent BMPs can greatly affect the selection of project preferred alternatives. Therefore, it is critical to develop permanent BMPs early during the project planning phase and include them in impact assessment and project cost estimating. Early consideration of storm water permanent BMPs will likely lead to more cost-effective projects.
The storm water permanent BMP concept studies should begin when design alternatives are selected for detailed study.

Concept Development

Once it is determined that a project is subject to permanent BMP requirements, the concept should be developed by a licensed engineer with support from project planners and landscape architects. The study should be completed prior to advancing to detailed design.

Certain basic information is needed in order to conduct a concept development study. The information should at minimum include topographic mapping for the entire study area, including adequate area on both sides of all the alignments being considered for the extents of the project in order to locate permanent BMP facilities. The topographic mapping should identify approximate property lines, existing developments, and publicly owned land. The proposed project extents should be superimposed on the mapping.
Approximate locations of permanent BMPs should be identified on the topographic map. Once study points are identified, the volumetric storage requirements should be estimated. This process requires delineation of approximate drainage areas reaching the study point. Water quality volume should be estimated based on the criteria set forth in Chapter 3 of this manual. Since the required volume and

footprint of the permanent BMP may affect the right-of-ways required, which in turn influences the selection of the alternative, additional volumes based on a reasonable estimation should included. This additional volume should be estimated based on site specific conditions.

Surface areas for the permanent BMPs can be estimated using an assumed depth and the volumes computed. In cases where the designer is proposing flow-through based BMPs, the surface areas of the BMPs should be identified based on the flow rate requirement presented in Chapter 3 and specific BMP type.

Once the surface area required is determined, the BMP footprints can be placed on the topographic maps. Design engineers should consult with environmental scientists, and landscape architects to ensure that terrain, natural resources, and land use are properly considered in the concept development and to avoid unnecessary impacts. Available software such as the Water Balance Model should be reviewed and incorporated into the concept design as a valuable resource.

Content of Permanent BMP Concept Report

The storm water permanent BMP planning concept report should include the following:

- Description of the project area;
- Description of the environmental resources such as receiving waters, wetlands and waters of floodplains/floodways etc.;
- Description of the outfalls and how they are identified;
- Regulatory requirements;
- Proposed permanent BMP concept descriptions along with assumptions made. List BMP alternatives with recommended design;
- Surface area and volume tabulation;
- Rights-of-way required;
- Preliminary construction cost for the proposed BMPs; and
- Appendices which consist of existing and proposed drainage area maps (including study points), photos, and calculations.

Review and Approval

The project planner/engineer shall submit the permanent BMP concept report and required information to the District for review and approval.

2.3 Storm Water Permanent BMP in Project Design Phase

Development of permanent BMP design concepts starts at the initiation of project design. Detailed surveys and design information are necessary to produce conceptual designs which can be refined as the project progresses. For projects that have a planning concept report, the permanent BMP planning concept should be the basis for developing the design concept.

Permanent BMP Conceptual Design Process

For District projects, the permanent BMP conceptual design should be completed by the 30% plan stage. This requires the engineers to begin the design earlier to identify conflicts, solutions, and cost before a formal 30% cost estimate is generated.

At the design phase, study point identification is similar to the process used for the development of the planning concept. For projects where storm water runoff is discharged from the site in a sheet flow fashion, lines of study (LOS) should be identified and care should be taken to follow the drainage patterns within and outside the site boundaries

Hydrologic analysis should be conducted in accordance with District hydrologic and hydraulic guidelines. Drainage area maps using the best available information should be developed for both existing and proposed conditions.

Outfalls at all study points should be evaluated thoroughly by a licensed engineer. The evaluation should include photographs and channel stability assessment. In some cases, the outfall channel evaluation may be required to extend beyond District rights-of-way. For connections to a closed storm drain system, the evaluation should include the capacity of the downstream drainage system.

If the proposed project reduces existing water quality treatment in the existing grass channels and buffers by adding new curb or reducing existing sheet flow buffer, the preconstruction pavement draining towards such grass channels and buffers must be identified to compensate for the lost water quality treatment. Computations should be made to determine the amount of existing water quality treatment reduced. Means of compensation or mitigation should also be identified in addition to the new water quality treatment required.

Content of Permanent BMP Design Report

The storm water permanent BMP design concept report should include the following:
- Description of the project area;
- Description of the environmental resources;
- Description of the outfalls and how they are identified;
- Outfall condition report;
- Regulatory requirements;
- Preliminary permanent summary and checklist sheet;
- Proposed BMP location;
- Proposed permanent BMP concept descriptions including assumptions, type, and treatment;
- Surface area and volume tabulation;
- Right-of-way needed;
- 30% plans with topographic maps showing footprints of proposed BMPs;
- Preliminary construction cost for the proposed BMPs; and
- Appendices which consist of existing and proposed drainage area maps (including study points), photos, and computations.

Review and Approval

Submittals for review and approval include in the permanent BMP plans, design report, and other required information will be performed by District staff.

2.4 Hydraulic Design Criteria

Computations for runoff, conduit and channel sizes, slopes, losses, hydraulic gradient, and other hydraulic characteristics and information pertinent to the system shall be properly arranged and presented in such a manner that they may be readily checked. The following data shall be shown on the construction plans:

• Design flow (Q), watershed area (A), roughness coefficient (n), and velocity (v) for all conduits and channels;
• Hydraulic grade lines, including water surface elevation at each manhole and catch basin;
• Building setback lines, where required; and
• Floodway/flood fringe boundary, as applicable.

Where interim drainage measures are required due to restrictions in the downstream drainage systems, the following additional data shall also be provided:

- Runoff rate using the design storm for existing upstream land use conditions;
- Runoff volume using the design storm for existing upstream land use conditions;
- Detention volume and discharge rate;
- If necessary, capacity of downstream drainage systems.
- Backwater will not significantly increase flood damage to property upstream of the crossing. No increase in backwater where possible. No flooding onto private property.
- Velocities through the structure will not damage the adjacent property.
- Maintain the existing flow distribution to the extent possible.
- Where practicable site works should be designed to avoid discharge directly into receiving waters. Otherwise BC Ministry of Environment approval required.

Chapter B3 - Storm Water Quality Control

3.1 Water Quality Criteria

Objectives of Water Quality Criteria

The purpose of the water quality objectives is to present a unified approach for sizing and selecting storm water permanent BMPs. The ultimate goal is to reduce the pollution associated with storm water runoff from new development and significant redevelopment from discharging into receiving waters to the “maximum extent practicable” (MEP).

The BC MoE have developed “Provisional Water Quality Objectives” for Mission, Kelowna (Mill) and Brandt’s Creeks. The Objectives are summarized in Table 1a of the 2001 document “Ambient Water Quality Objectives for the Tributaries to Okanagan Lake near Kelowna. The Objectives are based on the approved BC and Working Criteria for water quality and were based on available data, ambient water quality, waste discharges, water uses and stream flows. These Objectives have no legal standing and cannot be directly enforced. They can be considered as policy guidelines to be used to protect receiving waters.

Management Practices to Meet Criteria

The objectives can be met by detaining storm water for a period of time which allows storm water pollutants to settle (i.e. detention based treatments) and include devices such as storm water wetlands, extended detention pond, wet ponds, and structural underground or above ground vaults/tanks. Additional devices can include flow-through based treatments such as infiltration facilities, filtering systems, and commercially available proprietary BMPs. A flow-through based treatment system may be used in combination with downstream detention to meet the objectives.

Additional Requirements

If the District determines that additional controls and/or additional water quality objectives for developments are required to meet specific water quality needs in specific receiving waters, additional requirements may be imposed. These may include design requirements that result in larger facilities as well as additional types of structural or non-structural controls. The design solution will be contingent upon the pollutants that are found to be impacting such water bodies and the regulatory status of the water body

3.2 Detention Based Water Quality Control

Design Volume

Where structural facilities for contaminant removal are required and single event runoff models are used, facilities should be designed to treat runoff from the 24-hour storm with a six month return frequency. The six-month, 24 hour storm can be estimated as 70% of the two-year, 24-hour storm. Where continuous runoff modeling is used, contaminant removal facilities should be designed to treat 90 percent of the runoff volume in an average year

Runoff Coefficient

The runoff coefficient should be determined from the table below. Use the lower values for minor storms, for flat slopes and permeable soil; use higher values for major storms, steep slopes and impermeable soil. For drainage areas with multiple land uses (e.g. residential area adjacent to a commercial development), a weighted runoff coefficient based upon the individual land uses should be used.

Rational Method "C" Coefficient for Design

Runoff Coefficients for Urban Watersheds

Type of Drainage Area	Runoff Coefficient
Composite Areas	
Business:	
Downtown areas	0.70-0.95
Neighbourhood areas	0.30-0.70
Residential:	
Single family areas	0.30-0.50
Multi-units, detached	0.40-0.60
Multi-units, attached	0.60-0.75
Suburban	0.25-0.40
Apartment dwelling areas	0.40-0.70
Industrial:	
Light areas	0.40-0.80
Heavy areas	0.60-0.90
Parks, cemeteries	0.07-0.25
Playgrounds	0.07-0.20
Railroad yards	0.20-0.40
Unimproved areas	
Sand or sandy loam soil, 0-5%	0.05-0.10
Sand or sandy loam soil, >5%	0.10-0.20
Rock and soil mix, 0-10%	0.07-0.15

Rock and soil mix, >10%	0.10-0.20
Lawns:	
Sandy soil, flat 2%	0.05-0.10
Sandy soil, average 2-7%	0.07-0.15
Sandy soil, steep 7%	0.15-0.20
Heavy soil, flat 2%	0.13-0.17
Heavy soil, average 2-7%	0.18-0.22
Heavy soil, steep >7%	0.25-0.35
Streets:	
Asphaltic	0.90-0.95
Concrete	0.90-0.95
Brick	0.70-0.85
Drives and walks	0.85-0.95
Roofs	0.90-0.95

Runoff coefficients, listed for urban and rural watersheds and others apply to storms of two year, five year and 10 year frequencies. Higher frequency storms require modifying the runoff coefficient because infiltration and other abstraction have a proportionally smaller effect on runoff. Adjust the runoff coefficient by the factor C_f as indicated in the table titled Runoff Coefficient Adjustment Factors for Rational Method. The product of C and C_f should not exceed 1.0.

Runoff Coefficient Adjustment Factors for Rational Method

Recurrence Intervals (years)	**Cf**
25	1.1
50	1.2
100	1.25

Detention Time

For water quality treatment to be effective, longer detention times are required. The draw-down (or draining) time for the detention volume, which is intended to drain down completely (vs. permanent wet volume), should be greater than or equal to 48 hours.

Short-circuiting

The detention system shall be designed to maximize the distance between the inlet and outlet, and to minimize "dead spaces" (areas where little or no exchange occurs during a storm event), there-by limiting short-circuiting. A minimum flow-path length to width ratio of 3 should be designed.

Outlet sizing

The outlet should be sized to achieve the above required detention times. In addition, it should be large enough that clogging is unlikely to occur. It should be 50mm or larger in diameter. If this is not possible, the use of flow-through based measures should be considered, unless special measures to prevent clogging are provided.

3.3 Flow-Through Based Water Quality

Flow-through based water quality control measures achieve water quality treatment by directing flow through a filtration media or letting the flow be infiltrated to ground. In addition, there are devices which utilize hydraulic particle separation techniques ("hydrodynamic" BMPs), however, these alone do not typically address the smaller sized fractions of solids (which typically have a higher portion of other pollutants such as metals attached to them) that are desired to be removed.
The runoff coefficient should be the same as used in "Detention Based Water Quality Control' section.

Design Storm Size

The required flow rate for treatment is the runoff that would be produced from a 24hr storm with a six month return frequency. This peak flow rate must be maintainable for a minimum of three hours.

3.4 Water Quality Design Standards

Detention Based Storm Water Quality Control Facilities

Detention facilities can be designed as the following:

- **Wet Ponds** - The wet pond volume is equal to the water quality design volume and is entirely a permanent wet pond where storm water exchanges with the pond water to achieve treatment. Detention time requirements do not apply.
- **Wet Extended Detention Ponds** - These are ponds that provide for gradual release of the water quality design volume in order to promote the settling of pollutants. The drawdown time that meets the criteria is required for the extended detention volume.

The design of wet ponds must show a water balance that demonstrates that there will be sufficient dry weather flows to maintain the planned pool volume without creating stagnant conditions.

Detention based water quality systems are recommended to be off-line from flood conveyance. If they are to be on-line or combined with a flood detention facility, then the facility must be designed to meet the detentions storage requirements without damaging the facility, as well as to minimize re-entrainment of pollutants.

Flow-Through Based Storm Water Quality Control Facilities

For flow-through treatment, the level of treatment shall be addressed as follows:

- **Infiltration** - Infiltrated storm water shall be infiltrated through soils capable of filtering pollutants (or other suitable media as described below) prior to entering groundwater. Infiltration shall only be used where soil conditions and slope stability are suitable.

- **Vegetated Swales** - Vegetated (wetland/native plants and/or grass) swales shall be designed so that at the water quality flow rate (WQFR), the swale width is such that the flow depth is no greater than 100mm and the hydraulic grade line is no greater than 2 percent (unless drop structures are employed) between structures. The inflow should be directed towards the upstream end of the swale as much as possible, but should at a minimum occur evenly over the length of the swale. The length of flow in the swale is a minimum of 30m.

- **Bioretention Filters** - Bioretention filters are vegetated (landscaped) areas where runoff is directed through vegetation and soils for filtration. In most cases, unless there is shown to be adequate infiltration capacity, underdrains and overflow drains should be included to collect filtered runoff and discharge runoff to the storm drainage system. The ponding depth should be 150mm or less with a mulch layer of 50 to 75mm. A sandy planting soil of 50 to 75mm should be used. Each facility should have no more than 0.4Ha of tributary area and should be designed to convey larger flows in a manner that does not cause re-entrainment of trapped materials.

- **Other Filters** - Other filters shall be accompanied by a certification from a licensed engineer that the filter/device will remove a minimum of 80 percent of the total suspended solids (of the size fractions typical for urban runoff) from the design flow rate.

Flow-Through Based Treatment Upstream of Detention Based Treatment

Flow-through based treatment can be placed upstream of a detention-based treatment to reduce the sizing of each. In this case, the flow-through treatment must be designed to treat the runoff produced from a minimum rainfall intensity of 5mm per hour. The treated runoff shall then flow to a downstream detention system that is designed to capture and treat the entire runoff volume that would occur from the area contributing to the detention facility from a 15mm rain storm.

Chapter B4 - Storm Water Permanent BMP Options

4.1 Introduction

Permanent BMPs that control urban runoff and provide storm water quality treatment can be categorized into the following:

- Vegetative Swales;
- Infiltration Facilities;
- Storm Water Wetlands (Created Wetlands);
- Storm Water Ponds;
- Filtering Systems; and
- Proprietary BMPs including "Hydrodynamic" type.

Selection of BMPs must be site specific and applicable to the site conditions. No single BMP can achieve pollutant reduction for every given situation. There are pros and cons for every water quality treatment BMP listed in this chapter. The designer should consider the benefits, costs, pollutant removal efficiency, aesthetical acceptability, and other pertinent factors when selecting BMPs for individual project application. A summary of BMP limitations and factors to consider is provided in Table 4-1 to aid the project designer in selecting the most appropriate permanent BMP. It is important to note that the selected BMPs should meet the quantity and quality criteria as specified in the previous chapters and in the District's drainage design standards. There are many proprietary BMP products available on the market. These products were not designed to perform alike and each product is designed to remove certain pollutants. Their performance can vary significantly. The District does not endorse any particular type of proprietary BMP product and will review its application and performance on a case by case basis. It is the designer's responsibility to consult with manufacturer and obtain independent performance testing data to support the use of each device and demonstrate it will meet the water quantity and quality control criteria. For this reason, Table 4-1 does not include any proprietary BMPs.

4.2 Storm Water Quality Treatment

Dry Swale

Description and Purpose
Swales are vegetated open channels that are designed to capture and treat the full water quality volume within dry or wet cells that are formed by check dams or other means.

Applications
Dry swales are used at low density residential projects or for very small impervious areas. Dry swales are applicable for land uses such as roads, highways, residential development, and small pervious areas.

Design Criteria

- Required volume is based on a 24hr storm with a six month return frequency.
- Longitudinal slopes shall be less than 4.0% to qualify for water quality volume treatment.

Table 4.1
BMP Selection – Stormwater Treatment Suitability

BMP LIST	SAFETY CONCERNS	SPACE REQUIREMENT	ACCEPT HEAVILY POLLUTED RUNOFF	SOILS	WATER TABLE	DRAINAGE AREA (Ha)	SLOPE RESTRICTIONS	ULTRA URBAN	EASE OF MAINTENANCE	COMMUNITY ACCEPTANCE	COST (RELATIVE TO DA)	HABITAT QUALITY	OTHER FACTORS
4.1.1 Dry Swale	No	Varies	Yes	Manufactured soil	0.6m	2 max	4% max cross-slope	Not practical	Easy	High	Medium	Low	
4.1.2 Wet Swale	No	Varies	No	OK	Below WT	2 max	4% max cross-slope	Not Practical	Easy	High	Low	Low	Mosquitoes possible
4.1.3 Infiltration Trench	No	Low	No	f ≥ 13mm/hr	1.2m	2 max	Installed in no more than 15% slopes	Depends	Difficult	High	Medium	Low	Avoid large stone
4.1.4 Infiltration Basin	No	Varies	No	f ≥ 13mm/hr	1.5m	4 max	None	Not practical	Medium	Low	Medium	Low	Frequent pooling
4.1.5 Bioretention	No	Varies	Yes	Manufactured soil	2.1m	2 max	None	Not practical	Medium	Medium	Medium	Low	Landscaping
4.1.6 Shallow Wetland	No	High	Yes	Highly permeable soils may require liner	1.2m If hotspot or aquifer	10 min	None	Not practical	Medium	High	Medium	High	
ED Wetland	Varies	Varies	Yes	Highly permeable soils may require liner	1.5m If hotspot or aquifer	10 min	None	Not practical	Medium	Medium	Medium	High	Limited ED depth
Pond/Wetland	Yes	High	Yes	Highly permeable soils may require liner	1.8m If hotspot or aquifer	10 min	None	Not practical	Difficult	High	Medium	High	
4.1.7 Pocket Wetland	No	Varies	Yes	OK	Below WT	2 max	None	Depends	Medium	Low	Low	Medium	Drawdowns
4.1.8 Wet ED Pond	Yes	Low	Yes	Highly permeable soils may require pond liner. Moderately permeable soils may require testing	1.8m If hotspot or aquifer	10 min	None	Not practical	Easy	High	Low	High	
Micropool ED	No	Low	Yes	Highly permeable soils may require pond liner. Moderately permeable soils may require testing	1.2m If hotspot or aquifer	4 min	None	Not practical	Medium	Medium	Low	Medium	Trash/Debris
4.1.9 Wet Pond	Yes	Varies	Yes	Highly permeable soils may require pond liner. Moderately permeable soils may require testing	1.5m If hotspot or aquifer	10 min	None	Not practical	Easy	High	Low	High	
Pocket Pond	Varies	Low	Yes	OK	Below WT	2 max	None	OK	Difficult	Medium	Low	Low	Drawdowns
Multiple Pond	Yes	High	Yes	Highly permeable soils may require pond liner. Moderately permeable soils may require testing	2.1m If hotspot or aquifer	10 min	None	Not practical	Easy	High	Medium	High	
4.1.10 Surface Sand Filter	No	Low	Yes	OK	0.6m	4 max	None	Depends	Medium	Medium	High	Low	
4.1.11 Underground SF	Varies	Low	Yes	OK	0.9m	0.8 max	None	OK	Difficult	High	High	Low	Underground out of site
Perimeter SF	No	Low	Yes	OK	1.2m	0.8 max	None	OK	Difficult	High	High	Low	Traffic bearing
Pocket Sand Filter	No	Low	Yes	OK	1.8m	2 max	None	OK	Medium	Medium	Medium	Low	

• Channels shall have moderate side slopes (flatter than 3:1) for most conditions and may NOT be steeper than 2:1.
• Peak velocity shall be non-erosive for the soil and vegetative cover provided.
• The maximum allowable ponding time shall be less than 48 hours, and the minimum ponding time shall be 30 minutes is recommended.
• A bottom width of no wider than 2.4m or a meandering drainage pattern shall be established.
• There should be a maximum ponding depth of 300mm at the mid-point of the channel profile and a maximum depth of 450mm at the downstream end of the channel.
• At the water quality flow rate, the swale width should be that which will have a flow depth of no greater than 100mm and the hydraulic grade line is no greater than 2% between structures.
• The flow length in the swale should be a minimum of 30m.

See Figure WQ 4-1

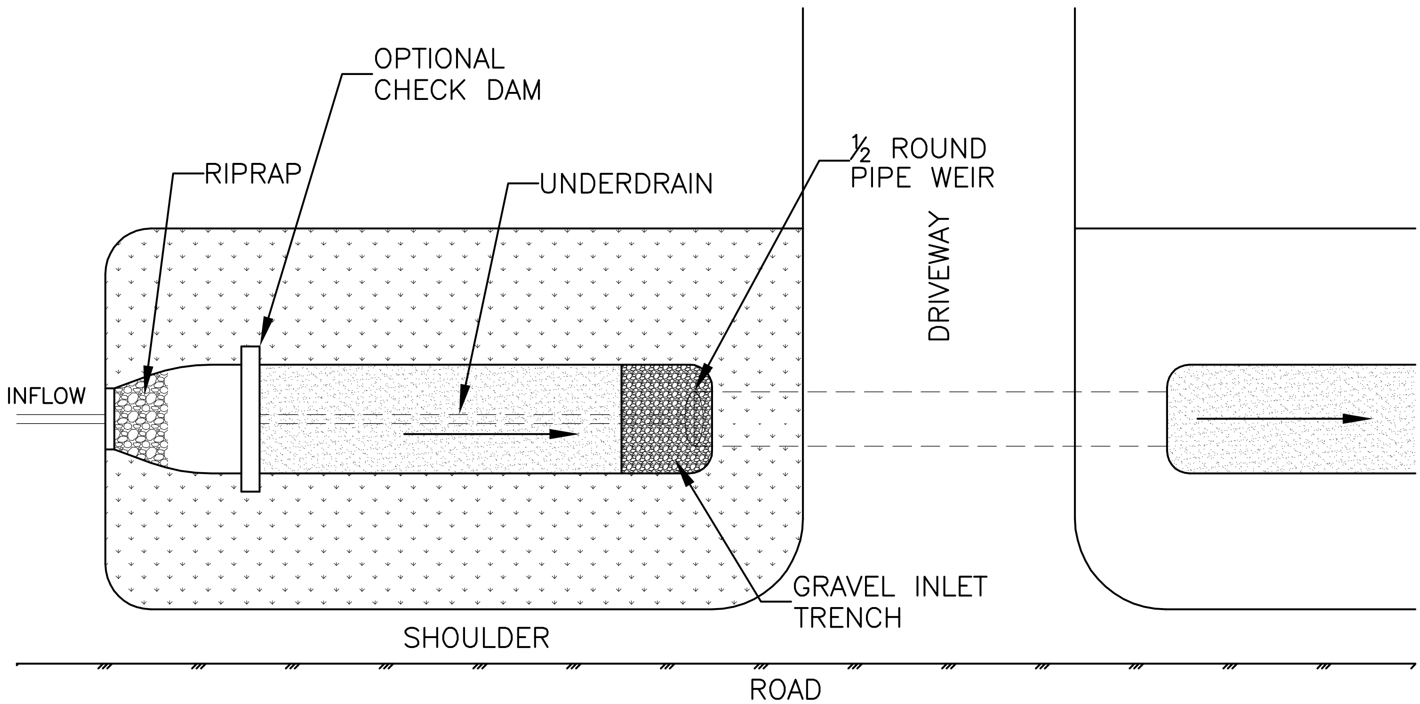
Pretreatment Requirements
• Pretreatment storage of 6mm of runoff per impervious Ha storage shall be provided, which is usually obtained by check dams at pipe inlets and/or driveway crossings.
• Gentle side slopes should be provided along the top of channels to accommodate pretreatment for lateral sheet flows.
• Direct discharge of concentrated flow shall be pretreated.

Construction Considerations
• The inflow should be directed towards the upstream end of the swale but should occur evenly over the swale.
• Swales that directly receive runoff from impervious surfaces may have a 150mm drop onto a protected shelf of pea gravel to minimizing the clogging of the inlet.
• An underdrain shall be provided to ensure maximum ponding time of 48 hours.

Landscaping Requirements
• Landscape design should specify proper grass species and wetland plants based on the specific site, soils and hydric conditions present along the channel.
• A permeable soil mixture 750mm deep should meet the bioretention “planting” soil specifications listed in the Bioretention section.
• Seed should be flood and drought resistant grasses.

Maintenance and Inspections
• Swales should be mowed as required during the growing season to maintain heights in the 100-150mm range.
• Sediment buildup in the bottom of the swale shall be removed when 25% of the original water quality volume has been exceeded.

Challenges
• The bottom of the facility shall be above the seasonally high water table.
• No gravel or perforated pipe shall be placed under driveways.



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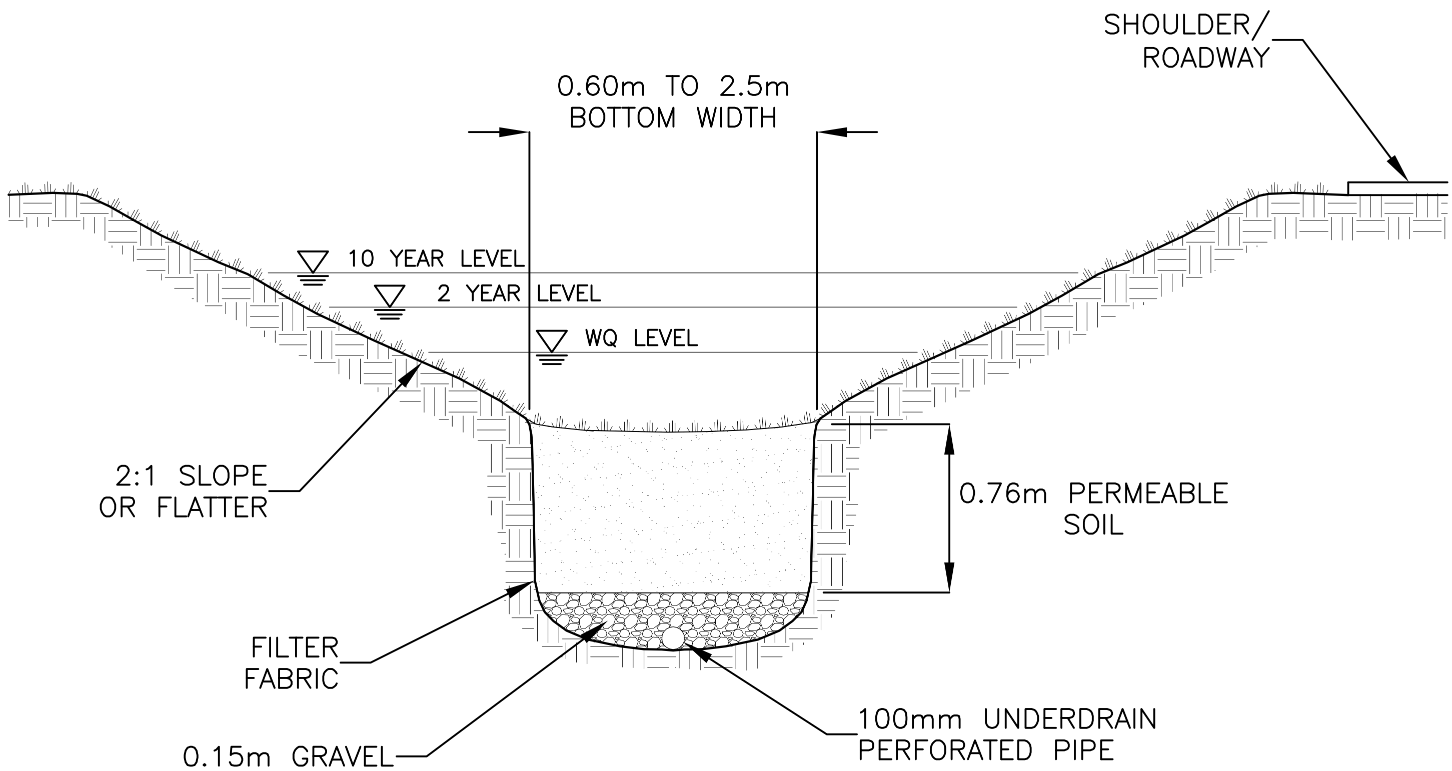


SECTION

N.T.S.

DRY SWALE	WQ-4-1

Wet Swale

Description and Purpose

Swales are vegetated open channels that are designed to capture and treat the full water quality volume within dry or wet cells that are formed by check dams or other means.

Applications

Wet swales are ideal for treating highway runoff in low lying or flat areas. Wet swales are applicable for land uses such as roads, highways, and pervious areas.

Design Criteria

- Required volume is based on a 24 hour storm with a 6 month return frequency
- Longitudinal slopes shall be less than 4.0% to qualify for water quality volume treatment.
- Channels shall have moderate side slopes (flatter than 3:1) for most conditions and may NOT be steeper than 2:1.
- Peak velocity shall be non-erosive for the soil and vegetative cover provided.
- A bottom width of no wider than 2.4m or a meandering drainage pattern shall be established.
- There should be a maximum ponding depth of 300mm at the mid-point of the channel profile and a maximum depth of 450mm at the downstream end of the channel.
- At the water quality flow rate, the swale width should be that which will have a flow depth of no greater than 100mm and the hydraulic grade line is no greater than 2% between structures.
- The flow length in the swale should be a minimum of 30m.

Pretreatment Requirements

- Pretreatment storage of 6mm of runoff per impervious Ha storage shall be provided, which is usually obtained by check dams at pipe inlets and/or driveway crossings.
- A diaphragm of pea gravel and gentle side slopes should be provided along the top of channels to accommodate pretreatment for lateral sheet flows.
- Direct discharge of concentrated flow shall be pretreated.

Construction Considerations

- The inflow should be directed towards the upstream end of the swale but should occur evenly over the swale.
- Swales that directly receive runoff from impervious surfaces may have a 150mm drop onto a protected shelf of pea gravel to minimizing the clogging of the inlet.
- Excavation should be performed in undisturbed areas.
- No underdrain system should be used.

Landscaping Requirements

- Landscape design should specify proper grass species and wetland plants based on the specific site, soils and hydric conditions present along the channel.
- A permeable soil mixture 750mm deep should meet the bioretention “planting” soil specifications listed in the Bioretention section.
- Seed should be flood and drought resistant grasses.

Maintenance and Inspections

• Swales should be mowed (dry areas) as required during the growing season to maintain heights in the 100-150mm range.

• Sediment buildup in the bottom of the swale shall be removed when 25% of the original water quality volume has been exceeded.

• Swales with wetland vegetation or other low maintenance ground cover do not require frequent mowing of the channel.

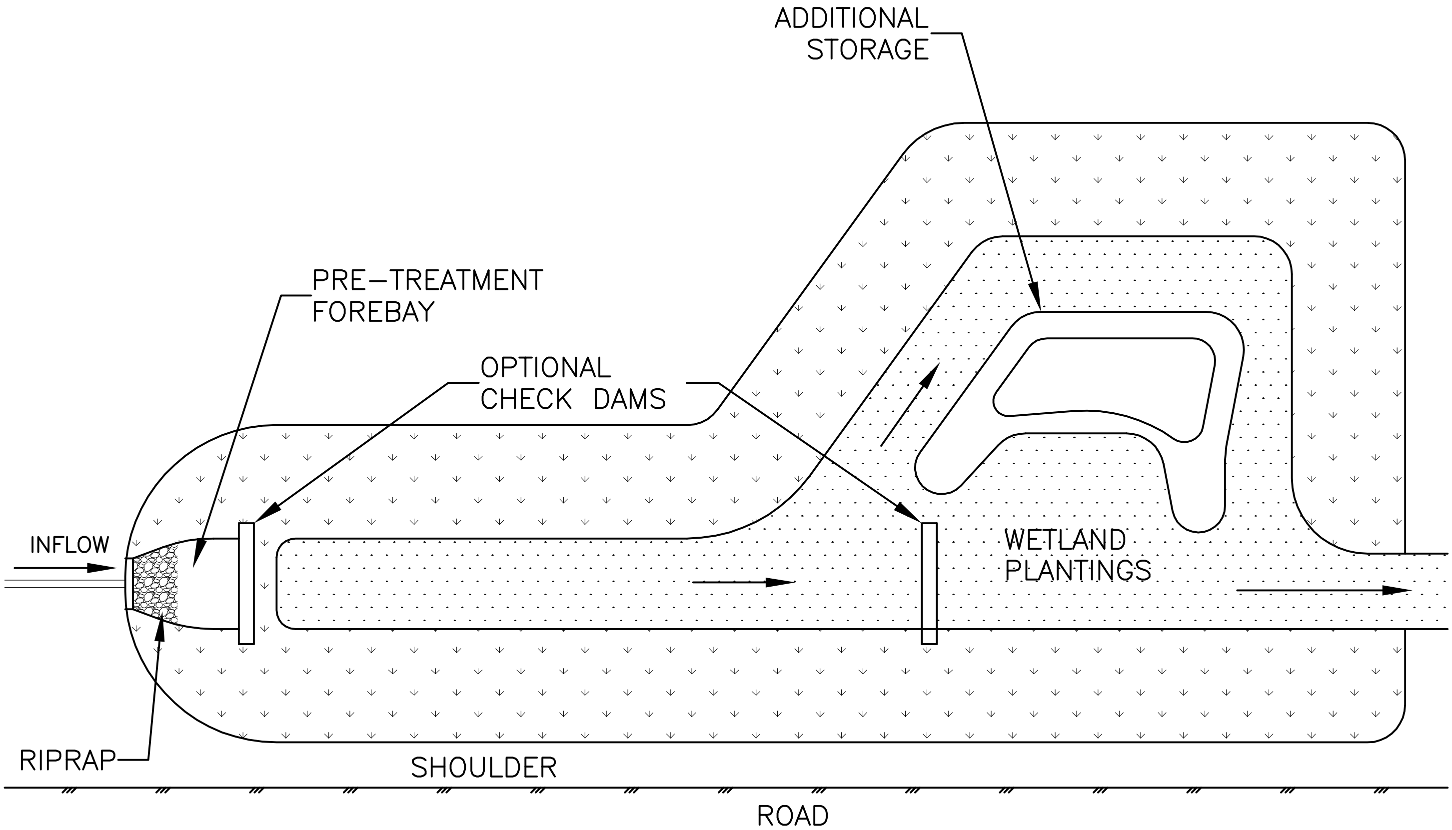
Challenges

• The seasonally high water table may inundate the swale, but not above the bottom of the channel.

• No gravel or perforated pipe shall be placed under driveways.

• Not recommended for residential developments since they can create potential nuisance or mosquito breeding conditions.

See Figure WQ 4-2



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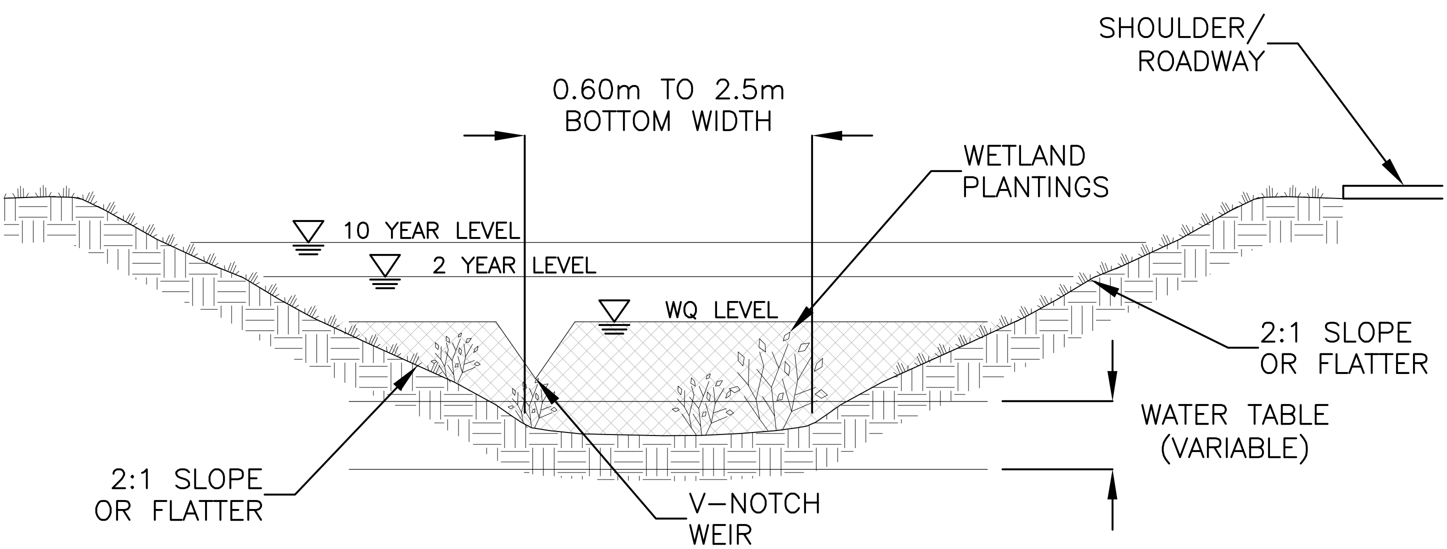

SECTION

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WET SWALE	WQ-4-2

Infiltration Trench

Description and Purpose

The infiltration trench provides recharge and water quality volume in one location.

Applications

Storm water shall be infiltrated through soils capable of filtering pollutants prior to entering the groundwater. Other suitable media filters that are accompanied by a certification from a licensed engineer that the filter/device will remove 80% of total suspended solids from the design flow rate are also acceptable. Infiltration shall only be used where soil conditions and slope stability are suitable.

Design Criteria

• A porosity value “n” (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
• Required volume is based on a 24 hour storm with a 6 month return frequency
• Groundwater shall be protected from possible contamination by avoiding potential storm water areas.
• The bottom of the facility shall be separated by at least 1.2m (vertically) from the seasonally high water table or bedrock layer.
• Facilities shall be located at least 30m from any water supply well.
• Facilities shall have a maximum contributing area of 2 Ha.
• The facility should not be placed in locations that may cause water problems to downgrade properties and should be setback (7.5m) downgrade from structures
• All trenches shall be designed to fully de-water the entire water quality volume within 48 hours after the storm event.
• Adequate storm water outfalls shall be provided for the overflow associated with the five-year design storm event.
• Since the trench will be located “off-line” from the main conveyance system, a flow splitter will be required to divert the water quality volume into the filter.

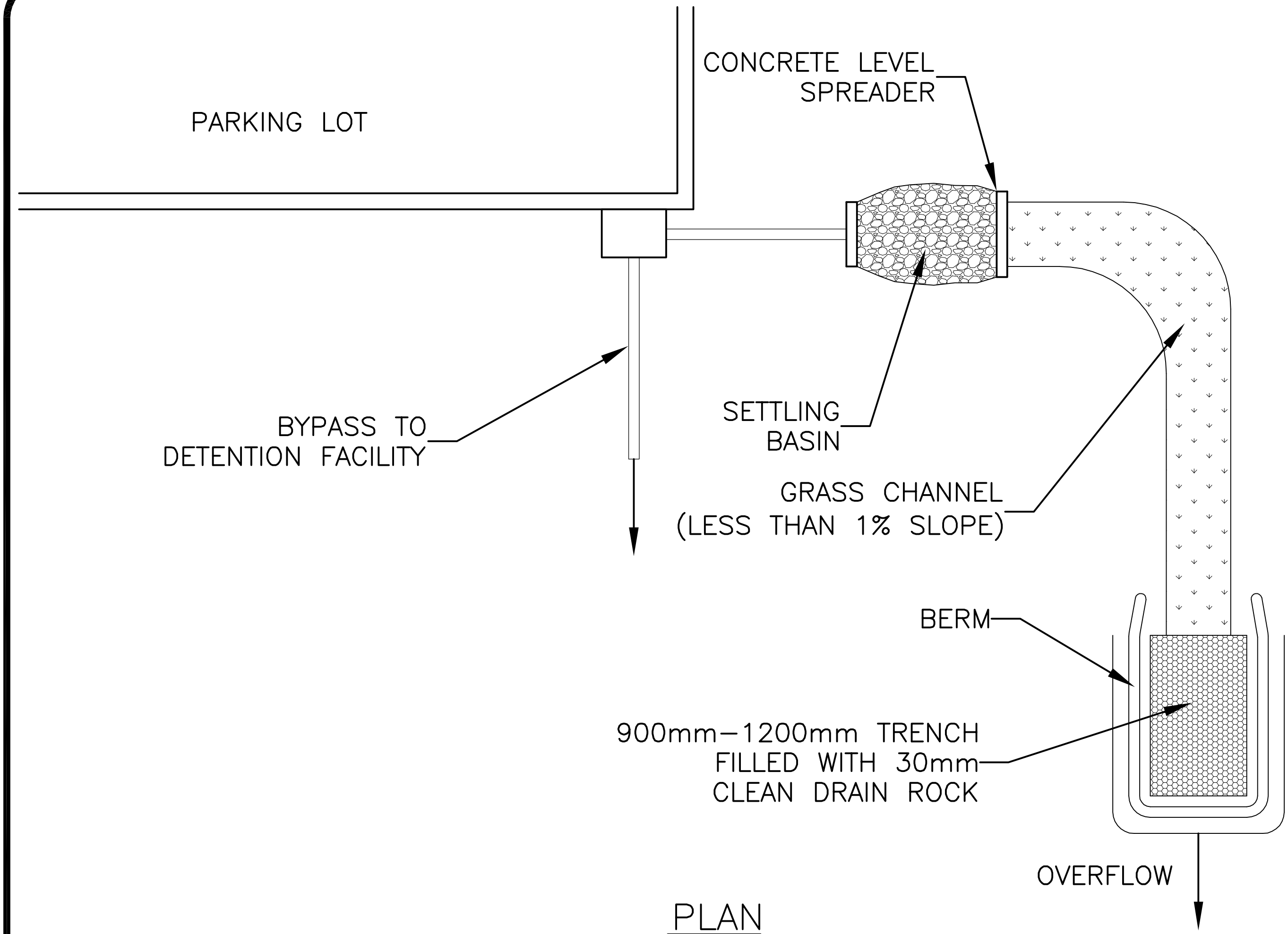
See Figure WQ 4-3

Pretreatment Requirements

• A minimum of 25% of the water quality volume is to be pretreated in the stilling basin prior to entering the facility.
• Exit velocities shall be non-erosive during the two year design storm.
• Long-term techniques for infiltration protection (2 per trench):
    o Grass channel;
    o Grass filter strip (minimum 6m and only if sheet flow is established and maintained);
    o Bottom sand layer;
    o Upper sand layer (150mm minimum) with filter fabric at sand/gravel interface; and
    o Washed bank run gravel used as aggregate.

Construction Considerations

• Phases of trench construction shall be coordinated with the overall project construction schedule.
• Rough excavation and rough grading phases of construction should be scheduled together to permit the exchange of cut and fill. The partially excavated trench cannot serve as a sedimentation basin.
• Construction plans should state:
    o The earliest point in progress when storm drainage may be directed to the trench; and
    o The means by which the delay will be accomplished.



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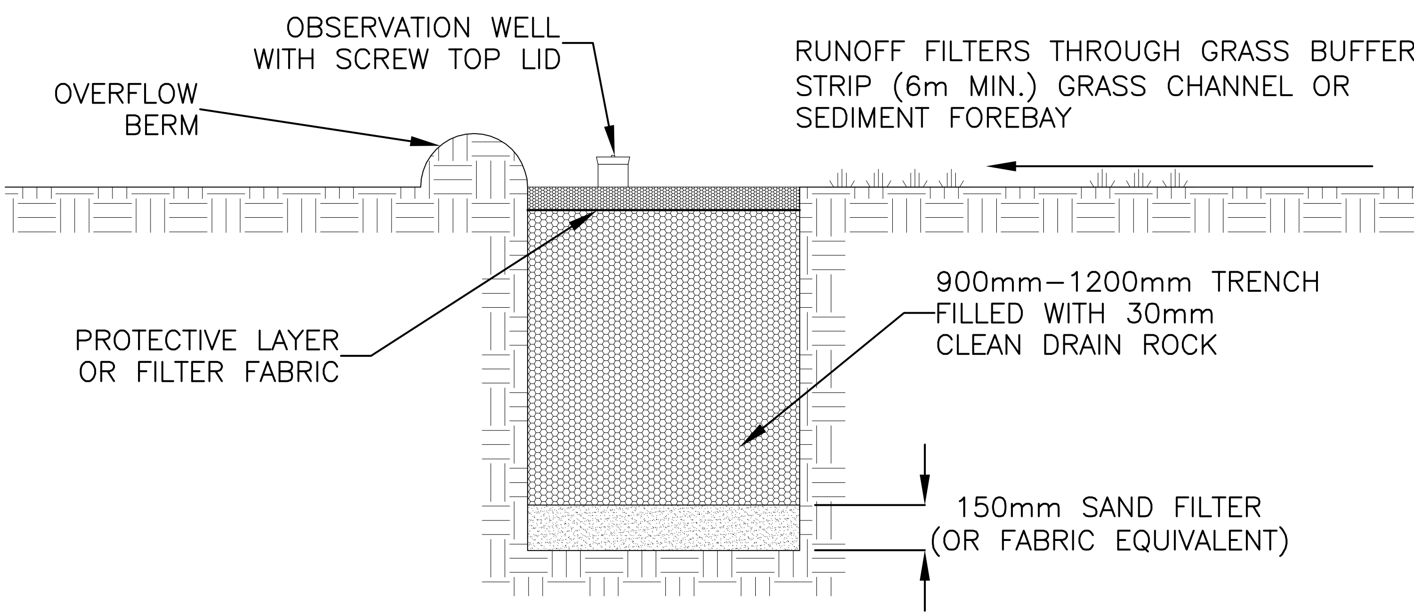


SECTION

N.T.S.

INFILTRATION TRENCH

WQ–4–3

• Initial trench excavation should be carried to within 600mm of the final elevation of the trench floor.
• Final excavation to the final grade should be done after all disturbed areas in the watershed area stabilized or protected.
• Final phase excavation should remove all accumulated sediment.
• Light tracked equipment is recommended to avoid compaction in the trench.
• After the completion of final grading, the trench should be well-aerated and have a highly porous surface texture.
• Trenches may be lined with a 150-300mm layer of filter material, such as coarse sand to help prevent the buildup of impervious deposits. The filter layer can be replaced or cleaned when clogged.
• Establish dense vegetation on trench side slopes and floor, preventing erosion, sloughing, and a natural means of maintaining high infiltration rates.
• Fescue family grasses are recommended for seeding.

Landscaping Requirements

• Dense and vigorous vegetative cover is to be established over the contributing pervious drainage areas before runoff can be accepted into the facility. Infiltration trenches are not to be constructed until all of the contributing drainage areas have been completely stabilized.

Maintenance and Inspections

• Are not to serve as a sediment control device during site construction.
• Erosion and sediment plans for the site must clearly indicate methods that will prevent sediment from entering the infiltration device.
• Recommended that infiltration designs include dewatering methods such as underdrain pipe systems to accommodate drawdown in the event of a failure.
• Direct access provided to all infiltration practices for maintenance and rehabilitation.
• Should not be covered by an impermeable surface.

Challenges

• Often best used with other BMPs downstream.
• Underlying soils shall have specific infiltration rates to be tested with geotechnical borings.
• Soils shall have a clay content of less than 20% and a silt/clay content of less than 40%.
• Infiltration cannot be located on slopes greater than 15% or within fill soils.

Infiltration Basin

Description and Purpose

Water quality volume is retained in an infiltration basin, where it percolates through the basin in a two day period. The facility must be able to completely treat the flow rate as determined from storm water quality control flow design.

Flows above this rate can either be by-passed, or routed through the facility if it can be demonstrated that velocities will not re-entrain captured pollutants.

Applications

Storm water shall be infiltrated through soils capable of filtering pollutants prior to entering the groundwater. Other suitable media filters that are accompanied by a certification from a licensed civil engineer that the filter/device will remove 80% of total suspended solids from the design flow rate are also acceptable. Infiltration shall only be used where soil conditions and slope stability are suitable.

Challenges

- Often best used with other BMPs downstream.
- Underlying soils shall have specific infiltration rates to be tested with geotechnical borings.
- Soils shall have a clay content of less than 20% and a silt/clay content of less than 40%.
- Infiltration should not be located on slopes greater than 15% or within fill soils.

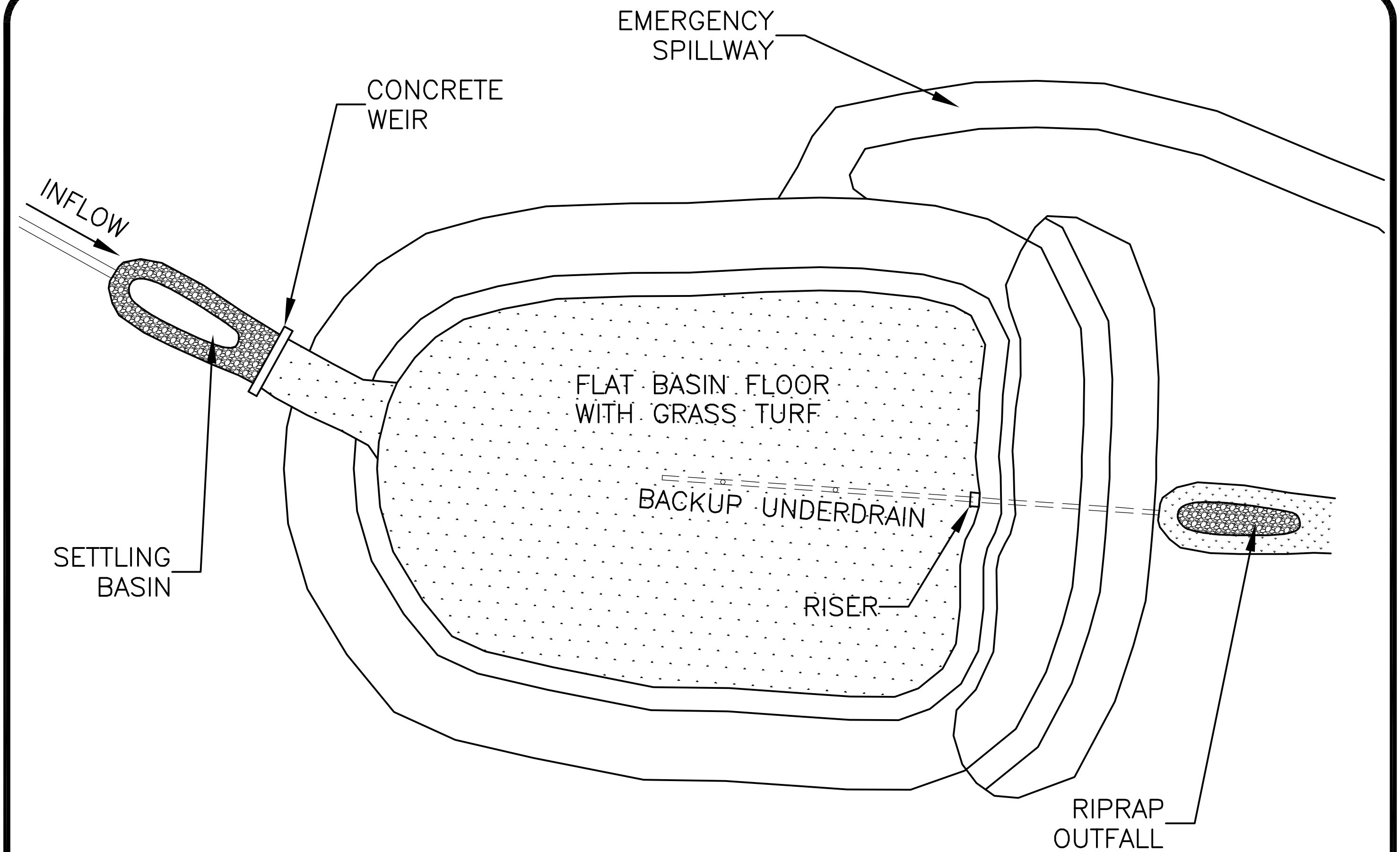
Design Criteria

- A porosity value "n" ($n=V_v/V_t$) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
- Required volume is based on a 24 hour storm with a 6 month return frequency
- Groundwater shall be protected from possible contamination by avoiding potential storm water areas.
- The bottom of the facility shall be separated by at least 1.2m (vertically) from the seasonally high water table or bedrock layer.
- Facilities shall be located at least 30m from any water supply well.
- Facilities should have a maximum contributing area of 2 Ha.
- The facility should not be placed in locations that may cause water problems to downgrade properties and should be setback 7.5m downgrade from structures.
- All basins shall be designed to fully de-water the entire water quality volume within 48 hours after the storm event.
- Adequate storm water outfalls shall be provided for the overflow associated with the five-year design storm event.

See Figure WQ4-4

Pretreatment Requirements

- A minimum of 25% of the water quality volume is to be pretreated in the stilling basin prior to entering the facility.
- Exit velocities shall be non-erosive during the storm
- Long-term techniques for infiltration protection (2 per basin)
    - o Grass channel;
    - o Grass filter strip (minimum 6m and only if sheet flow is established and maintained);
    - o Bottom sand layer;
    - o Upper sand layer (150mm minimum) with filter fabric at sand/gravel interface; and
    - o Washed bank run gravel used as aggregate.



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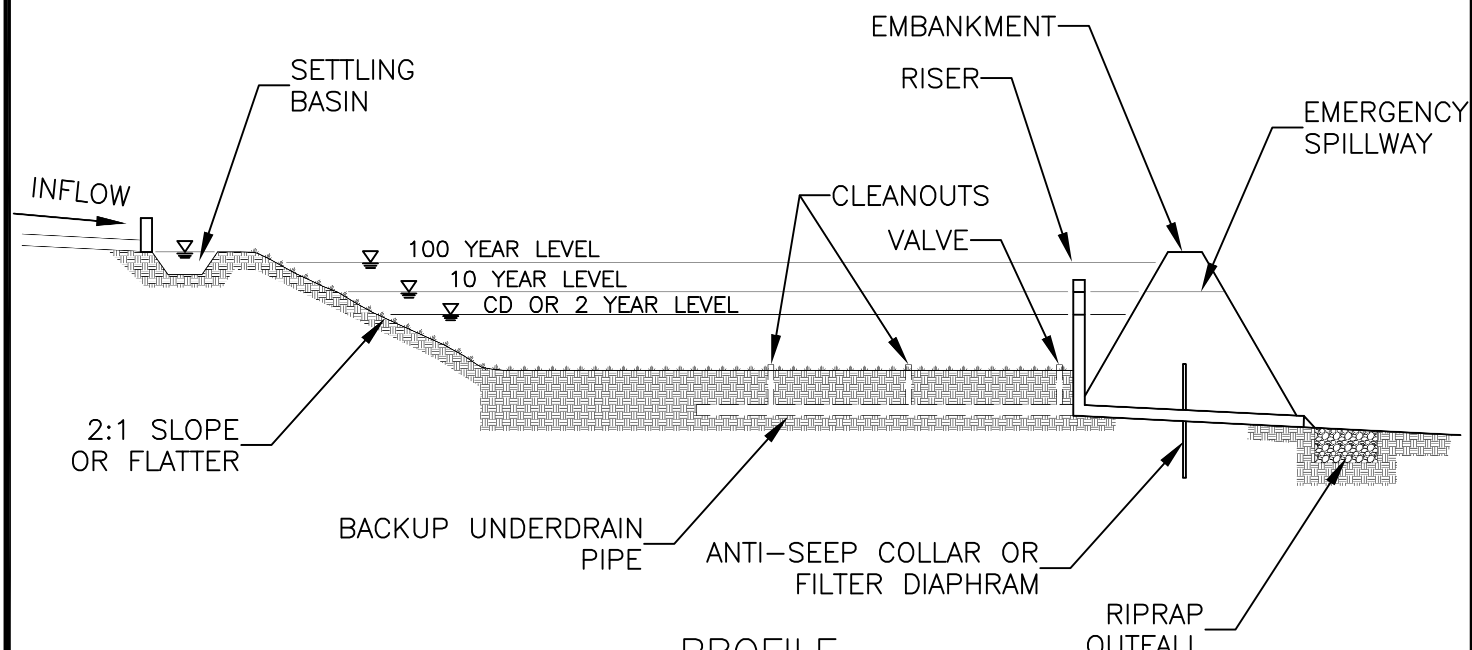


PROFILE

N.T.S.

INFILTRATION BASIN

WQ–4–4

Construction Considerations

• Phases of basin construction shall be coordinated with the overall project construction schedule.

• Rough excavation and rough grading phases of construction should be scheduled together to permit the exchange of cut and fill. The partially excavated basin cannot serve as a sedimentation basin.

• Basin construction plans should state:

  o The earliest point in progress when storm drainage may be directed to the basin; and

  o The means by which the delay will be accomplished.

• Initial basin excavation should be carried to within 600mm of the final elevation of the basin floor.

• Final excavation to the final grade should be done after all disturbed areas in the watershed area stabilized or protected.

• Final phase excavation should remove all accumulated sediment.

• Light tracked equipment is recommended to avoid compaction in the basin.

• After the completion of final grading, the basin should be well-aerated and have a highly porous surface texture.

• Basins may be lined with a 300 to 600mm layer of filter material, such as coarse sand to help prevent the buildup of impervious deposits. The filter layer can be replaced or cleaned when clogged.

• Establish dense vegetation on basin side slopes and floor, preventing erosion, sloughing, and a natural means of maintaining high infiltration rates.

• Fescue family grasses are recommended for seeding.

Landscaping Requirements

• Dense and vigorous vegetative cover is to be established over the contributing pervious drainage areas before runoff can be accepted into the facility. Infiltration trenches are not to be constructed until all of the contributing drainage areas have been completely stabilized.

Maintenance and Inspections

• Are not to serve as a sediment control device during site construction.

• Erosion and sediment plans for the site must clearly indicate methods that will prevent sediment from entering the infiltration device.

• Recommended that infiltration designs include dewatering methods such as underdrain pipe systems to accommodate drawdown in the event of a failure.

• Direct access provided to all infiltration practices for maintenance and rehabilitation.

• Should not be covered by an impermeable surface.

Bioretention

Description and Purpose

Bioretention combines open space with storm water treatment in vegetated areas where runoff is directed through vegetation and soils for filtration. It captures and temporarily stores the water quality volume and passes it through a filter bed of sand, organic matter, soil, or other media.

Applications

Filtered runoff may be collected and returned to the conveyance system or allowed to partially exfiltrate into the soil.

Design Criteria

• A porosity value "n" (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
• Required volume is based on a 24 hour storm with a 6 month return frequency
• The required filter bed area (Af) is computed using the following equation:

$$Af = (WQv)(df) / [(k)(hf+df)(tf)]$$

  o WQv is the water quality volume (cu. m);
  o df is the filter bed depth (m);
  o k is the coefficient pf permeability of the filter bed (m/day);
  o hf is the height of water above the filter bed (m); and
  o tf is the design filter bed drain time (days)- 2 days recommended.

See Figure WQ 4-5

Pretreatment Requirements

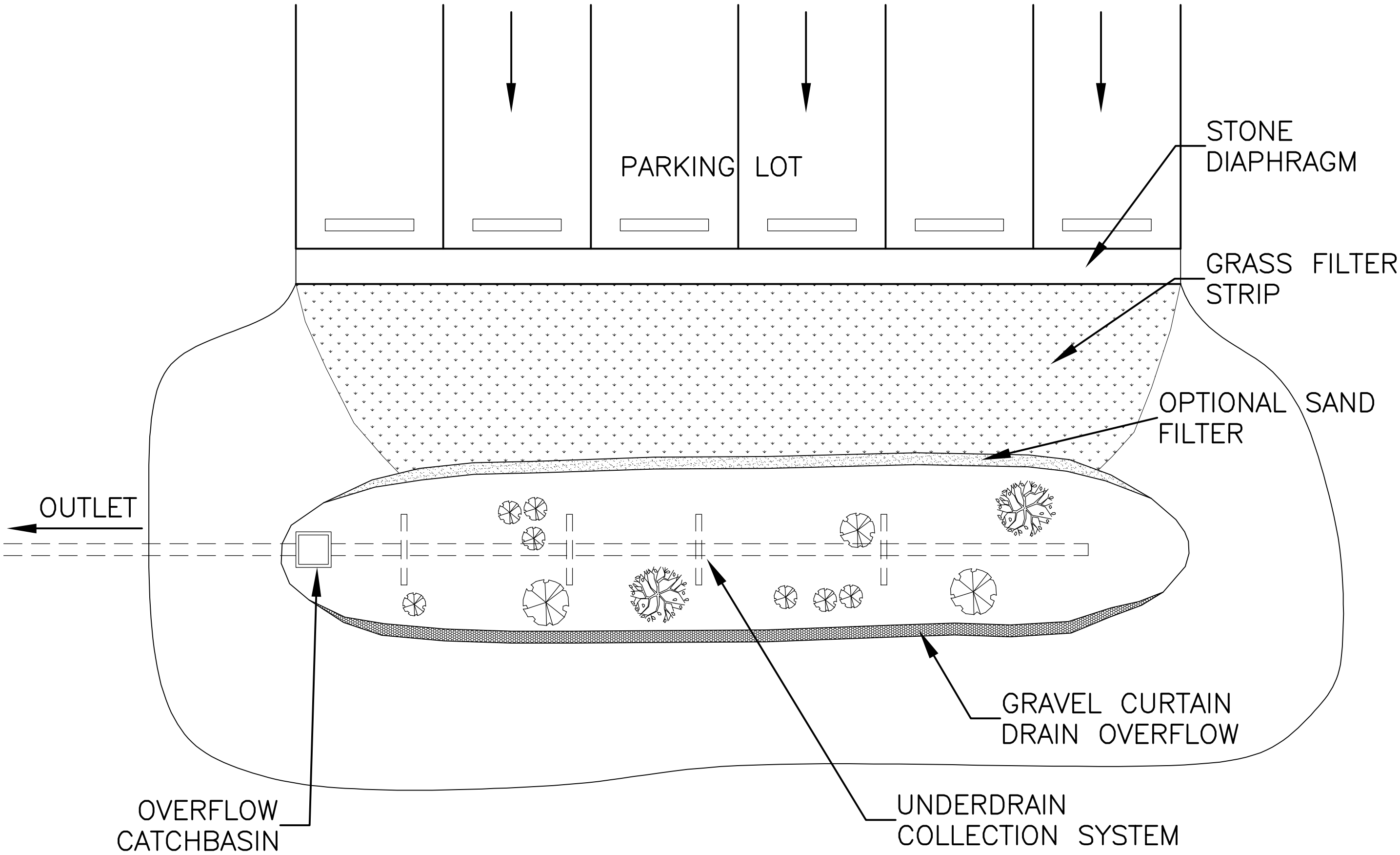
• Pretreatment is provided when all of the following are provided:
  o 6m grass filter strip below a level spreader or sand filter layer;
  o A perimeter gravel diaphragm; and
  o Mulch layer.
• Treatment components shall include:
  o 750 to 1200mm deep planting soil bed;
  o Surface mulch layer; and
  o 300mm deep surface ponding area.

Construction Considerations

• Overflow for the five-year storm event shall be provided to a non-erosive outlet point and non-erosive velocities shall result.
• A flow regulator shall be provided to divert the water quality volume to the filtering practice.
• The filters shall have a 150mm perforated underdrain pipe in a gravel layer.
• A permeable filter fabric shall be places between the gravel layer and the filter media.

Landscaping Requirements

• Landscaping is critical to the function and performance of the bioretention areas. A landscaping plan shall be provided for these areas.
• Planting recommendations:
  o Native plant species;



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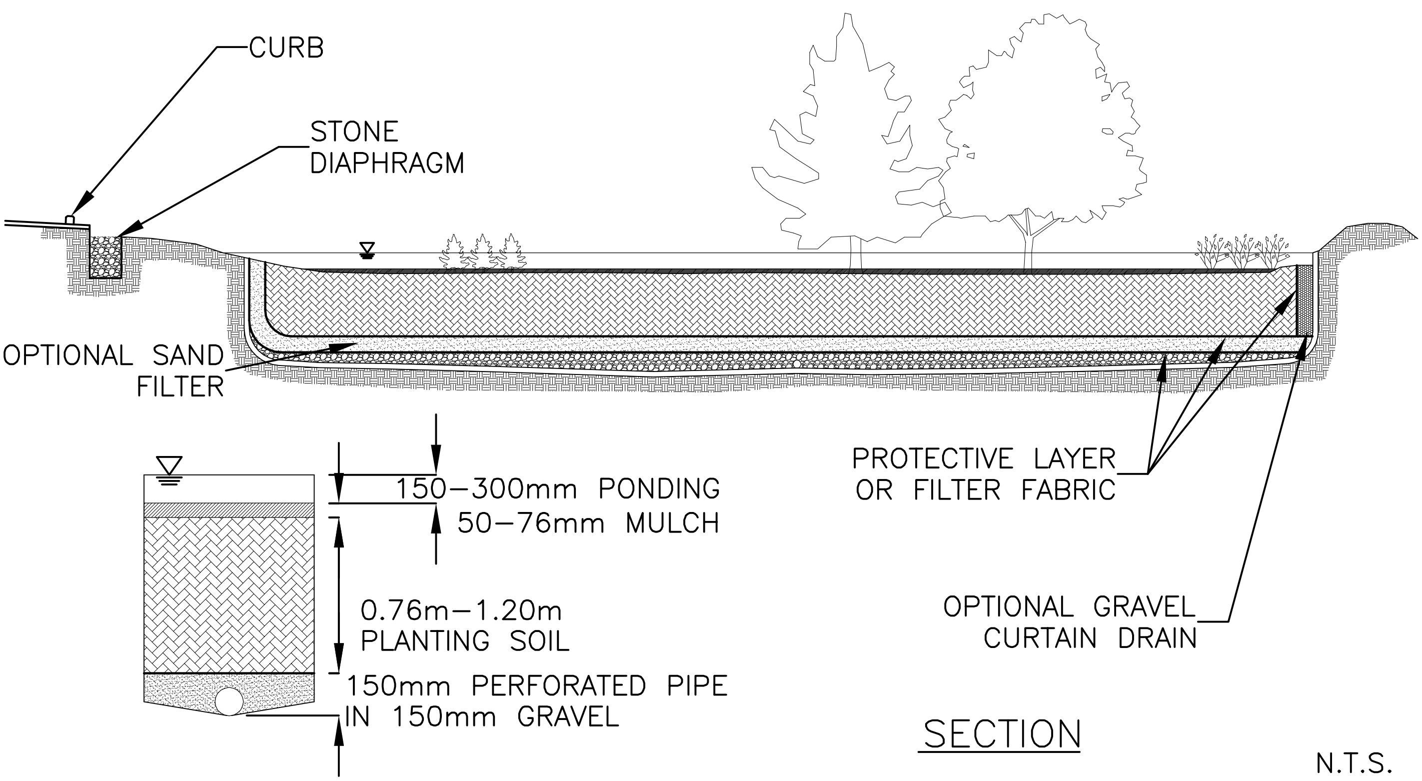


SECTION

N.T.S.

BIORETENTION	WQ–4–5

- Select vegetation based on the zone of hydric tolerance;
  - Trees with an understory of shrubs and herbaceous materials should be selected; and
  - Woody vegetation should not be used at inflow locations.
- The ponding depth should be 150mm or less with a mulch layer of 50 to 75mm.
- A sandy planting soil of 50 to 75mm should be used.
- Dense and vigorous vegetation should be established over the contributing drainage area before accepting runoff into the facility.

Maintenance and Inspections

- Direct maintenance access is to be provided to the pretreatment area and the filter bed.
- At least a 150mm drop shall be provided at the inlet of the facility (stone diaphragm).
- Dead or diseased plants shall be replaced.
- Areas with mulch that has been washed out should be re-mulched annually.

Challenges

- Unless there is adequate infiltration capacity, underdrains and overflow drains should be included to collect and discharge filtered runoff to the storm drainage system.

Shallow Wetland

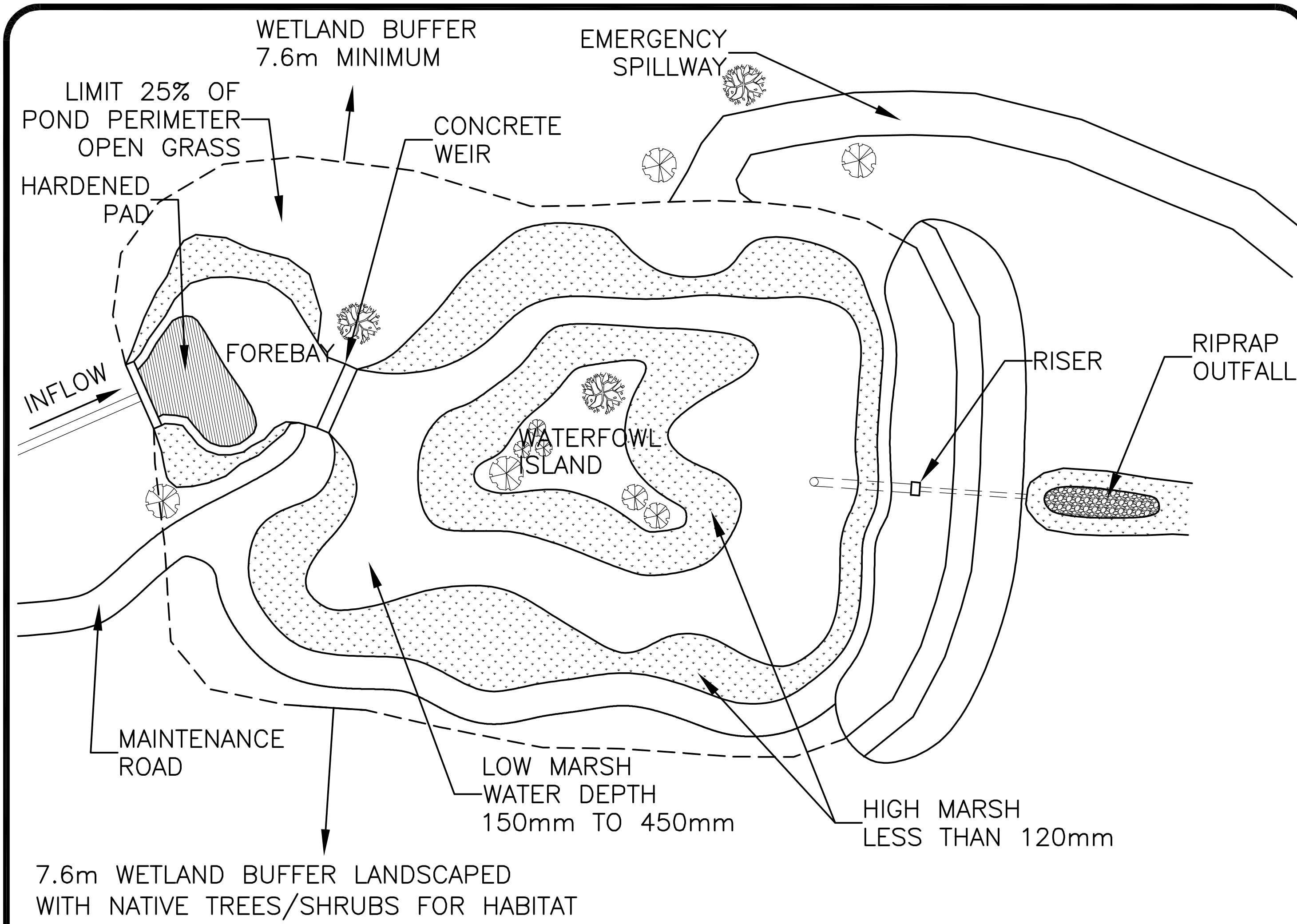
Description and Purpose
Shallow wetlands provide water quality volume in a shallow pool that has a large surface area.

Applications
Practices that create shallow wetland areas to treat urban storm water and often incorporate small permanent pools and/or extended detention storage to achieve the full water quality volume.

Design Criteria
• Required volume based on the 25mm storm.
• C=0.05+0.009*IMP is the runoff coefficient.
• IMP is the percentage of impervious area.
• WQDV=C*25mm*A*10 (Water Quality Design Volume (m^3).
• C is the runoff coefficient.
• 25mm is the 25mm storm.
• A is the area of the site in Ha.
• 10 is a conversion factor.
• The volume must meet minimum detention times.
• Flowpaths from inflow points to outflow points within storm water wetlands shall be maximized.
• Flowpaths of 1.5:1 (L:W) and irregular shapes are recommended and achieved by constructing internal berms.
• Microtopography is encouraged to enhance diversity in the wetland.
• Surface area shall be at least 1.5 percent of the total drainage area to the facility.
• At least 25% of the total water quality volume shall be in deepwater zones with a minimum depth of 1200mm. This may be reduced if the wetland is located where thermal impacts area a primary concern.
• A minimum of 35% of the total surface area shall have a depth of 150mm or less.
• At least 65% of the total surface area shall be shallower than 450mm.
• If using extended detention, the extended detention volume shall not comprise more than 50% of the total wetland design. Maximum surface elevation shall not extend more than 900mm above the normal pool.
• In order to promote greater nitrogen removal, rock beds may be used as a medium for growth of wetland plants. Rock should be 25-75mm in diameter and placed up to the normal pool elevation. Rock beds should be open to flow-through from either direction.

See Figure WQ 4-6

Pretreatment Requirements
• Sediment regulation is critical for sustaining storm water wetlands.
• Sediment forebay:
    o Located at the inlet and the micropool shall be located at the inlet;
    o Micropool located at the outlet; and
    o Forebay shall be sized to contain 6.5mm per impervious Ha of contributing drainage. The storage in the forebay counts toward the total amount of water quality volume required to be treated.
• Micropool is a 900-1800mm deep pool used to protect the low flow pipe from clogging and prevent sediment re-suspension.
• Exit velocities shall be non-erosive.



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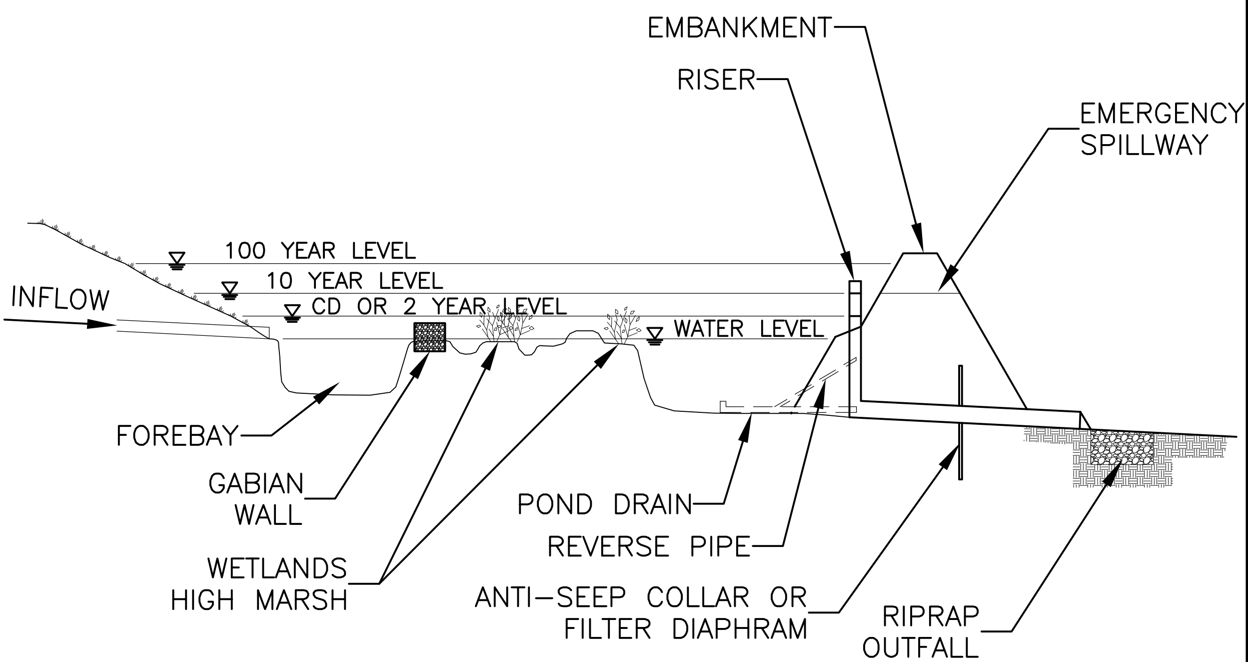


PROFILE

N.T.S.

SHALLOW WETLAND	WQ-4-6

Construction Considerations

• The wetland bed should be graded to create maximum internal flowpaths and micro-topography.

Landscaping Requirements

• Landscaping plans shall be provided that indicate methods used to establish and maintain wetland coverage.

• Minimum plan elements include:

    o Delineation of pondscaping zones;
    o Selection of corresponding plant species;
    o Planting configuration; and
    o Sequence for preparing wetland bed.

• Landscaping plans should incorporate plant species and plants found in local wooded wetlands.

• Woody/organic material or straw bales can be used in high energy areas of the storm water wetland to create shallow marsh cells.

• Landscaping plans should promote greater wildlife and waterfowl use within the watershed.

• A wetland buffer should extend 7.5m outward from the maximum water surface elevation with an additional 4.5m setback to structures.

Maintenance and Inspections

• If a minimum coverage of 50% is not achieved in the planted wetland zones after the second growing season, a reinforcement planting will be required.

Challenges

• A water balance must be performed to demonstrate that a wetland can withstand a thirty day drought at summer evaporation rates without completely drawing down.

• Critical watersheds may require a small pond review and approval from dam safety in wetlands that include permanent ponds as design components.

Pocket Wetland

Description and Purpose

A high water table or groundwater interception helps maintain the shallow wetland pool in the pocket wetland.

Applications

Practices that create wetland areas to treat urban storm water and often incorporate small permanent pools and/or extended detention storage to achieve the full water quality volume.

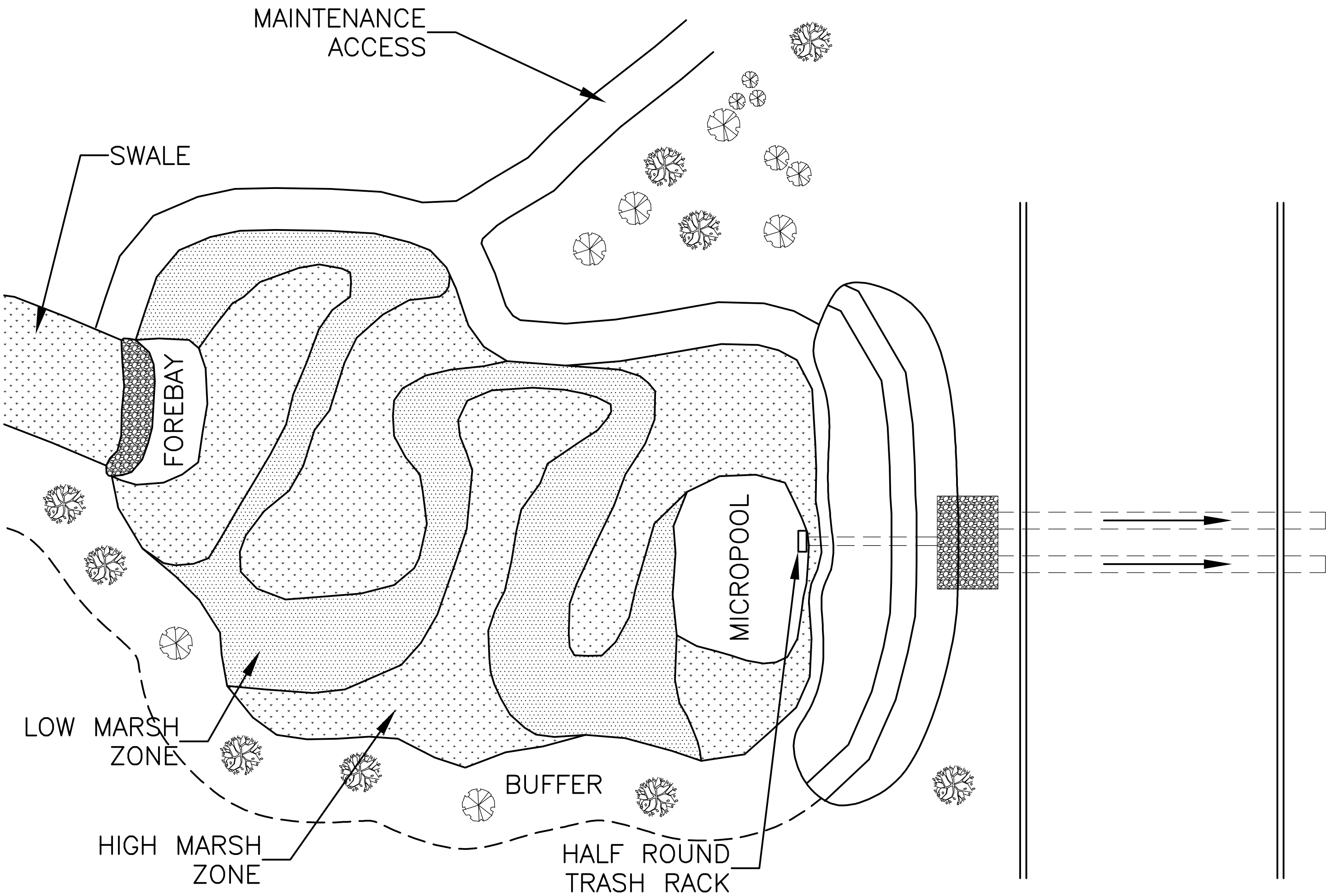
Design Criteria

- Required volume based on the 25mm storm.
- C=0.05+0.009*IMP is the runoff coefficient.
- IMP is the percentage of impervious area.
- WQDV=C*25mm*A*10 (Water Quality Design Volume (m^3).
- C is the runoff coefficient.
- 25mm is the 25mm storm.
- A is the area of the site Ha.
- 10 is a conversion factor.
- The volume must meet minimum detention times.
- Flowpaths from inflow points to outflow points within storm water wetlands shall be maximized.
- Flowpaths of 1.5:1 (L:W) and irregular shapes are recommended and achieved by constructing internal berms.
- Microtopography is encouraged to enhance diversity in the wetland.
- Surface area shall be at least one percent of the total drainage area to the facility.
- At least 25% of the total water quality volume shall be in deepwater zones with a minimum depth of 1.2m. This may be reduced if the wetland is located where thermal impacts area a primary concern.
- A minimum of 35% of the total surface area shall have a depth of 150mm or less.
- At least 65% of the total surface area shall be shallower than 450mm.
- If using extended detention, the extended detention volume shall not comprise more than 50% of the total wetland design. Maximum surface elevation shall not extend more than 900mm above the normal pool.
- In order to promote greater nitrogen removal, rock beds may be used as a medium for growth of wetland plants. Rock should be 25-75mm in diameter and placed up to the normal pool elevation. Rock beds should be open to flow through from either direction.

See Figure WQ 4-7

Pretreatment Requirements

- Sediment regulation is critical for sustaining storm water wetlands.
- Sediment forebay:
    - o Located at the inlet and the micropool shall be located at the inlet;
    - o Micropool located at the outlet; and
    - o Forebay shall be sized to contain 6.5mm per impervious Ha of contributing drainage. The storage in the forebay counts toward the total amount of water quality volume required to be treated.
- Micropool is a 900-1800mm deep pool used to protect the low flow pipe from clogging and prevent sediment re-suspension.
- Exit velocities shall be non-erosive.



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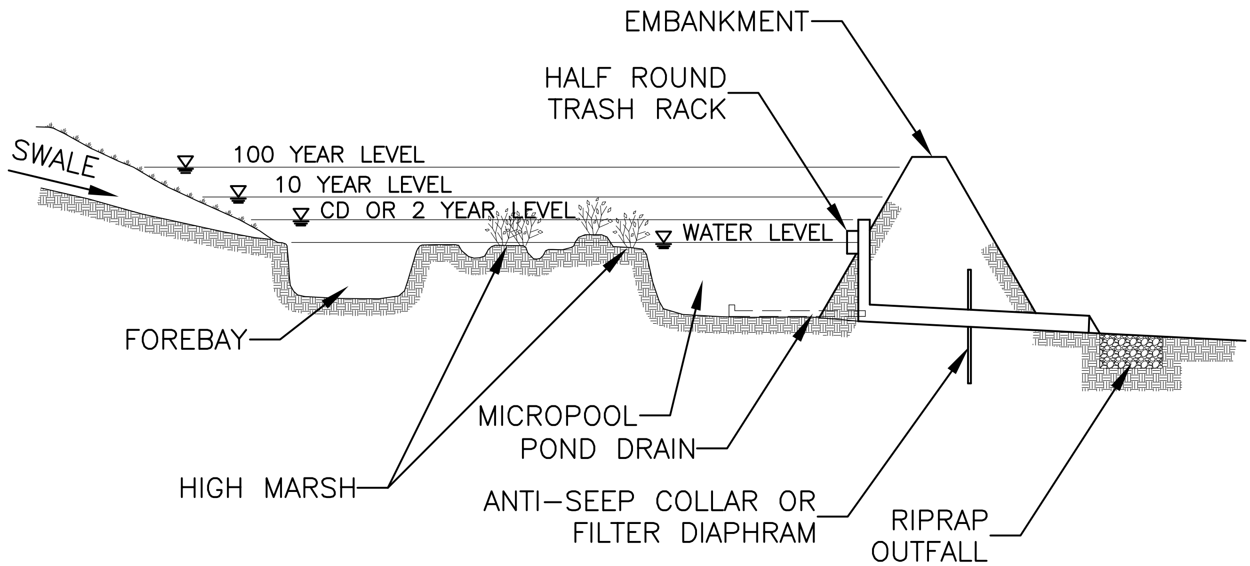


PROFILE

N.T.S.

POCKET WETLAND

WQ-4-7

Construction Considerations

• The wetland bed should be graded to create maximum internal flowpaths and micro-topography.

Landscaping Requirements

• Landscaping plans shall be provided that indicate methods used to establish and maintain wetland coverage.
• Minimum plan elements include:
  - o Delineation of pondscaping zones;
  - o Selection of corresponding plant species;
  - o Planting configuration; and
  - o Sequence for preparing wetland bed.
• Landscaping plans should incorporate plant species and plants found in local wooded wetlands.
• Woody/organic material or straw bales can be used in high energy areas of the storm water wetland to create shallow marsh cells.
• Landscaping plans should promote greater wildlife and waterfowl use within the watershed.
• A wetland buffer should extend 7.5m outward from the maximum water surface elevation with an additional 4.5m setback to structures.

Maintenance and Inspections

• If a minimum coverage of 50% is not achieved in the planted wetland zones after the second growing season, a reinforcement planting will be required.
• Storm water wetlands are created in upland areas and away from jurisdictional wetlands and are not regulated by local/Provincial laws as long as regular maintenance is performed.

Challenges

• A water balance must be performed to demonstrate that a wetland can withstand a thirty day drought at summer evaporation rates without completely drawing down.
• May require a small pond review and approval from dam safety in wetlands that include permanent ponds as design components.

Wet Extended Detention Pond

Description and Purpose

Water quality storage is provided through a combination of permanent pool and extended detention storage.

Applications

Detention of storm water runoff allows for the settling of fine particles and pollutants that are associated with these particles.

Design Criteria

• Required volume based on the 25mm storm.
• C=0.05+0.009*IMP is the runoff coefficient.
• IMP is the percentage of impervious area.
• WQDV=C*25mm*A*10 (Water Quality Design Volume (m^3))
• C is the runoff coefficient;
• 25mm is the 25mm storm;
• A is the area of the site in Ha; and
• 10 is a conversion factor
• The volume must meet minimum detention times.
• The draw-down time for the detention volume shall be greater than or equal to 48 hours. For the bottom half of the detention volume, the draw-down time shall be greater than or equal to 36 hours.
• The detention system shall be designed to maximize the distance between the inlet and outlet, and to minimize “dead spaces” (areas with little or no exchange occurs during a storm event), limiting short-circuiting. A minimum flow path length to width ratio of 3 should be utilized.
• The outlet shall be sized to achieve the above required detention times. It shall also be large enough that clogging is unlikely to occur. It should be 50mm or larger in diameter. If this is not possible, the use of flow-through based measures should be considered, unless it can be demonstrated that clogging can be avoided.
• There shall be a minimum contributing drainage area of 4Ha or more unless groundwater ground water is the primary water source.
• Dams shall meet BC Dam Safety requirements.
• The principal spillway/riser shall provide anti-floatation, anti-vortex, and trashrack designs.
• 300mm of freeboard shall be provided above the design high water for the 100 year storm.
• Woody vegetation is prohibited on the embankment.
• Pond benches:
    o The safety bench extends outward from the normal water edge to the toe of the pond side slope. Maximum slope=6%; and
    o Aquatic bench extends inward from the normal shoreline and has a maximum depth of 450mm below normal pool water surface elevation.
    Not required in forebays.
• Pond buffers and setbacks:
    o Buffer should be provided that extends 7.5m outward from the maximum water surface elevation of the pond and should be contiguous with other required buffer areas; and
    o Existing trees should be preserved during construction and forest conservation areas should be located.
• Non-clogging low flow orifice:
    o Shall have a minimum diameter of 50mm and shall be adequately protected from clogging by an external trash rack;

- o Orifice diameter can be reduced to 25mm if using an internal orifice;
  - o Submerged reverse-slope pipe that extends downward from the riser to an inflow point 300mm below normal pool elevation is preferred;
  - o Alternatives include broad crested rectangular, v-notch, or proportional weird, protected by half-round CMP that extends 300mm below permanent pool;
  - o Horizontal perforated pipe protected by geotextile and gravel not recommended; and
  - o Vertical pipes can be used if a permanent pool is present.
- Riser:
  - o Shall be located within the embankment for maintenance access, safety and aesthetics;
  - o Access to riser to be provided by lockable manhole covers and steps within reach of valves and controls; and
  - o Openings should be fenced with pipe or rebar to prevent trash accumulation.
- Pond Drain:
  - o Ponds shall have a drain pipe that can drain the pond within 24 hours;
  - o Prevent downstream discharge of sediment and slope instability caused by drawdown by exercising care during these processes; and
  - o Appropriate jurisdictions shall be notified before draining a pond.
- Valves:
  - o Drain shall be equipped with adjustable valve;
  - o Drain should be sized one pipe size larger than the calculated design diameter;
  - o Controls should be located inside of the riser they will not be inundated and can be operated safely; and
  - o Handwheel shall be chained to a ringbolt or manhole step to prevent vandalism.

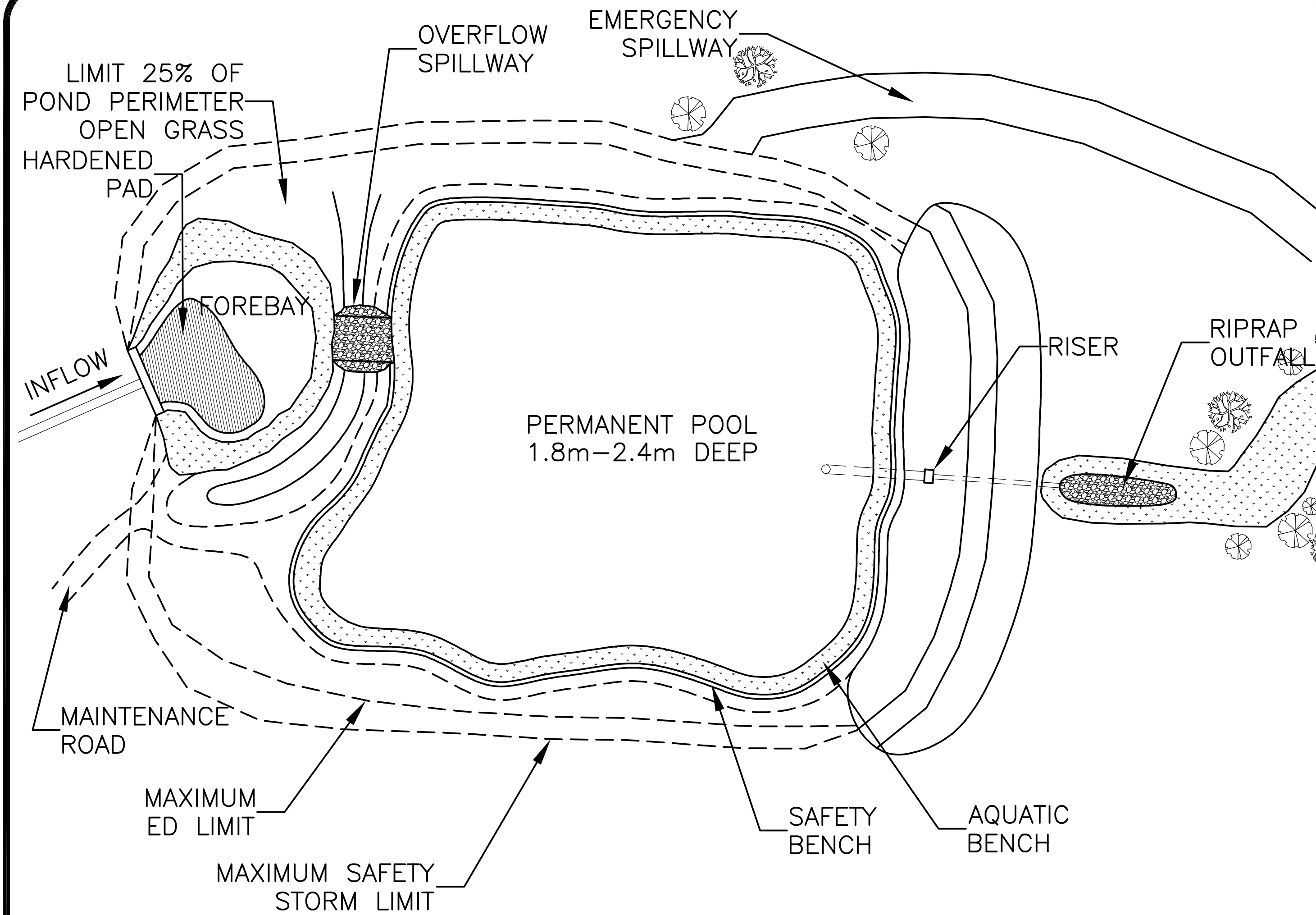
See Figure WQ 4-8

Pretreatment Requirements

- Sediment forebay:
  - o Each pond shall have a sediment forebay or equivalent upstream treatment and shall consist of a separate cell, formed by an adequate barrier; and
  - o Forebay shall be sized to contain 6mm per impervious Ha of contributing drainage. The storage in the forebay counts toward the total amount of water quality volume required to be treated.
- Exit velocities shall be non-erosive.
- The bottom may be hardened to make sediment removal easier.
- The fixed vertical sediment depth marker should be installed to measure sediment deposition over time.

Construction Considerations

- Inlet protection shall not be fully submerged at normal pool elevations.
- A forebay shall be provided at each inlet.
- Flared pipe sections that discharge at or near the stream invert or into a steppool arrangement should be used at the spillway outlet.
- The channel immediately below the pond outfall shall be modified to prevent erosion and conform to natural dimensions in the shortest possible distance, usually by the use of large riprap over filter cloth.
- A stilling basin or other outlet protection should be used to reduce flow velocities from the principal spillway to be non-erosive.
- In ponds that daylight to channels with dry weather flow, tree clearing should be minimized along the downstream channel. Avoiding the excessive use of riprap is important to prevent stream warming.
- Pond liners should be used in areas of karst topography, gravelly sands or fractured bedrock.



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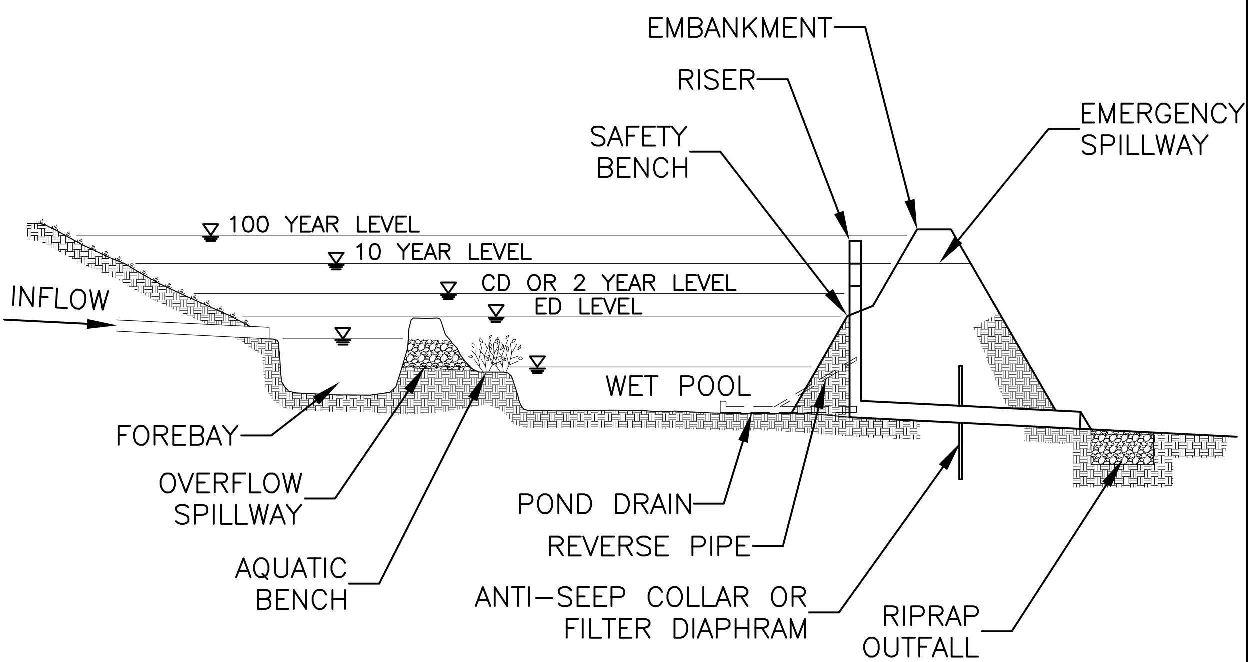


PROFILE

N.T.S.

WET EXTENDED DETENTION POND

WQ–4–8

Landscaping Requirements

• The landscaping plan for storm water ponds and its buffer shall indicate how aquatic and terrestrial areas will be vegetatively stabilized and established.

• Wetland plants are encouraged either along the aquatic bench, safety bench and side slopes, or within shallow areas of the pool. The best elevations for establishing these plants are within 150mm of the normal pool.

• It is advised to excavate large and deep holes around the proposed planting sites
and backfill with un-compacted topsoil.

• Planting holes should be at least 150mm larger than the diameter of the rootball (balled and burlap stock) and 75mm wider for container grown stock.

• Avoid species requiring full shade which are prone to wind damage.

• Extra mulching around the base is strongly recommended to conserve moisture and prevent weeds.

Maintenance and Inspections

• Maintenance responsibility for the pond and its buffer shall be given to a responsible party by means of a legally binding and enforceable maintenance agreement.

• The principal spillway shall be equipped with a trash rack that has maintenance access.

• Sediment removal in the forebay shall take place when 50% of the forebay capacity is lost.

• Sediment removed from ponds shall be disposed of according to current erosion and sediment control regulations.

• A maintenance right-of-way or easement at least 3.5m wide and a maximum slope of 15% and stabilized shall extend to a pond from a public or private road.

• Maintenance access should extend to the forebay, safety bench, riser, and outlet and should allow vehicles to turn around.

• Annual mowing of the buffer is only required on maintenance rights-of-way.

Challenges

• Although a detention system for water quality could be combined with a flood control system, the volume assigned for water quality control must meet minimum detention times. This volume will typically not be available for peak rate volume control.

• Ponds cannot be located within jurisdictional waters such as wetlands without obtaining proper permits.

Wet Pond

Description and Purpose
A wet pond provides all of the water quality volume storage in a permanent pool.

Applications
Detention of storm water runoff allows for the settling of fine particles and pollutants that are associated with these particles. The wet pond volume is equal to the water quality design volume and is entirely a permanent wet pond, where storm water exchanges with the pond water to achieve treatment.

Design Criteria
• Required volume based on the 25mm storm.
• C=0.05+0.009*IMP is the runoff coefficient.
• IMP is the percentage of impervious area.
• WQDV=C*25mm*A*10 (Water Quality Design Volume (m^3))
• C is the runoff coefficient;
• 25mm is the 25mm storm;
• A is the area of the site in Ha; and
• 10 is a conversion factor.
• Detention time requirements do not apply.
• The draw-down time for the detention volume shall be greater than or equal to 48 hours. For the bottom half of the detention volume, the draw-down time shall be greater than or equal to 36 hours.
• The detention system shall be designed to maximize the distance between the inlet and outlet, and to minimize "dead spaces" (areas with little or no exchange occurs during a storm event), limiting short-circuiting. A minimum flow path length to width ratio of 3 should be utilized.
• The outlet shall be sized to achieve the above required detention times. It shall also be large enough that clogging is unlikely to occur. It should be 50mm or larger in diameter. If this is not possible, the use of flow-through based measures should be considered, unless it can be demonstrated that clogging can be avoided.
• There shall be a minimum contributing drainage area of 4 Ha or more unless groundwater is the primary water source.
• The 100 year design storm is to be used to design for a stable outfall.
• Dams shall meet BC dam safety requirements.
• The principal spillway/riser shall provide anti-floatation, anti-vortex, and trashrack designs.
• 300mm of freeboard shall be provided above the design high water for the 100 year storm.
• Woody vegetation is prohibited on the embankment.
• Pond benches:
    o The safety bench extends outward from the normal water edge to the toe of the pond side slope. Maximum slope=6%; and
    o Aquatic bench extends inward from the normal shoreline and has a maximum depth of 450mm below normal pool water surface elevation. Not required in forebays.
• Pond buffers and setbacks:
    o Buffer should be provided that extends 7.5m outward from the maximum water surface elevation of the pond and should be contiguous with other required buffer areas; and
    o Existing trees should be preserved during construction and forest conservation areas should be located.
• Non-clogging low flow orifice:

- o Shall have a minimum diameter of 50mm and shall be adequately protected from clogging by an external trash rack;
- o Orifice diameter can be reduced to 25mm if using an internal orifice;
- o Submerged reverse-slope pipe that extends downward from the riser to an inflow point 300mm below normal pool elevation is preferred;
- o Alternatives include broad crested rectangular, v-notch, or proportional weir, protected by half-round CMP that extends 300mm below permanent pool;
- o Horizontal perforated pipe protected by geotextile and gravel not recommended; and
- o Vertical pipes can be used if a permanent pool is present.

- Riser:
  - o Shall be located within the embankment for maintenance access, safety and aesthetics;
  - o Access to riser to be provided by lockable manhole covers and steps within reach of valves and controls; and
  - o Openings should be fenced with pipe or rebar to prevent trash accumulation.
- Pond Drain:
  - o Ponds shall have a drain pipe that can drain the pond within 24 hours;
  - o Prevent downstream discharge of sediment and slope instability caused by drawdown by exercising care during these processes; and
  - o Appropriate jurisdictions shall be notified before draining a pond.
- Valves:
  - o Drain shall be equipped with adjustable valve;
  - o Drain should be sized one pipe size larger than the calculated design diameter;
  - o Controls should be located inside of the riser they will not be inundated and can be operated safely;
  - o Handwheel shall be chained to a ringbolt or manhole step to prevent vandalism; and
  - o Applicant must show a water balance that demonstrates that there will be sufficient dry weather flows to maintain the planned pool volume, without creating stagnant conditions.

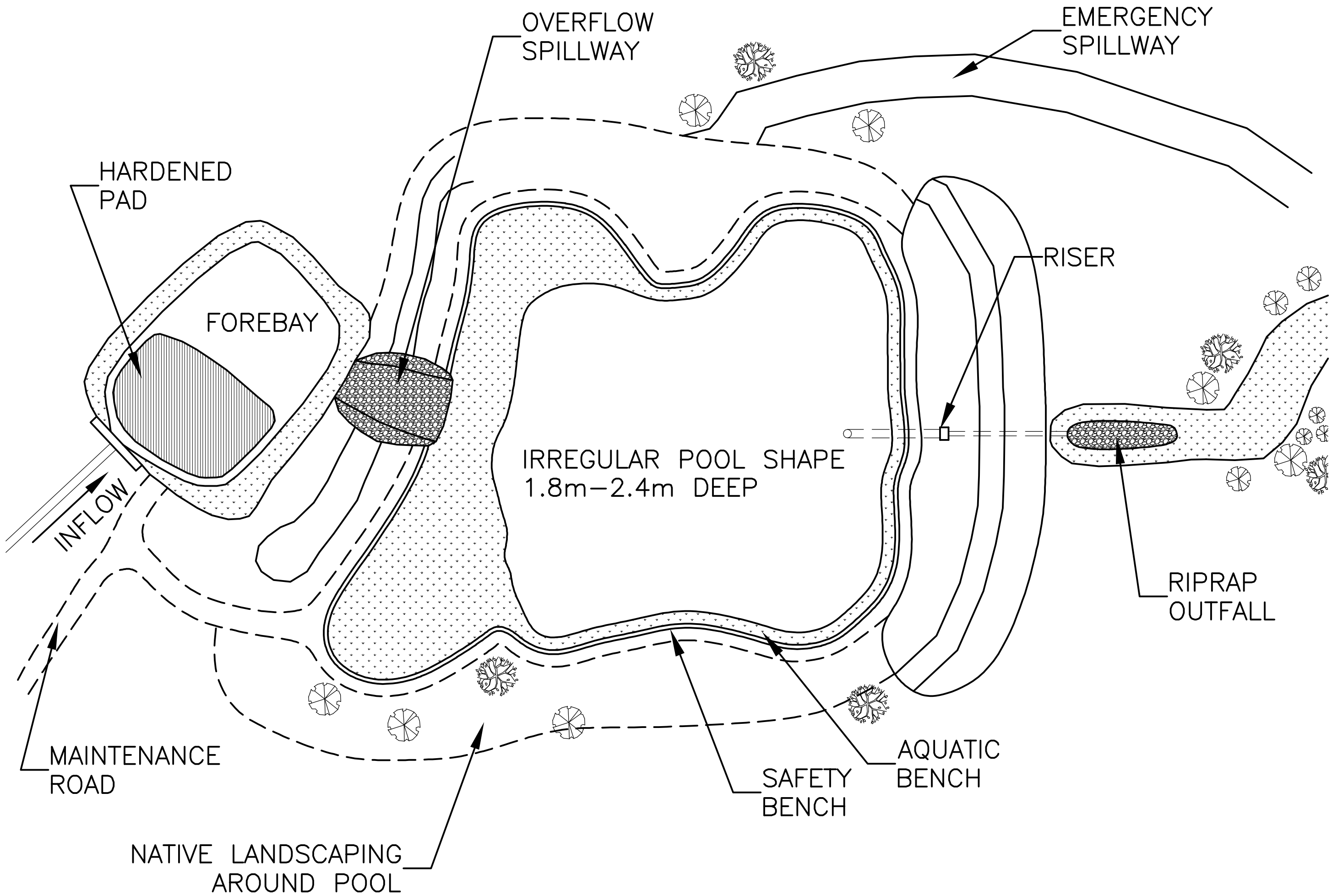
See Figure WQ 4-9

Pretreatment Requirements

- Sediment forebay:
  - o Each pond shall have a sediment forebay or equivalent upstream treatment and shall consist of a separate cell, formed by an adequate barrier; and
  - o Forebay shall be sized to contain 6mm per impervious Ha of contributing drainage. The storage in the forebay counts toward the total amount of water quality volume required to be treated.
- Exit velocities shall be non-erosive.
- The bottom may be hardened to make sediment removal easier.
- The fixed vertical sediment depth marker should be installed to measure sediment deposition over time.

Construction Considerations

- Inlet protection shall not be fully submerged at normal pool elevations.
- A forebay shall be provided at each inlet.
- Flared pipe sections that discharge at or near the stream invert or into a steppool arrangement should be used at the spillway outlet.
- The channel immediately below the pond outfall shall be modified to prevent erosion and conform to natural dimensions in the shortest possible distance, usually by the use of large riprap over filter cloth.



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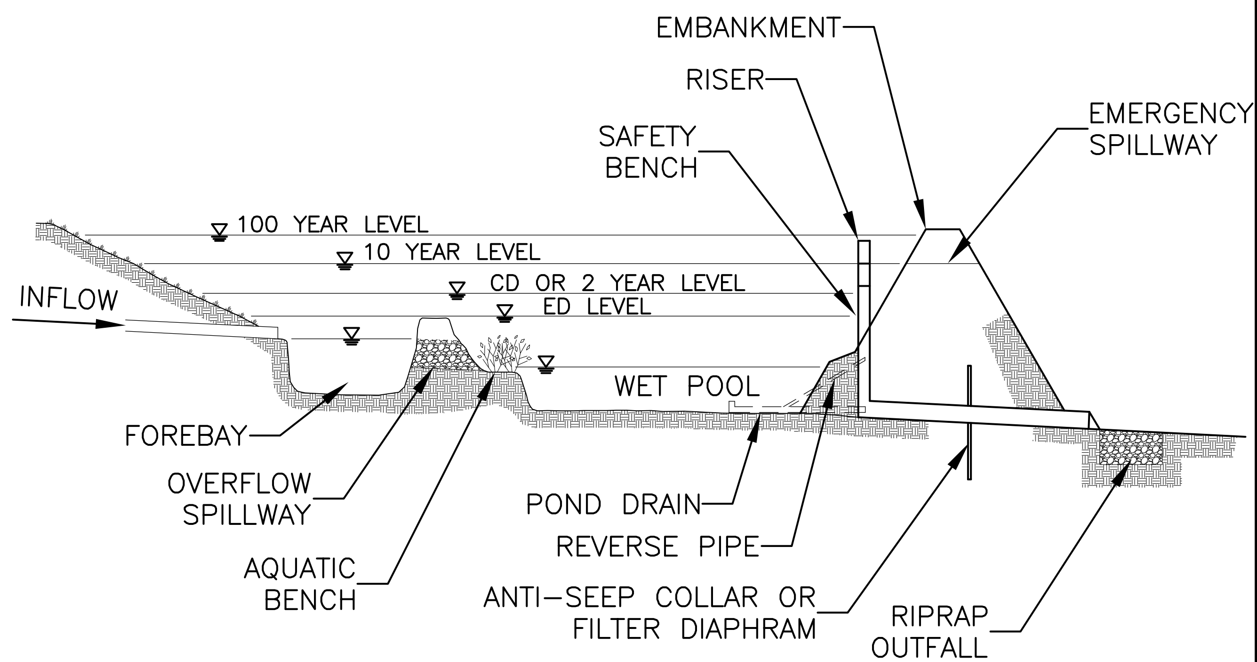


PROFILE

N.T.S.

WET POND	WQ–4–9

• A stilling basin or other outlet protection should be used to reduce flow velocities from the principal spillway to be non-erosive.
• In ponds that daylight to channels with dry weather flow, tree clearing should be minimized along the downstream channel. Avoiding the excessive use of riprap is important to prevent stream warming.
• Pond liners should be used in areas of gravelly sands or fractured bedrock.

Landscaping Requirements
• The landscaping plan for storm water ponds and its buffer shall indicate how aquatic and terrestrial areas will be vegetatively stabilized and established.
• Wetland plants are encouraged either along the aquatic bench, safety bench and side slopes, or within shallow areas of the pool. The best elevations for establishing these plants are within 150mm of the normal pool.
• It is advised to excavate large and deep holes around the proposed planting sites and backfill with uncompacted topsoil.
• Planting holes should be at least 150mm larger than the diameter of the rootball (balled and burlap stock) and 75mm wider for container grown stock.
• Avoid species requiring full shade which are prone to wind damage.
• Extra mulching around the base is strongly recommended to conserve moisture and prevent weeds.

Maintenance and Inspections
• The principal spillway shall be equipped with a trash rack that has maintenance access.
• Sediment removal in the forebay shall take place when 50% of the forebay capacity is lost.
• Sediment removed from ponds shall be disposed of according to current erosion and sediment control regulations.
• A maintenance right-of-way or easement at least 4.5m wide and a maximum slope of 15% and stabilized shall extend to a pond from a public or private road.
• Maintenance access should extend to the forebay, safety bench, riser, and outlet and should allow vehicles to turn around.
• Annual mowing of the buffer is only required on maintenance rights-of-way.

Challenges
• Although a detention system for water quality could be combined with a flood control system, the volume assigned for water quality control must meet minimum detention times. This volume will typically not be available for peak rate volume control.

Surface Sand Filter

Description and Purpose

Surface sand filters can treat the largest drainage area of all the filtering systems. It captures and temporarily stores the water quality volume and passes it through a filter bed of sand, organic matter, soil, or other media.

Applications

Filtered runoff may be collected and returned to the conveyance system or allowed to partially exfiltrate into the soil. Applied to land uses with a high percentage of impervious surfaces. Drainage areas with imperviousness less than 75% discharging to a filtering practice shall require full sedimentation pretreatment techniques.

Design Criteria

• A porosity value "n" (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
• Required volume is based on a rainfall intensity of 10mm per hour.
• WQFR: C*10mm*A/360 is the Water Quality Flow Rate (m^3/s).
• C is the runoff coefficient, calculated using tables.
• 10mm is the hourly rainfall intensity.
• A is the site area in Ha.
• The required filter bed area (Af) is computed using the following equation:

Af= (WQv) (df) / [(k) (hf+df) (tf)]

- o WQv is the water quality volume (m^3);
- o df is the filter bed depth (m);
- o k is the coefficient pf permeability of the filter bed (m/day);
- o hf is the height of water above the filter bed (m); and
- o tf is the design filter bed drain time (days)- 2 days recommended.

• If runoff is delivered by a storm drain pipe or is along the main conveyance system, the filtering practice shall be designed off-line.
• Filter bed has a minimum depth of 300mm.

See Figure WQ 4-10

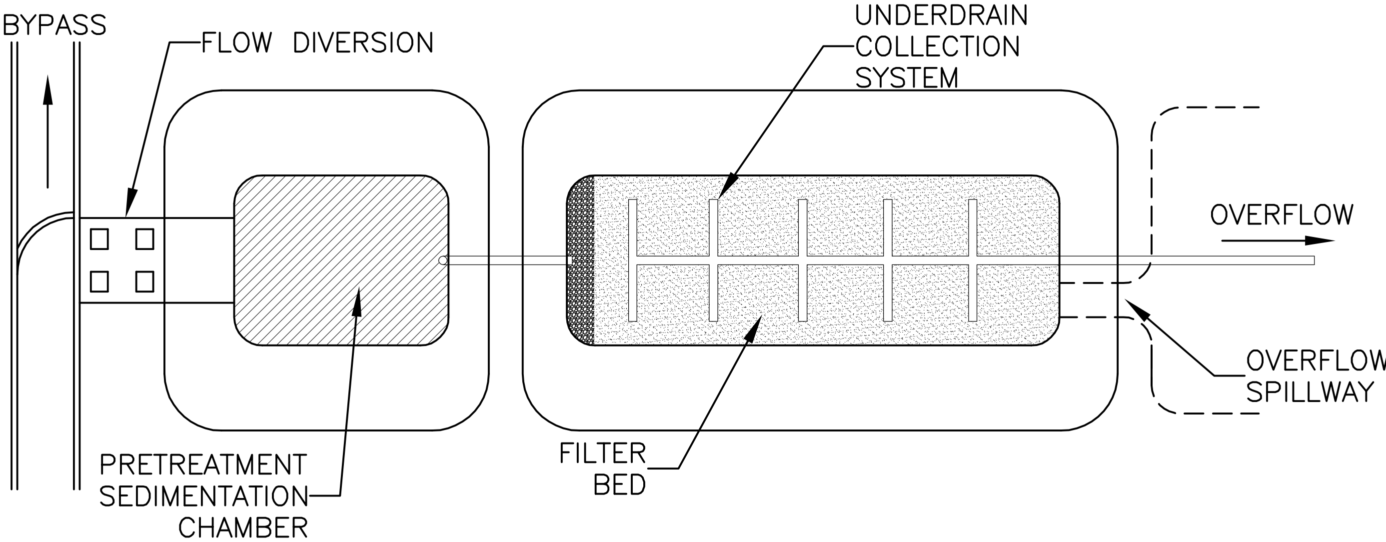
Pretreatment Requirements

• Dry or wet pretreatment equivalent to at least 25% of the computed water quality volume shall be provided prior to the filter media.
• Typically, sedimentation basins with a length to width ratio of 2:1 are used.
• Pretreatment is provided when all of the following are provided:

- o 6m grass filter strip below a level spreader or sand filter layer;
- o Gravel diaphragm; and
- o Mulch layer.

• Treatment components shall include:

- o 750 to 1200mm deep planting soil bed;
- o Surface mulch layer; and
- o 300mm deep surface ponding area.



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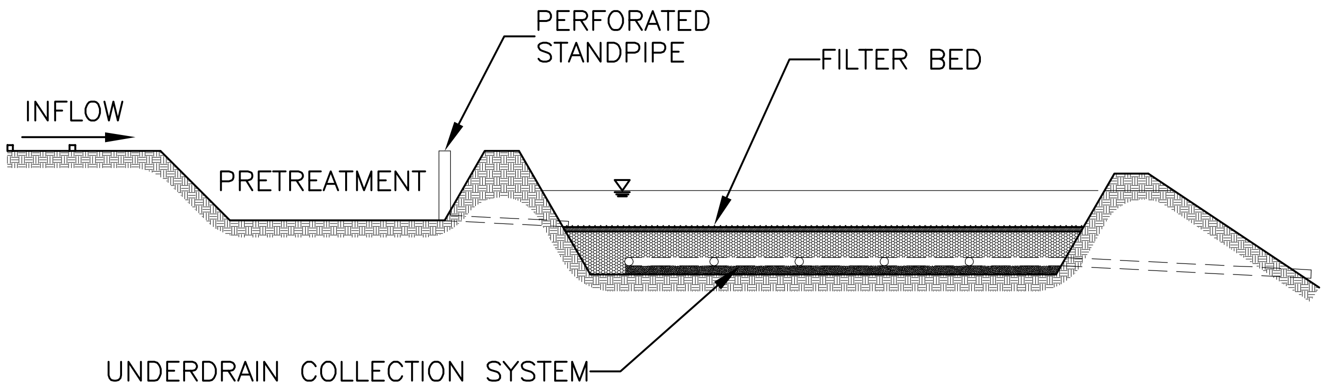

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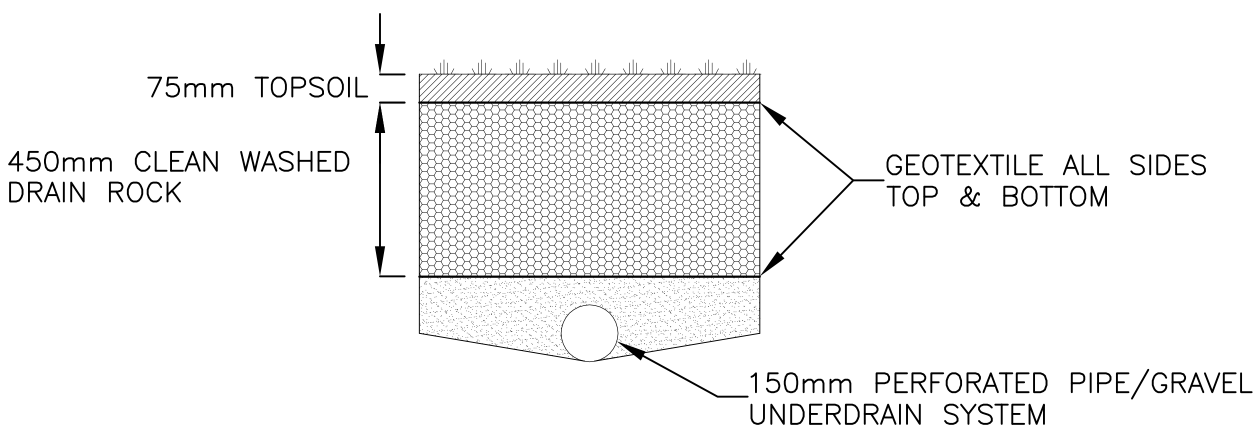

SECTION

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SURFACE SAND FILTER

WQ–4–10

Construction Considerations

• A flow regulator shall be provided to divert the water quality volume to the filtering practice.
• The filters shall have a 150mm perforated underdrain pipe in a gravel layer.
• A permeable filter fabric shall be places between the gravel layer and the filter media.

Landscaping Requirements

• The ponding depth should be 150mm or less with a mulch layer of 50 to 75mm.
• A sandy planting soil of 50 to 75mm should be used.
• Dense and vigorous should be established over the contributing drainage area before accepting runoff into the facility.
• A grass cover is permitted to aid in pollutant adsorption and should be cable of withstanding frequent periods of inundation and drought.

Maintenance and Inspections

• Direct maintenance access is to be provided to the pretreatment area and the filter bed.
• Dead or diseased plants shall be replaced.
• Areas with mulch that has been washed out should be re-mulched annually.
• The sediment chamber outlet devices shall be cleaned/repaired when drawdown times within the chamber exceed 36 hours. Trash and debris shall be removed as necessary.
• Sediment shall be cleaned out of the sedimentation chamber when it accumulates to a depth of more than 150mm.
• Vegetation in the sediment chamber should be no greater than 450mm in height.
• When water ponds on the surface of the filter for more than 72 hours, the top 50mm of the discolored material shall be replaced with fresh material, and the removed sediment should be disposed of (landfill).
• When silt and sediment accumulation exceeds 25mm, it should be removed from the filter bed.
• Filters with a grass cover should be mowed at least 3 times per growing season to maintain grass heights of less than 300mm.

Challenges

• Unless there is adequate infiltration capacity, underdrains and overflow drains should be included to collect and discharge filtered runoff to the storm drainage system.

Underground Sand Filter

Description and Purpose

The underground sand filter is an option for providing water quality volume where space is limited.

Applications

Filtered runoff may be collected and returned to the conveyance system or allowed to partially exfiltrate into the soil. Applied to land uses with a high percentage of impervious surfaces. Drainage areas with imperviousness less than 75% discharging to a filtering practice shall require full sedimentation pretreatment techniques.

Design Criteria

• A porosity value “n” (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
• Required volume is based on a rainfall intensity of 10mm per hour.
• WQFR: C*10mm*A/360 is the Water Quality Flow Rate (m^3/s).
• C is the runoff coefficient, calculated using tables.
• 10mm is the hourly rainfall intensity.
• A is the site area in Ha.
• The required filter bed area (Af) is computed using the following equation:
Af= (WQv) (df) / [(k) (hf+df) (tf)]

o WQv is the water quality volume (m^3);
o df is the filter bed depth (m);
o k is the coefficient pf permeability of the filter bed (m/day);
o hf is the height of water above the filter bed (m); and
o tf is the design filter bed drain time (days)- 2 days recommended

• If runoff is delivered by a storm drain pipe or is along the main conveyance system, the filtering practice shall be designed off-line.
• Filter bed has a minimum depth of 300mm.

See Figure WQ 4-11

Pretreatment Requirements

• Dry or wet pretreatment equivalent to at least 25% of the computed water quality volume shall be provided prior to the filter media.
• Typically, sedimentation basins with a length to width ratio of 2:1 are used.
• Pretreatment is provided when all of the following are provided:

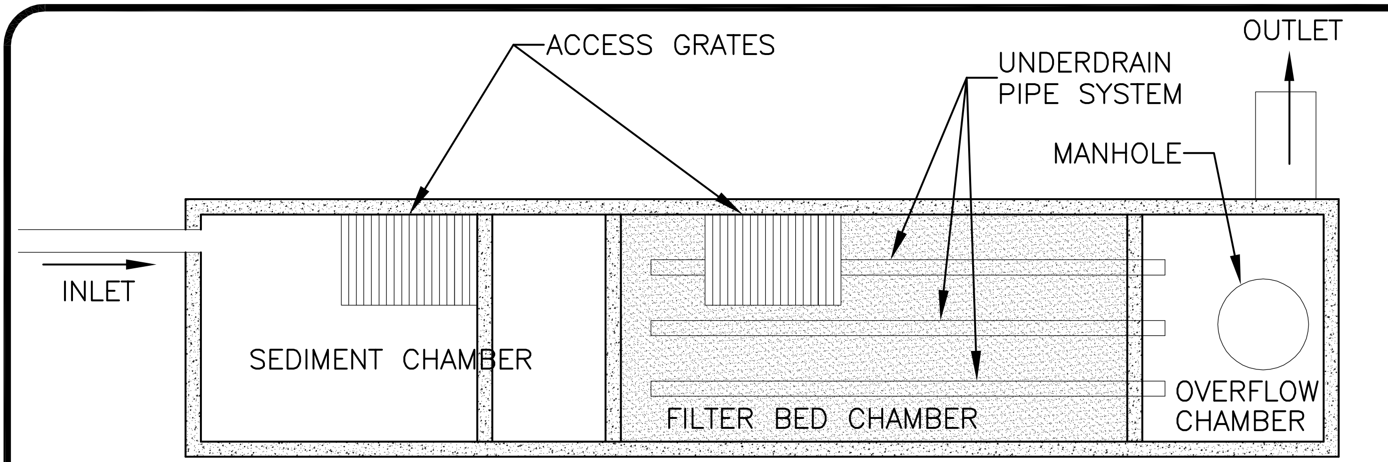
o 6m grass filter strip below a level spreader or sand filter layer;
o Gravel diaphragm; and
o Mulch layer.

• Treatment components shall include:

o 750 to 1200mm deep planting soil bed;
o Surface mulch layer; and
o 300mm deep surface ponding area.

Construction Considerations

• A flow regulator shall be provided to divert the water quality volume to the filtering practice.



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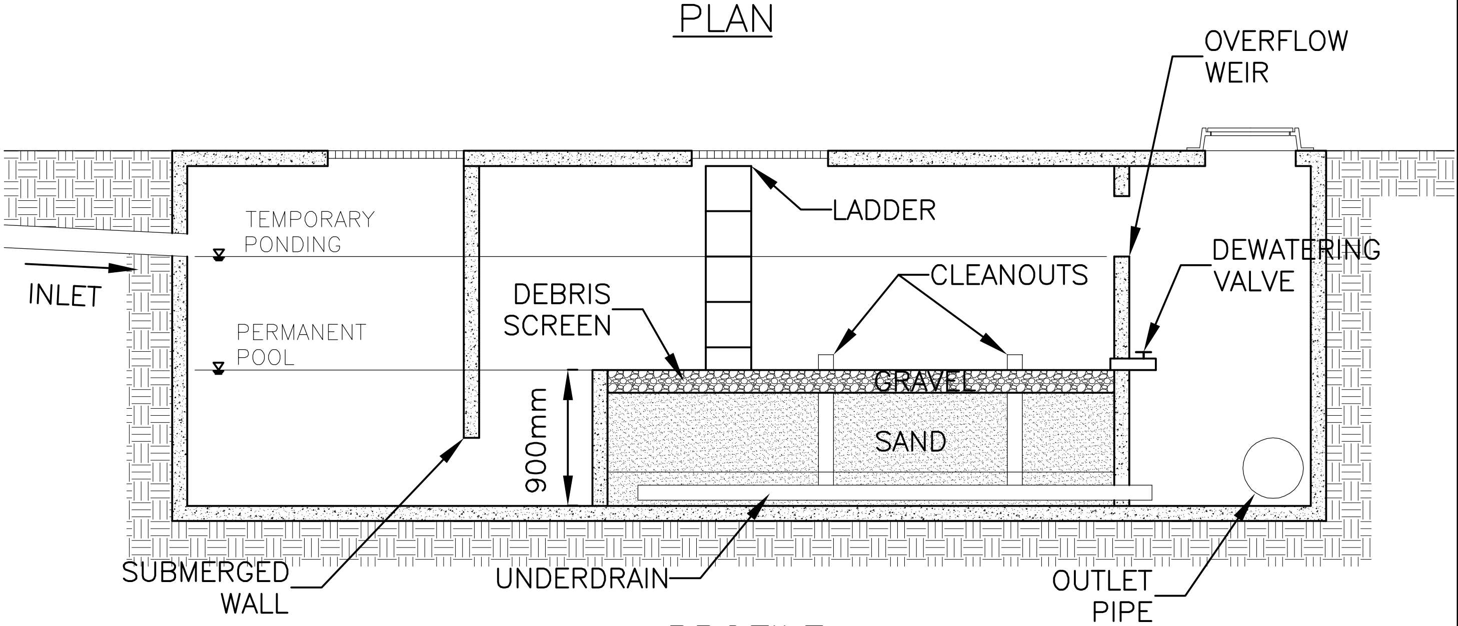

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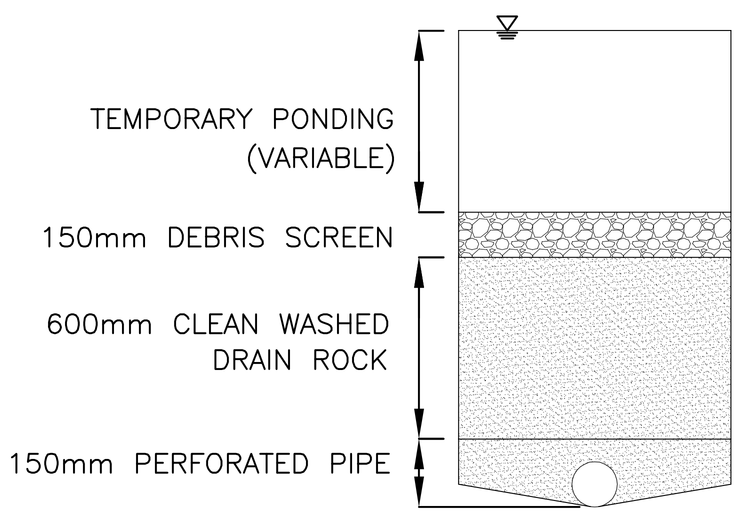

SECTION

N.T.S.

UNDERGROUND SAND FILTER

WQ–4–11

• The filters shall have a 150mm perforated underdrain pipe in a gravel layer.
• A permeable filter fabric shall be places between the gravel layer and the filter media.

Landscaping Requirements
• The ponding depth should be 150mm or less with a mulch layer of 50 to 75mm.
• A sandy planting soil of 50 to 75mm should be used.
• Dense and vigorous should be established over the contributing drainage area before accepting runoff into the facility.

Maintenance and Inspections
• Direct maintenance access is to be provided to the pretreatment area and the filter bed.
• Dead or diseased plants shall be replaced.
• Areas with mulch that has been washed out should be re-mulched annually.
• The sediment chamber outlet devices shall be cleaned/repaired when drawdown times within the chamber exceed 36 hours. Trash and debris shall be removed as necessary.
• Sediment shall be cleaned out of the sedimentation chamber when it accumulates to a depth of more than 150mm.
• Vegetation in the sediment chamber should be no greater than 450mm in height.
• When water ponds on the surface of the filter for more than 72 hours, the top 50mm of the discolored material shall be replaced with fresh material, and the removed sediment should be disposed of (landfill).
• When silt and sediment accumulation exceeds 25mm, it should be removed from the filter bed.

Challenges
• Unless there is adequate infiltration capacity, underdrains and overflow drains should be included to collect and discharge filtered runoff to the storm drainage system.

Structural, Hydrodynamic and other Proprietary BMPS

Many current "structural" BMPs, which are commercially available proprietary products, may not be utilized as stand alone BMPs in meeting the performance criteria specified in the water quality control chapter of this manual. These "structural" BMPs include:

- Catch basin inserts;
- Water quality inlets;
- Oil/grit separators; and
- Hydrodynamic devices.

Structural, hydrodynamic, and proprietary BMPs have not been studied as extensively as other BMPs described in this manual but have been used with varying degrees of success. The intended functions of these products may vary widely. Some BMPs are designed to primarily remove solid waste and floatable trashes while others use hydrodynamic separation techniques to separate sediment and oil/grease. Many of these BMP devices are not able to decrease Total Suspended Solids (TSS) and/or Total Phosphorus (TP) to meet water quality standards and some lack adequate independent testing data or long-term records. In some cases, these devices are used for pretreatment or part of an overall storm water quality treatment system ("treatment train").

For example, they may be helpful in removing a portion of the pollutants present in storm water runoff before it enters storm water ponds or filtration practices.

The American Society of Civil Engineers has developed a comprehensive database on BMP performance under an EPA cooperative agreement. The long-term goal of the project is to promote technical design improvements for BMPs and to better match their selection and design to the local storm water problems being addressed.

The District does not endorse any specific "structural" BMP described in this section. Designers working on District projects are encouraged to consult with manufacturers, obtain independent performance testing data, and demonstrate how these devices will be utilized to meet both quantity and quality criteria.

Catch Basin Inserts

Catch basin inserts consist of a frame that fits below the inlet grate of a catch basin and can be fitted with various trays that target specific pollutants. The trays may also contain a variety of media. The device is typically designed to accept the design flow rate of the inlet grate with bypasses as the trays become clogged with debris. The media require routine maintenance for replacement and cleaning. Catch basin inserts are typically used for smaller drainage areas.

Water Quality Inlets

Water quality inlets are underground retention systems designed to remove settleable solids. There are several water quality inlet designs. Some water quality inlets include a second chamber with a sand filter to remove finer suspended solids by filtration.

Oil / Grit Separators

Typical oil/grit separators consist of three chambers. The first chamber removes coarse material and debris; the second chamber separates oil, grease, and gasoline; and the third chamber provides safety relief if blockage occurs. Similar to water quality inlets, frequent maintenance and disposal of trapped residuals and hydrocarbons are necessary for oil/grit separators.

Hydrodynamic Devices
A variety of manufactured hydrodynamic devices are available for removing pollutants from storm water runoff. The hydrodynamic separation concept these devices are based on involves the settlement of sediment as runoff moves in a swirling path. Typically these devices are prefabricated in a range of sizes targeted at specific flow rates.

One type of hydrodynamic device is designed to remove suspended particles, oil, and grease during low flow conditions. Higher flows are diverted around the treatment chamber to prevent scour and high velocity from carrying the collected pollutants out of the treatment chamber. Maintenance requirements include the periodic removal of oil/grease and sediments by using a vacuum truck. Examples include Stormceptor® and Baysavers®.

Oil/water separators and oil/grit separators are manufactured in Kelowna by Koncast and American Forcecrete of Canada Inc. (AFC).

A second type of hydrodynamic device utilizes centrifugal motion to remove litter, floatable debris, and larger sediment particles from runoff. Examples include CDS® and various storm water devices manufactured by Contech®. Since this technology is designed to capture trash rather than pollutants, these devices are most applicable in areas that receive heavy trash loads. These devices are constructed so that a vacuum truck can regularly remove the floatable and settled debris collected in the treatment chamber.

4.3 Soil Stabilization

Preservation of Existing Vegetation

Description and Purpose
Identification of existing vegetation to remain provides erosion and sediment control on a site with future land disturbing activities.

Applications
Preservation of existing vegetation practices apply to the following:

- Areas on-site where no construction activity occurs or will occur at a later date.
- Areas where the existing vegetation should be preserved such as steep slopes, watercourses, and building sites in wooded areas.
- Natural resources or environmental protection areas such as wetlands and marshes requiring preservation by local, provincial, and federal governments.

Installation and Implementation Requirements

- Incorporate existing vegetation into landscaping plans when possible. Proper care of this vegetation before and after construction is required.
- Consider aesthetic and environmental values, tree/plant health, life span, sun exposure limitations, and space requirements when determining which vegetation to preserve.
- When preparing the landscaping plans, avoid using vegetation which competes with the existing vegetation.
- Establish setback distances defined by devices such as berms, fencing, or signs.

Setback distances are based on vegetation species, location, size, and age. The type of construction activity in the vicinity of the vegetation shall also be considered. Construction activities are not permitted within the setback.

- Protect existing vegetation using one of the following methods:
    - Mark, flag, or fence areas of vegetation to be preserved;
    - Designate limits of root system (tree drip line);
    - Tree wells and retaining walls which are large enough to protect the root system;
    - Limit grading to within 300mm of the tree drip lines, if grading under the tree is necessary; and
    - Locate construction traffic routes, spoil piles, etc. away from existing vegetation.

Maintenance and Inspections

- Inspect protective measures and immediately repair or replace damaged protection measures.

Challenges

- Requires advanced planning and coordination between the owner/developer, contractor, and designer.
- Limited use if final site design does not incorporate existing vegetation.
- Diverse site topography may result in additional expenses to satisfy vegetation preservation and the grading required for the site improvements.

Seeding and Planting

Description and Purpose

Seeding and planting of trees, vines, shrubs, and ground cover for soil stabilization.

Applications

Soil stabilization during or after the construction phase applies to the following site conditions:

- Graded/cleared areas;
- Open space and fill areas;
- Steep slopes;
- Vegetated swales;
- Landscape corridors; and
- Stream banks.

Installation and Implementation Requirements

Requirements for each seeding/planting application shall be considered and include:

- Type of vegetation;
- Site and seedbed preparation;
- Seasonal planting times;
- Fertilization; and
- Water.

GRASSES

- Ground preparation requires fertilization and mechanical stabilization of the soil.
- Short-term temperature extremes and waterlogged soil conditions tolerable.
- Appropriate soil conditions include a shallow soil base, good drainage, and 2:1 or flatter slope.
- Quickly develops from seeds.
- Vigorous grass growth dependent on mowing, irrigating, and fertilizing.

TREES AND SHRUBS

- Selection dependent on vigor, species, size, shape, and potential wildlife food source.
- Consider wind/exposure and irrigation requirements.
- Use indigenous species where possible.

VINES AND GROUND COVER

- Lime and fertilizer required for ground preparation.
- Use appropriate seeding rates.
- Consider requirements for drainage, acidity, and ground slope.
- Use indigenous species where possible.
- Avoid species which require irrigation.

Maintenance and Inspections

- Monitor vegetation growth
- Water, fertilize, mow, and/or prune the grasses/plants as needed.

Challenges

- Vegetation may not be appropriate during dry periods without irrigation.
- Improper application of fertilizer may contribute to storm water pollution.

Mulching

Description and Purpose

Mulching is the application of loose bulk material to stabilize disturbed soil by protecting bare soil, increasing infiltration, and reducing runoff. Materials used for mulching include green material, hydraulic matrices, hydraulic mulches of recycled paper or wood fibre, stone and aggregate, vegetable fibres (hay or straw), and wood/bark chips.

Applications

Mulching BMPs apply to the following:

- Temporary ground cover until permanent vegetation has been established.
- Method used in combination with temporary or permanent seeding to enhance plant growth.
- Areas requiring soil moisture retention to prevent cracking of the soil.
- Ground cover for exposed soil between trees or shrubs.

Installation and Implementation Requirements

The following materials may be used for mulching:

VEGETABLE FIBRES (HAY OR STRAW)

- Loose hay or straw which may be used in combination with seeding. Mulching usually follows seeding and the process is described in the following:
  - o Apply seed and fertilizer to bare soil;
  - o Apply loose hay or straw over top of seed and fertilizer prior to seed germination. Apply at a rate of 4500kg/Ha by machine or hand distribution;
  - o Evenly distribute mulch on the soil surface to cover 80% to 90% of the ground;
- Maintain maximum fibre length. Average fibre length shall be greater than 150mm.
  - o Use a tackifier, netting, or mechanical "punching" method to anchor mulch. Method depends on slope steepness, accessibility, soil conditions, and longevity; and
  - o "Punching" straw or hay into soil is the preferred method of anchoring mulch for the following conditions:
    - Use a spade or shovel on small areas,
    - Use a knife-blade roller or straight bladed coulter ("crimper") on slopes with soil, which can support construction equipment without undesirable compaction or instability,
    - Use plastic netting or jute on small areas and/or steep slopes.

    Geotextile pins, wooden stakes, or 11 gauge wire staples shall secure netting in place. This condition warrants consideration of the use of matting rather than mulch, and
    - Use tackifiers on steep slopes unable to support construction equipment or large application areas where use of nettings, straw, or hay is not cost-effective. Tackifiers glue vegetable fibres together and to the soil surface until the establishment of permanent vegetation.

GREEN MATERIAL

- Consists of recycled vegetation trimmings such as grass and shredded shrubs and trees.
- Generally applied by hand.
- Temporary ground cover with or without seeding.
- Evenly distribute green material on soil surface. Depth shall not exceed 100mm.

• Anchor with a tackifier or netting on steep slopes or for areas with anticipated overland sheet flow. This condition warrants consideration of the use of matting rather than mulch.

WOOD/BARK CHIPS

• Suitable for areas which will not be mowed such as around trees, shrubs, and landscape plantings.
• Test soils prior to application. Add a minimum of5.4kg per 900kg of mulch to counteract the effect of decomposing wood-based materials, which extract nitrogen from soil. Use a balanced, slow-release fertilizer or an organic source such as compost.
• Apply mulch by hand.
• Evenly distribute wood/bark chips on soil surface and maintain a mulch depth of 50 to 75mm.

HYDRAULIC MULCHES OF RECYCLED PAPER

• Consists of recycled newsprint, magazines, and other waste paper sources.
• May be applied with or without tackifiers.
• Hydraulic mulch materials shall conform to District Standard Specifications.
• Mix mulch in a hydraulic application machine (hydroseeder) and apply as a liquid slurry.
• May be sprayed from a cannon up to 60m or from a hose up to 450m away from the application area.
• Mix mulch with seed and fertilizer as specified by the manufacturer. Apply mulch at the manufacturer's recommended rate to ensure uniform, effective coverage.

HYDRAULIC MULCHES OF WOOD FIBRE

• Consists of wood waste from lumber mills or urban sources.
• May be manufactured with or without a tackifier.
• Hydraulic mulch shall generally conform to with the following requirements:
    o 100% wood fibre;
    o Maximum moisture content (total weight basis) shall not exceed 12% ±3%;
    o Minimum organic matter content (oven dry weight basis) of 99.3%;
    o Maximum inorganic matter (ash) content (oven dried basis) of 0.7%
    o pH of 4.9±10% for a 3% water slurry; and
    o Minimum water holding capacity (oven dried basis) of 10L/kg of fibre.
• Mix mulch in a hydraulic application machine (hydroseeder) and apply as a liquid slurry.
• Mix mulch with seed and fertilizer as specified by the manufacturer. Apply mulch at the manufacturer's recommended rate to ensure uniform, effective coverage.

HYDRAULIC MATRICES

• Hydraulic slurries consisting of wood fibre, paper fibre, or a combination of wood and paper fibre mixed with a binder system.
• Exceeds erosion control performance of blankets due to close contact with soil.
• Apply as an aqueous slurry (with seed) using standard hydroseeding equipment.
• Application rates vary for different combinations of conditions and products.
• A typical mixture based on one Ha of treated area includes the following:
    o 570kg wood fibre mulch;
    o 1140kg recycled paper mulch; and
    o 520L acrylic copolymer with a minimum solids content of 55%.
• Bonded Fibre Matrix (BFM) consists of premixed fibre and binders.
    o After application and upon drying, BFM shall adhere to soil and form a 100% cover. The cover shall be biodegradable, promote vegetation, and prevent soil erosion.
    o Composed of long strand, thermally produced wood fibres (>88% of total volume by weight), held together by organic tackifiers (10%) and mineral bonding agents (<2%), which become insoluble and non-dispersible upon drying. Composition of BFM varies based on supplier.

- o Perform a free liquid quality control test on the liquid slurry.
- o Binder shall not dissolve or disperse upon watering.
- o Upon application to the soil, holes in the matrix shall not exceed 1mm in size.
- o There shall not be any gaps between the matrix and the soil.
- o Minimum water holding capacity of the matrix shall be 10L/kg matrix.
- o The matrix shall be free of germination or growth inhibiting factors and shall not form a water resistant crust.
- o Materials used for the matrix shall be 100% biodegradable and 100% beneficial to plant growth.
- o Testing and evaluation of the matrix by an independent research laboratory shall have been conducted to verify reported erosion control performance.
- o A trained and manufacturer certified applicator with knowledge of proper mixing and product application shall install the BFM.
- o Typical BFM application rates range from 3400 to 9100 kg/Ha per recommendations from various manufacturers.
- o BFM shall not be applied immediately before, during, or after a rainfall event to ensure a drying time of 24 hours after installation.

• Mulch used as temporary ground cover shall be reapplied to bare areas until permanent vegetation has been established.
• Avoid spraying mulch onto sidewalk, lined drainage channels, travelway, and existing vegetation.

Maintenance and Inspections

• Mulches applied to seeded areas may be disturbed due to wind or runoff. Recover exposed areas until permanent vegetation has been established.
• Mulches applied to areas, which will be regraded and revegetated, shall be inspected once every 2 weeks. Corrective measures shall be initiated within 14 days of inspection.
• Inspect ornamental and landscape mulches of bark or wood chips once every 8 to 10 months. Replace mulch if soil is visible in more than 75% of the area.

Challenges

VEGETABLE FIBRES (HAY OR STRAW)
• Require three-step machinery.
• Labor intensive installation.
• Weed seeds and undesirable plant material may be introduced to sensitive areas.
• For Applications using straw blowers, the applicable area must be located within 450m of a road or surface capable of supporting loads from large vehicles. If both hay and straw are available, it is preferable to use straw.

GREEN MATERIAL
• Limited commercial availability.
• Variable quality.
• Weeds or undesirable plant material may be introduced to the mulched area.
• Application primarily uses manual labor.
• Unpredictable effectiveness as an erosion control measure. Requires overspray with a tackifying agent to increase effectiveness.
• Application of fertilizer may be required.
• Limit use to non-critical steep slopes and areas where alternative erosion control measures may be readily applied.

WOOD/BARK CHIPS

- Poor erosion control effectiveness.
- Anchoring of chips onto steep slopes is difficult due to potential movement from high winds.
- Subject to displacement from concentrated flows.
- Use of a fertilizer with high nitrogen content is required to prevent nutrient deficiency in plants due to decomposing wood-based materials, which extract nitrogen from soil. Improper fertilizer use may contribute to water quality pollution.
- Limit use to non-critical steep slopes and areas where alternative erosion control measures may be readily applied.

HYDRAULIC MULCHES OF RECYCLED PAPER

- Limited erosion control effectiveness due to short fibre length and absence of a tackifier.
- Limited moisture and soil temperature moderation.
- Residual inks within mulches may be an undesirable in environmentally sensitive areas.
- Significant decrease in longevity compared with wood fibre mulch.
- Difficulty budgeting for this product due to volatile prices for recycled paper products.

HYDRAULIC MULCHES OF WOOD FIBRE

- Limited erosion control effectiveness.
- Short-term use of one growing season.

HYDRAULIC MATRICES

- Avoid application of mulch immediately before, during, or after a rainfall event.
- Requires drying time of 24 hours.

Geotextiles and Mats

Description and Purpose

Natural or synthetic mats may be used for temporary or permanent soil stabilization.

Applications

Geotextiles and mats apply to the following:

- Drainage ditches, channels, and streams.
- Steep slopes.

Installation and Implementation Requirements

- Apply matting to disturbed soils and areas where vegetation has been removed.
- Organic matting provides temporary protection until permanent vegetation has been established, optimal weather conditions occur, or construction delays are resolved. Organic matting materials include the following:
    - Jute matting; and
    - Straw matting.
- Synthetic matting provides temporary or post-construction soil stabilization in both vegetated and non-vegetated areas. Synthetic matting materials include the following:
    - Excelsior matting;
    - Glass fibre matting;
    - Staples; and
    - Mulch netting.
- Other proprietary devices may be used and shall be installed per manufacturer's recommendations.

Maintenance and Inspections

- Periodically inspect matting after installation.

Challenges

- Minimize use of matting to areas where other erosion control measures are not applicable such as channels or steep slopes since matting is more costly compared to other erosion control measures.
- Seed germination may be delayed due to decreased soil temperature.
- An experienced maintenance engineer is required during installation.

Vegetated Buffer Strips and Channels

Description and Purpose

Vegetated buffer strips and channels protect soil from erosion, increase infiltration, and remove sediment from surface runoff. Located adjacent to pollutant sources such as construction sites, vegetated buffer strips also provide protection to downstream receiving inlets or water bodies.

Applications

Vegetated buffer strips and channels apply to the following conditions:

• Any site which is suitable for establishment of vegetation.

• Vegetated buffer strips are appropriate for uncurbed, paved areas; steep and potentially unstable slopes; and areas adjacent to sensitive water bodies.

• Vegetated channels are appropriate for surface runoff conveyed by channels to downstream inlets or receiving waters.

Installation and Implementation Requirements

• Refer to the Preservation of Existing Vegetation section in this manual if existing vegetation will be used as a buffer strip.

• Installation of a buffer strip with new vegetation shall comply with the following:

  o Prior to cultivation of the designated buffer strip area, remove and dispose of all weeds and debris in accordance with applicable requirements;

  o During construction, strip and stockpile good topsoil for surface preparation purposes prior to planting activities;

  o Plant the area upon completion of grading in the area;

  o Fine grade and roll areas to be planted after cultivating soil and, if applicable, installing the irrigation system;

  o Provide additional watering or irrigation of vegetation to supplement rainfall until vegetation has been established;

  o Fertilize vegetation in accordance with manufacturers' instructions and grass/soil requirements determined by testing of the soil;

  o Vehicular traffic passing through vegetated buffer strips or channels shall be avoided to protect vegetation from damage and maximize its effectiveness;

  o Comply with applicable regulations and manufacturers' instructions when applying fertilizers, pesticides, soil amendments, or chemicals;

  o Comply with the following during seeding activities:

    - Add soil amendments such as fertilizer when preparing seedbed. Apply mulch after seeding to protect vegetation during establishment. Select an appropriate seed mixture based on site conditions. Dense grasses are more effective in reducing flow velocities and removing sediment. Thick root structures are necessary for erosion control,

    - Use proper equipment and methods to ensure uniform distribution and appropriate seed placement, and

    - Overseed, repair bare spots, and apply additional mulch as necessary; and

  o Comply with the following during sodding activities:

    - Protect sod with tarps or other types of protective covering during delivery and do not allow sow to dry between harvesting and placement,

    - Any irregular or uneven areas observed prior to or during the plant establishment period shall be restored to a smooth and even appearance,

    - Prior to placing sod, ground surface shall be smooth and uniform,

- Areas, which will be planted with sod and are adjacent to paved surfaces such as sidewalks and concrete headers, shall be 25mm±5mm below the top grade of the paved surface after fine grading, rolling, and settlement of the soil,
- Ends of adjacent strips of sod shall be staggered a minimum of 600mm,
- Edges and ends of sod shall be placed firmly against paved borders,
- After placement of the sod, lightly roll sodded area to eliminate air pockets and ensure close contact with the soil,
- After rolling, water the sodded area to moisten the soil to a depth of 100mm,
- Do not allow sod to dry,
- Avoid planting sod during extremely hot or wet weather, and
- Sod shall not be placed on slopes steeper than 3:1 (H:V) if the area will be mowed.

Maintenance and Inspections

• Inspect weekly and after significant rain events until vegetation is established.
Repair eroded or damaged areas as necessary.

• Maintenance activities include mowing, weeding, and verification of a properly operating irrigation system, if applicable.

• Properly remove and dispose of clippings from mowing and trimming in accordance with applicable requirements.

Challenges

• Site conditions such as availability of land.
• Flow depth and vegetative condition determine BMP effectiveness.
• May require irrigation to maintain vegetation.
• High maintenance requirements may exist depending on the design condition of the vegetation.
• Unless existing vegetation is used as a buffer strip, an area will need to be provided specifically for a buffer strip and vegetation will need to be established.
• Maintaining sheet flow in buffer strips may be difficult.
• Vegetated channels require a larger area than lined channels.
• Vegetated channels require gradual slopes since runoff with high flow velocity may flow over grass rather than through it.

4.4 Storm Water Flow Control

Earth Dikes, Drainage Swales and Lined Ditches

Description and Purpose

Earth dikes, drainage swales, and lined ditches are structures that prevent erosion by intercepting, diverting, and conveying surface run-on to a stabilized area or other sediment trapping device.

Applications

Earth dikes, drainage swales, and lined ditches may be applied for the following purposes:

- Direct runoff around unstable or disturbed areas to a stabilized water course, drainage pipe, or channel.
- Divert runoff to sediment basins or sediment traps.
- Intercept runoff at the point of concentration.
- Supplement other sediment control measures.
- Intercept and divert runoff to prevent sheet flow over sloped surfaces.
- Convey surface runoff down sloping land.

Installation and Implementation Requirements

- Firmly compact to minimize erosion and prevent unequal settling.
- Drain to a stabilized outlet.
- Drain sediment laden runoff to a sediment trapping device.
- Ensure continuous, positive grade along dike, swale, or ditch to prevent ponding of runoff.
- Stabilize with vegetation, chemicals, or other physical devices.
- Conform to predevelopment drainage patterns and capacities.
- The design of dikes, swales, and ditches shall be submitted to the District Engineer for review. The review will evaluate structural stability and drainage capacity.
- Design flow and safety factor shall be determined by an evaluation of risks associated with overtopping, flow backups, or washout of structures.
- Evaluate potential run-on from off-site properties.
- Flow velocity limit shall be determined by on-site soil type and drainage flow patterns.
- Establish minimum flow velocity requiring lining (rip-rap, geotextile filter fabric, vegetation, concrete) for earthen diversion devices.
- Incorporate an emergency overflow section or bypass area into the design for storms exceeding the design storm.

Maintenance and Inspections

- Inspect dikes, swales, and ditches periodically. Inspections shall include the following:
    - o Check for erosion along berms, channel linings, embankments, or beds of ditches. Restore all bare areas with the appropriate lining material;
    - o Remove accumulated sediment and debris; and
    - o Inspect dike walls, embankments, compacted fills, and earthen channel
    sidewalls for cracks, washouts, animal habitation, exposed materials, and other signs of potential failure. Restore areas with the appropriate materials. Coordinate restoration with the District Engineer as necessary including problems associated with structural design or runoff flow patterns.

Challenges

- Unsuitable for use as a sediment trapping device.
- Use of additional sediment and erosion control devices may be required to prevent scour and erosion in recently graded dikes, swales, and ditches.
- Select size and location to prevent unintended consequences such as erosion along steep and unlined ditches and ponding within the travelway or material storage areas. Alteration of existing waterways and clearing of existing vegetation are subject to applicable permit requirements.
- Ditches and swales may require check dams or lining to prevent erosion.

Slope Drains and Subsurface Drains

Description and Purpose

Slope drains and subsurface drains are pipes which prevent erosion along slopes by intercepting and conveying runoff or groundwater from the top of the slope to a stabilized discharge point located at the bottom of the slope. Slope drains are primarily used to convey runoff down cut or fill slopes. Subsurface drains are primarily used to remove water from the soil in sloped areas.

Applications

Slope drains and subsurface drains may be used for the following purposes:

- Emergency spillways for sediment basins;
- Use of slope drains apply to the following conditions:
    - Drainage of concentrated runoff from within swales or behind dikes located at the top of slopes, and
    - Drainage of surface runoff to prevent erosion along the slope; and
- Use of subsurface drains applicable to areas where water must be removed from the soil to lower the groundwater table or to prevent excessive soil saturation.

Installation and Implementation Requirements

Design of slope drains shall consider the following:

- Consult with a hydro-geologist or qualified engineer regarding design flows;
- Limit drainage area discharging to slope drain to 2 Ha;
- Direct surface runoff into slope drain using interceptor dikes at the top of slope. Refer to Earth Dikes, Drainage Swales, and Lined Ditches in this manual for more information;
- Pipe slope drains exceeding 300mm in diameter require a standard flared end section or headwall constructed at the inlet and outlet;
- Install lining such as vegetation or geotextile filter fabric to protect area around inlet;
- Install rip-rap or other energy dissipation device at outlets;
- Compact soil under and around inlet, outlet, and along the pipe;
- Slope drains may be installed above ground or buried beneath the slope surface;
- Above ground installation shall utilize pipe anchors to secure pipe to ground;
- Align slope drain perpendicular to contours of slope;
- Generally limit maximum slope to 2:1 (H:V). For slopes exceeding 2:1 (H:V), velocity dissipation is required at the pipe outlet; and
- Direct sediment-laden storm water to a sediment trap or sediment basin.

Maintenance and Inspections

- Inspect regularly and after significant rainfall events for erosion at outlet and downstream scour. Repair damage and install energy dissipation devices as necessary.
- Inspect slope drains for debris and sediment accumulation. Remove sediment and debris from entrances, outlets, and within drains.
- Inspect pipe anchors to ensure pipe remains anchored to slope.
- Verify ponding does not occur in areas such as active traffic lanes and material storage areas.

Challenges

- Drainage area discharging to slope drains should not exceed 2 Ha. For larger areas, use multiple pipes, paved chute, or rock lined channel.
- Clogged slope drains direct runoff around pipe which may result in erosion along the slope.

• High flow velocities at the pipe outlet require implementation of velocity dissipation devices to prevent downstream erosion.
• Severe flooding and erosion may result from failure of slope drains.

Top and Toe of Slope Diversions Ditches and Berms

Description and Purpose

Slope diversion ditches and berms are placed along the top and/or toe of slopes to minimize sheet flow over slopes. These devices reduce erosion by intercepting and conveying runoff to sediment removing structures or a protected drainage system.

Applications

Top and toe of slope diversion ditches and berms apply to the following:

- Areas which must be protected from runoff flowing down slopes; and
- Areas where runoff must be intercepted at bottom of slope.

Installation and Implementation Requirements

- Design flows and safety factors shall be determined by an evaluation of risks associated with erosion and overtopping, flow backups, or structure washouts. Consult with the District Engineer to determine these values.
- Line or stabilize ditches with high flow velocities.
- Direct flows at top of slopes to slope drains. Refer to Slope Drains and Subsurface Drains (4.3.2) in this manual for more information.
- Protect outlets from erosion.

Maintenance and Inspections

- Inspect routinely and after large rainfall events exceeding the design storm intensity.
- Inspect ditches/berms for washouts. Repair requirements shall be reported and include replacement of rip-rap, damaged lining, or soil stabilizers and compaction and re-vegetation of fill berms and ditches.
- Establish a repair schedule with priority based on impacts to receiving waters followed by potential erosion, potential habitat damage, and land use of areas located downslope.
- All repairs shall be completed within 1 year of inspection.
- Inspect structures for accumulated sediment and debris and remove as necessary. The schedule for removal of sediment and debris shall be as described in the repair section.

Challenges

- Additional sediment trapping BMP devices may be necessary for sediment-laden runoff.

Outlet Protection and Velocity Dissipation Devices

Description and Purpose

Devices placed at outlets of pipes and channels prevent or minimize scouring and erosion resulting from the high velocity of storm water flows.

Applications

Applicable conditions include the following:

- Outlets with continuous flows.
- Outlets located at the bottom of slopes.
- Outlets subject to short, intense flows.
- Discharge points from lined conveyances to unlined conveyances.

Installation and Implementation Requirements

- Apron length shall be determined by outlet flow rate and tailwater level.
- Align apron with direction of flow and avoid curves in apron. If a curve is necessary, place it in the upper section of the apron.
- Protect the underlying geotextile filter fabric with a 100mm minimum rock blanket if the rip-rap is 300mm or larger.

Maintenance and Inspections

- Establish an inspection schedule and inspect all structures a minimum of once every three years.
- Inspect beneath the rip-rap and around the outlet for scour. Immediately repair damaged slopes or underlying geotextile filter fabric with priorities based on protection of receiving waters, followed by erosion potential and possible damage to down-slope areas.
- Inspect apron for damage to underlying geotextile filter fabric or dislodged riprap. Report any damage exceeding 10% of the apron surface area for evaluation by the District Engineer, as appropriate.

Challenges

- Potential for stones to wash away.
- Break up of grouted riprap resulting from hydrostatic pressure caused by water accumulation.

Flared Culvert End Sections

Description and Purpose

Flared culvert end sections are devices placed at the inlet or outlet of pipes and channels to enhance hydraulic operation while minimizing scour and erosion.

Applications

Flared culvert end sections may be placed at inlets and outlets of slope drains and culverts.

Installation and Implementation Requirements

- Construct on level ground where possible.
- Supplement with other outlet protection.
- Protect the transition to the flared end section at inlets to prevent scouring.

Maintenance and Inspections

- Establish an inspection schedule and conduct inspections a minimum of once every three years.
- Monitor accumulation of debris and sediment and remove within 60 days of notification. Immediately clean culverts located where receiving waters may be adversely affected.
- Inspect around and beneath flared end sections for scour. Report any scour exceeding 10% of the flared end section area for evaluation by the District Engineer.
- Establish a repair schedule with priorities based on protection of receiving waters, followed by erosion potential and possible damage to down-slope areas.

Challenges

- Limited use as an erosion control measure since primarily used to increase hydraulic efficiency.

Slope Roughening, Terracing and Rounding

Description and Purpose

Methods of slope grading such as slope roughening, terracing, and rounding reduce potential erosion by decreasing runoff velocities, trapping sediment, shortening slope length, and increasing infiltration into the soil.

Applications

Slope roughening, terracing, and rounding applies to the following:

• Areas where seeding, planting, and mulching erosion control measures may be enhanced by roughening of the soil surface.
• Graded areas with smooth, hard surfaces.
• Areas requiring terracing to shorten the slope length.

Installation and Implementation Requirements

CUT SLOPE ROUGHENING

• Cut slopes steeper than 3:1 (H:V) shall use stair-step grading or furrows.
• Use stair-step grading on soft soils that may be ripped by a bulldozer. Stair-step grading is particularly suitable for slopes consisting of soft rock with some subsoil.
• The vertical cut distance shall be less than the horizontal distance. The "step" shall drain towards the slope.
• Avoid individual vertical cuts greater than 600mm high in soft materials or greater than 900mm high in rocky materials.
• Create ridges and depressions along the slope contours using machinery.

FILL SLOPE ROUGHENING

• Fill slopes steeper than 3:1 (H:V) shall be placed in lifts not exceeding 200mm or as directed by the Geotechnical Engineer. Each lift shall be properly compacted.
• Slope faces shall consist of 100 to 150mm of loose and uncompacted soil.
• Grooving or tracking shall be used to roughen slope faces as necessary.
• Apply seed, fertilizer, and mulch. Track or punch in the mulch. Refer to Mulching and Seeding and Planting in this manual for additional information.
• The final slope face shall not be bladed or scraped.

CUTS, FILLS, AND GRADED AREAS

• Slopes that will be maintained by mowing shall be no steeper than 3:1 (H:V).
• Create shallow grooves by normal tilling, disking, harrowing, or use of a cultivator-seeder. Final pass of tillage shall be along the contour. Spacing between grooves shall be 250mm or less. Groove depth shall be a minimum of 25mm.

ROUGHENING WITH TRACKED MACHINERY

• Roughening with tracked machinery is primarily applicable to soils with a sandy texture. Other types of soil may be over-compacted by tracked machinery.
• Leave horizontal depressions in the soil by operating tracked machinery up and down the slope. During the final grading operation, do not back blade.
• Roughened areas shall be seeded and mulched for optimum seed germination and growth.

TERRACING

• Slope grades of 4:1 (H:V) shall include terraces or benches when slope heights exceed 9m. Steeper slope or highly erosive soil conditions may warrant terraces or benches for slope heights of 4.5m or higher.

• Runoff collected along terraces and benches shall be routed to lined diversion ditches. Install lined diversion ditches at the intersection of the terrace and slope.

ROUNDING

• All slopes shall be rounded with no sharp breaks in plan or profile.

Maintenance and Inspections

• Inspect slopes after storm events of more than 10mm of rain in the area.

• Inspect seeded and planted slopes for rills and gullies.

Challenges

• Since terracing is permanent, design and approval shall be under the direction of a licensed, qualified engineer.

• Design of terraces shall provide adequate drainage and stabilized outlets.

• Roughening may result in increased grading costs and sloughing in soil.

• Stair-step grading may not be applicable to sandy, steep, or shallow soils.

• During intense rainfall events, roughening may not be an effective temporary erosion control measure.

4.5 Low Impact Design Strategies

Introduction

Low impact development (LID) is a term used to describe a philosophy for urban development pertaining to a design approach to managing stormwater runoff. LID has only been a recognized terms since the early 1990's as an alternative to traditional stormwater management. In BC the concept was introduced by the Government in the "Stormwater Planning Guidebook". The basis of LID emphasizes resource conservation and the use of natural features to minimize impacts to receiving waters LID involves implementation of small hydrologic controls to replicate the pre-development conditions and can include such things as infiltration, filtration, storage, controlled release and evaporation.

In North America, the LID design approach is being promoted by the US Environmental Protection Agency (EPA) and has been accepted as a method to assist Municipalities as a method to meet goals of the US Clean Water Act. The following strategies are presented as "typical" examples and have been described by the EPA.

Green Roofs

Description and Purpose

Green roofs can be effectively used to reduce storm water runoff from commercial, industrial, and residential buildings. In contrast to traditional asphalt or metal roofing, green roofs absorb, store, and later evapotranspire initial precipitation, thereby acting as a storm water management system and reducing overall peak flow discharge to a storm sewer system. Furthermore, conventional roofing can act as a source for numerous toxic pollutants including lead, zinc, pyrene, and chrysene (Vane Metre and Mahler, 2003).

Figure 1. An intensive green roof at the Schwab Rehabilitation Hospital, Chicago, Illinois. *(picture courtesy of Green Roofs for Healthy Cities and American Hydrotech, Inc.).*

Green roofs have the potential to reduce discharge of pollutants such as nitrogen and phosphorous due to soil microbial processes and plant uptake. However, initial studies conflict as to the removal efficiency of nutrients, particularly nitrogen, by green roofs. If implemented on a wide scale, green roofs will reduce the volume of storm water entering local waterways resulting in less in-stream scouring, lower water temperatures and better water quality. Figure 1 shows an example of a green roof.

Green roofs offer additional benefits including reduction of urban heat island effects, increased thermal insulation and energy efficiency, increased acoustic insulation, and increased durability and lifespan compared to conventional roofs. Europeans, led by the Germans, have been using green roofs for decades and have found them to be a cost effective method to mitigate some environmental impacts of development.

Green roofs are classified as extensive, semi-intensive, or intensive. Generally, extensive green roofs have 150mm or less of growing medium, whereas intensive green roofs have greater than 150mm of substrate. Semi-intensive green roofs can be defined as a hybrid between intensive and extensive green roofs, where at least 25 percent of the roof square area is above or below the 150mm threshold. Extensive green roofs provide many of the environmental benefits of intensive green roofs, but they are designed to be very low-maintenance and are not typically designed for public access. Semi-intensive and intensive green roofs are designed to be used by the public or building tenants as a park or relaxation area. However, they also require greater capital and maintenance investments than extensive green roofs. Intensive green roofs are particularly attractive for developers, property owners, and municipalities, in areas where land prices command a premium, but property owners want to provide some of the amenities associated with parks.

Due to increasing demand for green roofs, there is now commercial industry in many areas. The industry organization website *Green Roofs for Healthy Cities* can provide additional information on green roofs and links to numerous companies that provide green roofing products and services.

Applications

Green roofs can be applied to new construction or retrofitted to existing construction. They are applicable on residential, commercial, and industrial buildings and are easily constructed on roofs with up to a 20 percent slope. Figure 2 shows an example of a green roof applied in a commercial setting.

Figure 2. An extensive green roof at the Deerborn Michigan, Ford Assembly Plant. *(picture courtesy of Green Roofs for Healthy Cities and William McDonough + Partners, ARCADIS).*

Figure 3. Cedar Creek pump station green roof, Kelowna

Many cities such as Chicago and Washington, DC are actively encouraging green roof construction as a means to reduce storm water runoff and combined sewer overflows. Other municipalities are encouraging green roof development with tax credits, density credits, or allowing a small impervious credit to be applied to other structural BMP requirements. Figure 3 shows a newly planted green roof above a municipal pump station building.

Regional Applicability

Green roofs are applicable in all parts of the country. In climates with extreme temperatures, green roofs provide additional building insulation, which makes them more financially justifiable for many facility operators.

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. Green roofs are ideal for ultra-urban areas because they provide storm water benefits and other valuable ecological services without consuming additional land. In a 2005 modeling study of Washington DC, Casey Trees and Limno-Tech found that green roofs on 20 percent of buildings over $900 m^2$ could add an additional 87 million litres of storage and reduce outflow to the storm sewer or combined sewer systems by an average of just under 1135 million litres per year. According to the authors, this would reduce the annual number of CSO events in DC by 15 percent.

Storm water Retrofit

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Green roofs are a useful tool for retrofitting existing impervious area associated with building footprints. The construction of most existing flat-roofed buildings is such that they can accommodate the weight of an extensive green roof without structural modifications. Although retrofitting existing structures with green roofs can be more complex and expensive than on new facilities, technological advances are bringing that cost down.

Design Criteria

Siting Considerations

Green roofs can be installed during initial construction or placed on buildings as part of a retrofit. The amount of storm water that a green roof mitigates is directly proportional to the area it covers, the depth and type of the growing medium, slope, and the type of plants selected. The larger the green roof area, the more storm water mitigated. Green roofs are appropriate for industrial and commercial facilities and large residential buildings such as condominiums or apartment complexes. Green roofs can also prove useful for small residential buildings under some circumstances. Single family residential structures, like all buildings with green roofs, must be able to support the loading from a saturated roof. Furthermore, the green roofs should be easily accessible and residents should understand the maintenance requirements necessary to keep the roof functional.

Design Considerations

A building must be able to support the loading of green roof materials under fully saturated conditions. These materials include a waterproofing layer, a soil or substrate layer, and a plant layer. Plants selected need to be suited for local climatic conditions and can range from sedums, grasses, and wildflowers on extensive roofs to shrubs and small trees on intensive roofs.

Design Variations

Green roofs can be designed to be either intensive, semi-intensive, or extensive green roofs. The type of design chosen will depend upon loading capacity, budget, design goals, and storm water retention desired. There will also be variations in the type of green roof selected depending upon climate, types of plants chosen, soil layer depth desired and feasibility and other design considerations. Green roofs can be constructed layer by layer, or can be purchased as a system. Some vendors offer modular trays containing the green roof components.

Maintenance and Inspections

Immediately after construction, green roofs need to be monitored regularly to ensure the vegetation thrives. During the first season, green roofs may need to be watered periodically if there is not sufficient precipitation. After the first season, extensive green roofs may only need to be inspected and lightly fertilized approximately once per year. The roofs may need occasional weeding and may require some watering during exceptionally dry periods. If leaks should occur in the roof, they are relatively easy to detect and fix. Intensive green roofs need to be maintained as any other landscaped area. This can involve gardening and irrigation, in addition to other roof maintenance. Green roofs are less prone to leaking than conventional roofs. In most cases, detecting and fixing a leak under a green roof is no more difficult than doing the same for a conventional roof.

Effectiveness

Green roofs have been shown to be effective at removing some pollutants and reducing peak flows associated with storm events. As a general rule, developers can assume that extensive green roofs will absorb 50 percent of rainfall (Stephen Peck, 9/1/2005, personal communication). In a modeling study, Casey Trees and Limno-Tech (2005) assumed that extensive green roofs absorbed 50mm of rainfall and intensive green roofs stored 100mm of rainfall. Due to evapotranspiration and plant uptake, this storage is assumed to recharge once every four days. A study by Moran (2005) found that monthly storm water retention rates varied between 40 percent and 100 percent on two green roofs in the Neuse River watershed, North Carolina. The study showed a decrease in peak flow runoff and total storm water runoff, and a gradual and delayed release of the storm water that was ultimately discharged. The reduction of peak flow discharge potentially mitigates stream channel scouring, resulting in improved aquatic habitat and lessening the risk of downstream property damage and flooding.

Penn State Green Roof Research Center has also noted a decrease in both total storm water runoff and peak flow discharge. The graphs below show both the decrease in total discharge and peak flow run-off from roof area associated with three green roofs. In this >25mm storm event, the green roofs captured approximately 25 percent of total runoff compared to the conventional roofs. Over the period from May 23, 2003 to June 1, 2003, 56mm of rain fell, of which the green roof detained 26mm (~47 percent). The center noted that the spring of 2003 was wet and cool.

Challenges

In most climates, green roofs will need to have drought tolerant plant species or an irrigation system to sustain vegetation. The slope of green roofs can range from 0 to 40 degrees. In new construction, buildings should be designed to manage a potentially increased load associated with the green roof. When designing green roofs for existing structures, engineers must take the load restrictions of the building into account.

On Lot Treatment

Description and Purpose

The term "on-lot treatment" refers to a range of practices designed to treat runoff from individual residential lots. The primary purpose of most on-lot practices is to manage runoff from rooftops and, to a lesser extent, driveways and sidewalks. Rooftop runoff, particularly from residential roofs, generally has low pollutant concentrations compared to other urban sources (Schueler, 1994b). Managing runoff from rooftops effectively disconnects these impervious surfaces, reducing a watershed's overall imperviousness. This is important because many of the deleterious effects of urbanization on water quality can be traced to fundamental changes in the hydrologic cycle caused by increases in impervious materials, like roofs, covering the landscape (Schueler, 1994a).

Although a variety of on-lot treatment options exist, all can be placed in one of three categories: 1) practices that infiltrate rooftop runoff; 2) practices that divert runoff to a pervious area; and 3) practices that store runoff for later use. The best option depends on the goals of a community, the feasibility at a specific site, and the preferences of the homeowner.

The practice most often used to infiltrate rooftop runoff is the drywell. In this design, the storm drain is directed to an underground rock-filled trench or pit that is similar in design to an infiltration trench. French drains drains can also be used for this purpose. In these designs, the relatively deep dry well is replaced with a long trench equipped with a perforated pipe buried within the gravel bed to distribute flow throughout the length of the trench.

Runoff can be diverted to a pervious area or a treatment area using site grading, or channels and berms. Treatment options can include grassed swales, bioretention, or filter strips. The bioretention design can be simplified for an on-lot application by limiting the pre-treatment filter and, in some cases, eliminating the underdrain. Alternatively, rooftop runoff can simply be diverted to pervious lawns, as opposed to flowing directly onto the street and then to the storm drain system.

Practices that store rooftop runoff, such as cisterns and rain barrels like the one shown in Figure 4, are the simplest of all of the on-lot treatment systems. Some of these practices are available commercially and can be applied in a wide variety of site conditions. Cisterns and rain barrels can be particularly valuable in the arid southwest, where water is at a premium, rainfall is infrequent, and reuse for irrigation can save homeowners money.

Figure 4. Backyard Rain Barrel in City of Vancouver

Applications

With very few exceptions (e.g., very small lots or lots with no landscaping), some sort of on-lot treatment can be applied to most sites. Traditionally, on-site treatment of residential storm water runoff has been encouraged, but it has not generally been an option to meet storm water requirements.

Design Criteria

Although most residential lots can incorporate on-lot treatment, options for a site design depend on design constraints and homeowner preferences. On-lot infiltration practices have the same restrictions regarding soils as other infiltration practices. If bioretention, grassed swales or other design practices are used, they need to meet the siting requirements of those practices. Of all of the practices, cisterns and rain barrels have the fewest site constraints. In order for the practice to be effective, however, homeowners need to have a use for the water collected. The design must also accommodate overflow and winter freezing conditions. These practices are best suited to an individual who has some active interest in gardening or landscaping, since the stored water may be used for irrigation.

Although simple compared to other post-construction storm water practices, on-lot infiltration needs to include the same basic elements of any storm water practice. Pretreatment is important to ensure they do not clog with leaf debris. A settling tank or, at a minimum, a debris-trapping grate or filter in the downspout, may precede infiltration practices. Some sort of pretreatment, such as a mesh filter, is often also found at the top of rain barrels and cisterns.

Both infiltration and storage practices typically incorporate some type of bypass to direct heavy runoff flows away from homes. For example, a hose mounted at the bottom of the barrel or cistern, is typically used for irrigating gardens or for landscaping. This hose can be attached to a standard garden hose or to drip tape, which is a hose with small holes that is laid on the ground surface to allow the water to soak into the ground. Then the flow can be controlled with an adjustable valve. In infiltration practices, an above ground opening in the downspout can serve as the bypass. In on-lot practices, grassed swales and bioretention cells can be designed to absorb all but the largest of storm water flows. In extreme cases, flows generally flow untreated over the practices.

When designing infiltration practices, it is important to locate the infiltration area far enough away from the house's foundation to prevent the undermining of the foundation or basement seepage. The infiltration area should be at least 3m away from the house.

Maintenance and Inspections

Bioretention areas, filter strips, and grassed swales require regular maintenance to ensure that the vegetation remains in good condition. Infiltration practices require regular removal of sediment and debris settled in the pretreatment area, and the media might need to be replaced if it becomes clogged.

Rain barrels and cisterns require minimal maintenance, but the homeowner needs to ensure that the hose remains elevated during the winter to prevent freezing and cracking. In addition, the tank needs to be cleaned out about once per year. Furthermore, rain barrels and cisterns should be checked periodically to ensure that they are properly sealed to prevent mosquito breeding.

Effectiveness

Although the practices used for on-lot applications can have relatively high pollutant removals, it is unclear that these pollutant removal rates can be realized, since the pollutant concentrations entering the systems are generally low. Some data suggest that, at least for storm water ponds, there may be an "irreducible concentration" below which no further pollutant removal can be achieved (Schueler, 1996). Another benefit of many on-lot practices is that they generally promote ground water recharge, either directly through infiltration or indirectly by applying or directing runoff to pervious areas.

Challenges

There are limitations to the use of on-lot practices, including the following:

- These practices require homeowners to perform some basic maintenance.
- For homeowners who do not enjoy landscaping, it may be difficult to find uses for water stored in rain barrels or cisterns, since the water is not potable.
- Some of these practices may be impractical on small lots.
- Even if applied to every home in a watershed, these practices would only treat a relatively small portion of the watershed imperviousness, which is largely composed of roads and parking areas.

Pervious Concrete Pavement

Description and Purpose

Pervious concrete, also known as porous, gap-graded, or enhanced porosity concrete, is concrete with reduced sand or fines and allows water to drain through it. Pervious concrete over an aggregate storage bed will reduce storm water runoff volume, rate, and pollutants. The reduced fines leave stable air pockets in the concrete and a total void space of between 15 and 35 percent, with an average of 20 percent. The void space allows storm water to flow through the concrete as shown in Figure 5, and enter a crushed stone aggregate bedding layer and base that supports the concrete while providing storage and runoff treatment. When properly constructed, pervious concrete is durable, low maintenance, and has a low life cycle cost. Figure 6 shows a pervious concrete walkway installed at the EPA Headquarters in Washington, D.C.

Figure 5. Pervious concrete allows water to flow through. *Photo courtesy of the National Ready Mix Concrete Association.*

Figure 6. Pervious concrete walkway bordered by paving stones, Washington D.C.
Photo courtesy of the Low Impact Development Center Inc.

Applications

Pervious concrete can be used for municipal storm water management programs and private development applications. The runoff volume and rate control, plus pollutant reductions, allow municipalities to improve the quality of storm water discharges. Municipal initiatives, such as Chicago's Green Alley program, use pervious concrete to reduce combined sewer overflows and minimize localized flooding by infiltrating and treating storm water on site. Private development projects use pervious concrete to meet post-construction storm water quantity and quality requirements. The use of pervious concrete can potentially reduce additional expenditures and land consumption for conventional collection, conveyance, and detention storm water infrastructure. Public and private developments have used pervious concrete, which is a naturally brighter surface than traditional asphalt, to reduce lighting needs and increase nighttime safety.

Pervious concrete can replace traditional impervious pavement for most pedestrian and vehicular applications except high-volume/high-speed roadways. Pervious concrete can be designed to handle heavy loads, but surface abrasion from constant traffic will cause the pavement to deteriorate more quickly than conventional concrete. Pervious concrete has performed successfully in pedestrian walkways, sidewalks, driveways, parking lots, and low-volume roadways. The environmental benefits from pervious concrete allow it to be incorporated into municipal green infrastructure and low impact development programs. In addition to providing storm water volume and quality management, the light color of concrete is cooler than conventional asphalt and helps to reduce urban temperatures and improve air quality (Grant, et al., 2003) (Vingarzan and Taylor, 2003). Unlike the smoothed surface of conventional concrete, the surface texture of pervious concrete is slightly rougher, providing more traction to vehicles and pedestrians.

Design Criteria

Pervious concrete should be designed and sited to intercept, contain, filter, and infiltrate storm water on site. Several design possibilities can achieve these objectives. For example, pervious concrete can be installed across an entire street width or an entire parking area. The pavement can also be installed in combination with impermeable pavements or roofs to infiltrate runoff. Several applications use pervious concrete in parking lot lanes or parking stalls to treat runoff from adjacent impermeable pavements and roofs. This design economizes pervious concrete installation costs while providing sufficient treatment area for the runoff generated from impervious surfaces. Inlets can be placed in the pervious concrete to accommodate overflows from extreme storms. The storm water volume to be captured, stored, infiltrated, or harvested determines the scale of permeable pavement required. Figures 7 and 8 illustrate some pervious concrete design variations.

Figure 7. Pervious concrete is used for a sidewalk in Olympia, WA. *Photo courtesy of City of Olympia, WA.*

Figure 8. A residential street in Portland, OR uses pervious concrete to reduce combined sewer overflows.. *Photo courtesy of Portland Bureau of Environmental Services.*

Pervious concrete comprises the surface layer of the permeable pavement structure and consists of Portland cement, open-graded coarse aggregate (typically 9.5 to 15mm), and water. Admixtures can be added to the concrete mixture to enhance strength, increase setting time, or add other properties. The thickness of pervious concrete ranges from 100 to 200mm depending on the expected traffic loads. Additional subsurface components of this treatment practice are illustrated in Figure 9 and include the following (NRMCA, 2008):

- *Choke course* - This permeable layer is typically 25 – 50mm thick and provides a level bed for the pervious concrete. It consists of small-sized, open-graded aggregate.
- *Open-graded base reservoir* - This aggregate layer is immediately beneath the choke layer. The base is typically 75 -100mm thick and consists of crushed stones typically 5 to 20mm. Besides storing water, this high infiltration rate layer provides a transition between the bedding and subbase layers.
- *Open-graded subbase reservoir* - The stone sizes are larger than the base, typically 20 to 65mm stone. Like the base layer, water is stored in the spaces among the stones. The subbase layer thickness depends on water storage requirements and traffic loads. A subbase layer may not be required in pedestrian or residential driveway applications. In such instances, the base layer is increased to provide water storage and support.
- *Underdrain (optional)* - In instances where pervious concrete is installed over low-infiltration rate soils, an underdrain facilitates water removal from the base and subbase. The underdrain is perforated pipe that ties into an outlet structure. Supplemental storage can be achieved by using a system of pipes in the aggregate layers. The pipes are typically perforated and provide additional storage volume beyond the stone base.
- *Geotextile (optional)* - This can be used to separate the subbase from the subgrade and prevent the migration of soil into the aggregate subbase or base.
- *Subgrade* - The layer of soil immediately beneath the aggregate base or subbase. The infiltration capacity of the subgrade determines how much water can exfiltrate from the aggregate into the surrounding soils. The subgrade soil is generally not compacted.

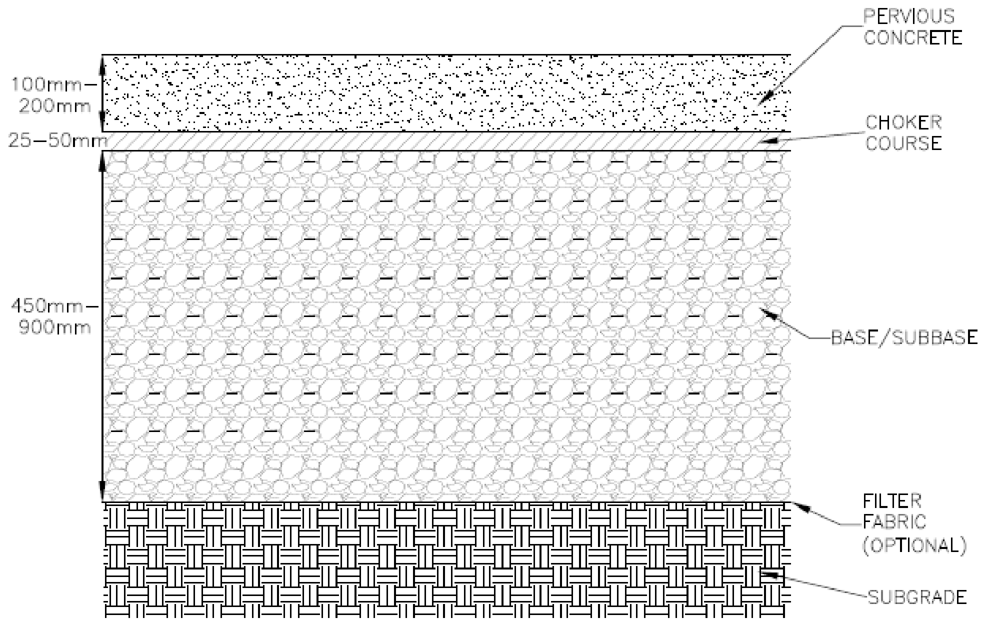

Figure 9. Typical Pervious Concrete Pavement Section. (*diagram adapted from US EPA)*

Properly installed pervious concrete requires trained and experienced producers and construction contractors. The installation of pervious concrete differs from conventional concrete in several ways. The pervious concrete mix has low water content and will therefore harden rapidly. Pervious concrete needs to be poured within one (1) hour of mixing. The pour time can be extended with the use of admixtures. A manual or mechanical screed set 12mm above the finished height can be used to level the concrete. Floating and troweling are not used, as those may close the surface pores. Consolidation of the concrete, typically with a steel roller, is recommended within 15 minutes of placement (Figure 10). Pervious concrete also requires a longer time to cure. The concrete should be covered with plastic within 20 minutes of setting and allowed to cure for a minimum of 7 days (NRMCA, 2008).

Figure 10. Pervious concrete being poured, consolidated and covered with plastic sheeting. *Photo courtesy of the National Ready Mix Concrete Association.*

Specific Design Considerations and Limitations

The load-bearing and infiltration capacities of the subgrade soil, the infiltration capacity of the pervious concrete, and the storage capacity of the stone base/subbase are the key storm water design parameters. To compensate for the lower structural support capacity of clay soils, additional subbase depth is often required. The increased depth also provides additional storage volume to compensate for the lower infiltration rate of the clay subgrade. Underdrains are often used when permeable pavements are installed over clay. In addition, an impermeable liner may be installed between the subbase and the subgrade to limit water infiltration when clay soils have a high shrink-swell potential, or if there is a high depth to bedrock or water table (Hunt and Collins, 2008).

Measures should be taken to protect permeable pavement from high sediment loads, particularly fine sediment. Appropriate pretreatment BMPs for run-on to permeable pavement include filter strips and swales. Preventing sediment from entering the base of permeable pavement during construction is critical. Runoff from disturbed areas should be diverted away from the permeable pavement until they are stabilized.

Key Siting and Maintenance Issues

- Do not in areas where hazardous materials are loaded, unloaded or stored
- Avoid high sediment loading areas
- Divert runoff from disturbed areas until stabilized
- Do not use sand for snow or ice treatment
- Periodic maintenance to remove fine sediments from paver surface will optimize permeability

Several factors may limit permeable pavement use. Pervious concrete has reduced strength compared to conventional concrete and will not be appropriate for applications with high volumes and extreme loads. It is not appropriate for storm water hotspots where hazardous materials are loaded, unloaded, stored, or where there is a potential for spills and fuel leakage. For slopes greater than 2 percent, terracing of the soil subgrade base may likely be needed to slow runoff from flowing through the pavement structure. In another approach for using pervious concrete slopes, lined trenches with underdrains can be dug across slope to intercept flow through the subbase (ACPA, 2006).

Consistent porosity through the concrete structure is critical to prevent freeze-thaw damage. Cement paste and smaller aggregate can settle to the bottom of the structure during consolidation and seal off the concrete pores. If surface water becomes trapped in pavement voids, then it can freeze, expand, and break apart the pavement. An evaluation of four (4) pervious concrete sites (3 with deterioration and 1 without) in Denver, CO by the Urban Drainage and Flood Control District, found that the larger aggregate size mix exhibited better permeability and less surface deterioration (UDFCD, 2008). The National Ready Mixed Concrete Association also recommends the following precautions to prevent pervious concrete from becoming saturated in regions where hard wet freezes occur (NRMCA, 2004):

- Use 200 to 600mm thick layer of clean aggregate base below the pervious concrete.
- Attempt to protect the cement paste by incorporating an air-entraining admixture in the mixture.
- Use an underdrain to drain the aggregate base.

Maintenance and Inspections

The most prevalent maintenance concern is the potential clogging of the pervious concrete pores. Fine particles that can clog the pores are deposited on the surface from vehicles, the atmosphere, and runoff from adjacent land surfaces. Clogging will increase with age and use. While more particles become entrained in the pavement surface, it does not become impermeable. Studies of the long-term surface permeability of pervious concrete and other permeable pavements have found high infiltration rates initially, followed by a decrease, and then leveling off with time (Bean, et al., 2007a). With initial infiltration rates of hundreds of mm per hour, the long-term infiltration capacity remains high even with clogging. When clogged, surface infiltration rates usually well exceed 25mm per hour, which is sufficient in most circumstances for the surface to effectively manage intense storm water events (ICPI, 2000). A study of eleven (11) pervious concrete sites found infiltration rates ranging from 125mm/hr to 40m/hr. The sites taking runoff from poorly maintained or disturbed soil areas had the lowest infiltration rates, but they were still high relative to rainfall intensities (Bean, et al., 2007a). Permeability can be increased with vacuum sweeping. In areas where extreme clogging has occurred, 12mm holes can be drilled through the pavement surface every 600mm or so to allow storm water to drain to the aggregate base. Many large cuts and patches in the pavement will weaken the concrete structure. Freeze/thaw cycling is a major cause of pavement breakdown, especially for parking lots in northern climates. Properly constructed permeable concrete can last 20 to 40 years because of its ability to handle temperature impacts. (Gunderson, 2008).

In cold climates, sand should not be applied for snow or ice conditions. However, snow plowing can proceed as with other pavements and salt can be used in moderation. Pervious concrete has been found to work well in cold climates as the rapid drainage of the surface reduces the occurrence of freezing puddles and black ice. Melting snow and ice infiltrates directly into the pavement facilitating faster melting (Gunderson, 2008).

Cold weather and frost penetration do not negatively impact surface infiltration rates. Permeable concrete freezes as a porous medium rather than a solid block because permeable pavement systems are designed to be well-drained; infiltration capacity is preserved because of the open void spaces (Gunderson, 2008). However, plowed snow piles should not be left to melt over the pervious concrete as they can receive high sediment concentrations that can clog them more quickly.

Permeable pavements do not treat chlorides from road salts but also require less applied deicers. Deicing treatments are a significant expense and chlorides in storm water runoff have substantial environmental impacts. Reducing chloride concentrations in runoff is only achieved through reduced application of road salts because removal of chloride with storm water BMPs is not effective. Road salt application can be reduced up to 75% with the use of permeable pavements (UNHSC, 2007).

Effectiveness

All permeable pavements, including pervious concrete, are on-site storm water management practices and will have the same or very similar effectiveness with regards to the reduction of the volume and rate of storm water runoff as well as pollutant concentrations. Pervious concrete, porous asphalt, and permeable pavers all have the same underlying storm water storage and support structure. The only difference is the permeable surface treatment. The choice of permeable surface is relevant to user needs, cost, material availability, constructability, and maintenance, but it has minimal impact on the overall storm water retention, detention, and treatment of the system.

Permeable pavement transforms areas that were a source of storm water to a treatment system and can effectively reduce or eliminate runoff that would have been generated from an impervious paved area. Because it reduces the effective impervious area of a site, permeable pavement should receive credit for pervious cover in drainage system design. The infiltration rate of properly constructed pervious concrete and base generally exceeds the design storm peak rainfall rate; the subsoil infiltration rate and base storage capacity are the factors determining storm water detention potential. Table 1 provides monitored reductions in storm water volumes via storage and infiltration.

Table 1. Volume Retention of Permeable Pavements				
Application	**Location**	**Soil Type**	**Underdrain**	**Volume Retention**
Pervious Concrete				
Residential street and sidewalk	Sultan, WA	--	--	100%
Parking lot	Kingston, NC	Clay	No	99.9%
Permeable Interlocking Concrete Pavers				
Residential street	Auckland, New Zealand	Clay	Yes	60%
Driveway	Cary, NC	Clay	Yes	66%
Field and laboratory tests	Guelph, Ontario, Canada	--	--	90%
Parking lot	Swansboro, NC	Sandy soil	No	100%
Parking lot	United Kingdom	Impermeable liner installed	Yes	34% - 45%
Parking lot	Renton, WA	---	No	100%
Parking lot	Kinston, NC	Clay	No	55%
Porous Asphalt				
Street	France	--	--	96.7%
Parking lot	State College, PA	--	--	Retained the 25 yr - 24 hr storm
Parking lot*	Durham, NH	Clay	Underdrain	25%
*System designed to collect infiltrated storm water in underdrain for monitoring purposes. (WA Aggregates & Concrete Association, 2006)(Collins, et al., 2008)(Fassman and Blackbourn, 2006)(Bean, et al., 2007a)(Bean et al., 2007b)(Pratt, 1999)(Booth and Leavitt, 1999)(Brattebo and Booth, 2003)(Collins, et al., 2008)(Legret, M. & Colandini, 1999)(Cahill et al., 2003)(Roseen and Ballestero, 2008)				

Permeable pavement reduces pollutant concentrations through several processes. The aggregate filters the storm water and slows it sufficiently to allow sedimentation to occur. The subgrade soils are also a major factor in treatment. Sandy soils will infiltrate more storm water but have less treatment capability. Clay soils have a high cation exchange capacity and will capture more pollutants but will infiltrate less. Also, studies have found that in addition to beneficial treatment bacteria in the soils, beneficial bacteria growth has been found on established aggregate bases. In addition, permeable pavement can process oil drippings from vehicles (Pratt et al., 1999). Table 2 provides measured pollutant removals from pervious pavement structures.

Table 2. Monitored Pollutant Removals of Permeable Pavement

Application	Location	TSS	Metals	Nutrients
Permeable Concrete				
Parking lot	Tampa, FL	91%	75-92%	--
Permeable Interlocking Concrete Pavers				
Driveways	Jordan Cove, CT	67%	Cu: 67% Pb: 67% Zn:71%	TP: 34% NO_3-N: 67% NH_3-N: 72%
Parking lot	Goldsboro, NC	71%	Zn: 88%	TP: 65% TN: 35%/td>
Parking lot	Renton, WA	---	Cu: 79% Zn: 83%	--
Parking lot	King College, ON	81%	Cu: 13% Zn: 72%	TP: 53% TKN: 53%
Porous Asphalt				
Highway (friction course only)	Austin, TX	94%	76-93%	43%
Parking lot	Durham, NH	99%	Zn: 97%	TP: 42%
(Rushton, 2001)(Bean, et al., 2007b)(Clausen and Gilbert, 2006)(Van Seters/TRCA 2007) (Barrett et al., 2006)(UNHSC, 2007)				

Permeable pavement water quantity and pollutant reduction characteristics such as 80% total suspended solids reductions can qualify it to earn credits under green or sustainable building evaluations systems such as Leadership in Energy and Environmental Design (LEED®) and Green Globes. Credits also can be earned for water conservation, urban heat island reduction, and conservation of materials by utilizing some recycled materials and regional manufacturing and resource use. Permeable concrete also allows less lighting to be used when compared to traditional asphalt because its lighter color reflects more light. See Figure 11.

Figure 11. Two of Chicago's Green Alley designs incorporate pervious concrete, a full alley width installation (left) and centre strip of alley installation (right). *Photos courtesy of Chicago Department of Transportation.*

Porous Asphalt Pavement

Description and Purpose

Porous asphalt, also known as pervious, permeable, "popcorn," or open-graded asphalt, is standard hot-mix asphalt with reduced sand or fines and allows water to drain through it. Porous asphalt over an aggregate storage bed will reduce storm water runoff volume, rate, and pollutants. The reduced fines leave stable air pockets in the asphalt. The interconnected void space allows storm water to flow through the asphalt as shown in Figure 12, and enter a crushed stone aggregate bedding layer and base that supports the asphalt while providing storage and runoff treatment. When properly constructed, porous asphalt is a durable and cost competitive alternative to conventional asphalt.

Figure 12. Porous asphalt allows water to flow through it. *Photo courtesy of the National Asphalt Paving Asociation.*

Applications

Porous asphalt can be used for municipal storm water management programs and private development applications. The runoff volume and rate control, plus pollutant reductions, allow municipalities to improve the quality of storm water discharges. Municipal initiatives, such as Portland's Green Streets program (Figure 13), use porous asphalt to reduce combined sewer overflows by infiltrating and treating storm water on site. Private development projects use porous asphalt to meet post-construction storm water quantity and quality requirements. The use of porous asphalt can potentially reduce additional expenditures and land consumption for conventional collection, conveyance, and detention storm water infrastructure.

Figure 13. A curb to curb installation of porous asphalt (left) and an installation of porous asphalt in the parking lanes and conventional asphalt in the drive lanes (right). *Photo courtesy of the Portland Bureau of Environmental Services.*

Porous asphalt can replace traditional impervious pavement for most pedestrian and vehicular applications. Open-graded asphalt has been used for decades as a friction course over impervious asphalt on highways to reduce noise, spray, and skidding. Highway applications with all porous asphalt surfacing have been used successfully for highway pilot projects in the United States, but, generally, porous asphalt is recommended for low volume and low speed applications (Hossain et al., 1992). Porous asphalt performs well in pedestrian walkways, sidewalks, driveways, parking lots, and low-volume roadways. The environmental benefits from porous asphalt allow it to be incorporated into municipal green infrastructure and low impact development programs. The appearance of porous asphalt and conventional asphalt is very similar. The surface texture of porous asphalt is slightly rougher, providing more traction to vehicles and pedestrians.

Design Criteria

Porous asphalt should be designed and sited to intercept, contain, filter, and infiltrate storm water on site. Several design possibilities can achieve these objectives. For example, porous asphalt can be installed across an entire street width or an entire parking area. The pavement can also be installed in combination with impermeable pavements or roofs to infiltrate runoff. Several applications use porous asphalt in parking lot lanes or parking stalls to treat runoff from adjacent impermeable pavements and roofs. This design economizes porous asphalt installation costs while providing sufficient treatment area for the runoff generated from impervious surfaces. Inlets can be placed in the porous asphalt to accommodate overflows from extreme storms. The storm water volume to be captured, stored, infiltrated, or harvested determines the scale of permeable pavement required.

Table 3 – Asphalt Mix (Adams 2003)

Sieve Size	% Passing
1/2”	100
3/8”	95
#4	35
#8	15
#16	10
#30	2

*Percent bituminous asphalt 5.75-6.0% by weight

Porous asphalt comprises the surface layer of the permeable pavement structure and consists of open-graded coarse aggregate, bonded together by bituminous asphalt. A typical reduced fines asphalt mix is shown in Table 1. Polymers can also be added to the mix to increase strength for heavy load applications. The thickness of porous asphalt ranges from 50 to 100mm depending on the expected traffic loads. For adequate permeability, the porous asphalt should have a minimum of 16% air voids. Additional subsurface components of this treatment practice are illustrated in Figure 14 and include the following (NAPA, 2008):

- *Choke course* - This permeable layer is typically 25 to 50mm thick and provides a level and stabilized bed surface for the porous asphalt. It consists of small-sized, open-graded aggregate.
- *Open-graded base reservoir* - This aggregate layer is immediately beneath the choke layer. The base is typically 75 -100mm thick and consists of crushed stones typically 5 to 19mm. Besides storing water, this high infiltration rate layer provides a transition between the bedding and subbase layers.
- *Open-graded subbase reservoir* - The stone sizes are larger than the base, typically 20 to 65mm stone. Like the base layer, water is stored in the spaces among the stones. The subbase layer

thickness depends on water storage requirements and traffic loads. A subbase layer may not be required in pedestrian or residential driveway applications. In such instances, the base layer is increased to provide water storage and support.

- *Underdrain (optional)* - In instances where porous asphalt is installed over low-infiltration rate soils, an underdrain facilitates water removal from the base and subbase. The underdrain is perforated pipe that ties into an outlet structure. Supplemental storage can be achieved by using a system of pipes in the aggregate layers. The pipes are typically perforated and provide additional storage volume beyond the stone base.
- *Geotextile (optional)* - This can be used to separate the subbase from the subgrade and prevent the migration of soil into the aggregate subbase or base.
- *Subgrade* - The layer of soil immediately beneath the aggregate base or subbase. The infiltration capacity of the subgrade determines how much water can exfiltrate from the aggregate into the surrounding soils. The subgrade soil is generally not compacted.

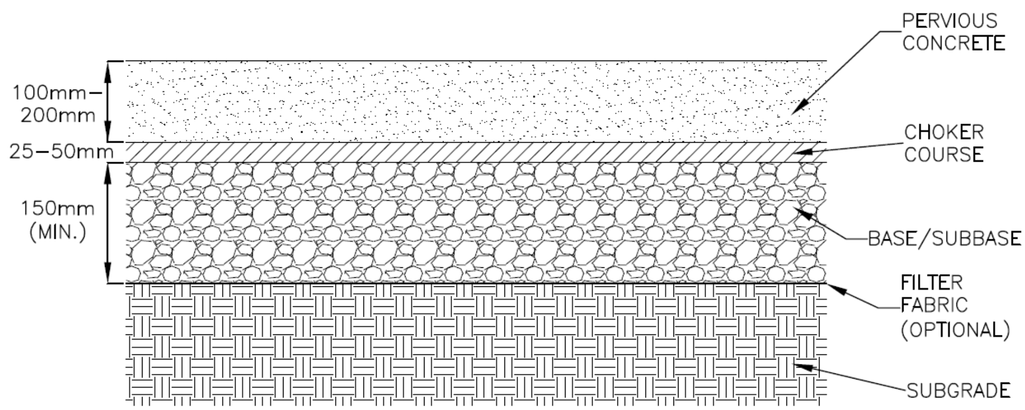

Figure 14. Typical Porous Asphalt Pavement Section. *(diagram adapted from US EPA)*

The same equipment can be used for mixing and laying permeable asphalt as conventional asphalt. The method for laying the asphalt will also be similar as shown above in Figure 15. During compaction of the asphalt, minimal pressure should be used to avoid closing pore space. Vehicular traffic should be avoided for 24 to 48 hours after pavement is installed.

Figure 15. Porous asphalt instllation for a Villanova parking lot. *Photo courtesy of the Villanova Urban Stormwater Partnership.*

Specific Design Considerations and Limitations

The load-bearing and infiltration capacities of the subgrade soil, the infiltration capacity of the porous asphalt, and the storage capacity of the stone base/subbase are the key storm water design parameters. To compensate for the lower structural support capacity of clay soils, additional subbase depth is often required. The increased depth also provides additional storage volume to compensate for the lower infiltration rate of the clay subgrade. Underdrains are often used when permeable pavements are installed over clay. In addition, an impermeable liner may be installed between the subbase and the subgrade to limit water infiltration when clay soils have a high shrink-swell potential, or if there is a high depth to bedrock or water table (Hunt and Collins, 2008).

Measures should be taken to protect permeable pavement from high sediment loads, particularly fine sediment. Appropriate pretreatment BMPs for run-on to permeable pavement include filter strips and swales. Preventing sediment from entering the base of permeable pavement during construction is critical. Runoff from disturbed areas should be diverted away from the permeable pavement until they are stabilized.

Several factors may limit permeable pavement use. Porous asphalt has reduced strength compared to conventional asphalt and will not be appropriate for applications with high volumes and extreme loads. It is not appropriate for storm water hotspots where hazardous materials are loaded, unloaded, stored, or where there is a potential for spills and fuel leakage. For slopes greater than 2 percent, terracing of the soil subgrade base may likely be needed to slow runoff from flowing through the pavement structure.

Key Siting and Maintenance Issues

- Do not install in areas where hazardous materials are loaded, unloaded or stored
- Avoid high sediment loading areas
- Divert runoff from disturbed areas until stabilized
- Do not use sand for snow or ice treatment
- Periodic maintenance to remove fine sediments from paver surface will optimize permeability

Maintenance and Inspections

The most prevalent maintenance concern is the potential clogging of the porous asphalt pores. Fine particles that can clog the pores are deposited on the surface from vehicles, the atmosphere, and runoff from adjacent land surfaces. Clogging will increase with age and use. While more particles become entrained in the pavement surface, it does not become impermeable. Studies of the long-term surface permeability of porous asphalt and other permeable pavements have found high infiltration rates initially, followed by a decrease, and then leveling off with time (Bean, et al., 2007a). With initial infiltration rates of hundreds of mm per hour, the long-term infiltration capacity remains high even with clogging. When clogged, surface infiltration rates usually well exceed 25mm per hour, which is sufficient in most circumstances for the surface to effectively manage intense storm water events (ICPI, 2000). Permeability can be increased with vacuum sweeping. In areas where extreme clogging has occurred, 12mm holes can be drilled through the pavement surface every 600mm or so to allow storm water to drain to the aggregate base. A stone apron around the pavement connected hydraulically to the aggregate base and subbase can be used as a backup to surface clogging or pavement sealing.

Due to the well draining stone bed and deep structural support of porous asphalt pavements, they tend to develop fewer cracks and potholes than conventional asphalt pavement. When cracking and potholes do occur, a conventional patching mix can be used. Freeze/thaw cycling is a major cause of pavement breakdown, especially for parking lots in northern climates. The lifespan of a northern parking lot is typically 15 years for conventional pavements; porous asphalt parking lots can have a lifespan of more than 30 years because of the reduced freeze/thaw stress (Gunderson, 2008).

Figure 16. Porous asphalt parking lot one hour after being plowed. *Photo courtesy of the University of New Hampshire Stormwater Centre.*

In cold climates, sand should not be applied for snow or ice conditions. However, snow plowing can proceed as with other pavements and salt can be used in moderation. See above Figure 16. Porous asphalt has been found to work well in cold climates as the rapid drainage of the surface reduces the occurrence of freezing puddles and black ice. Melting snow and ice infiltrates directly into the pavement facilitating faster melting (Gunderson, 2008).

Cold weather and frost penetration do not negatively impact surface infiltration rates. Porous asphalt freezes as a porous medium rather than a solid block because permeable pavement systems are designed to be well-drained; infiltration capacity is preserved because of the open void spaces (Gunderson, 2008). However, plowed snow piles should not be left to melt over the porous asphalt as they can receive high sediment concentrations that can clog them more quickly.

Permeable pavements do not treat chlorides from road salts but also require less applied deicers. Deicing treatments are a significant expense and chlorides in storm water runoff have substantial environmental impacts. Reducing chloride concentrations in runoff is only achieved through reduced application of road salts because removal of chloride with storm water BMPs is not effective. A porous asphalt lot installed at the University of New Hampshire required 25% of the salt routinely applied to other impervious asphalt lots for equivalent deicing. No salt application was required for the porous pavement to have an equivalent friction factor and traction than normally treated conventional pavements because porous pavement has higher frictional resistance than conventional pavement (UNHSC, 2007).

Effectiveness

All permeable pavements, including pervious asphalt, are on-site storm water management practices and will have the same or very similar effectiveness with regards to the reduction of the volume and rate of storm water runoff as well as pollutant concentrations. Porous asphalt, pervious concrete, and permeable pavers all have the same underlying storm water storage and support structure. The only difference is the permeable surface treatment. The choice of permeable surface is relevant to user needs, cost, material availability, constructability, and maintenance, but it has minimal impact on the overall storm water retention, detention, and treatment of the system.

Permeable pavement transforms areas that were a source of storm water to a treatment system and can effectively reduce or eliminate runoff that would have been generated from an impervious paved area. Because it reduces the effective impervious area of a site, permeable pavement should receive credit for pervious cover in drainage system design. The infiltration rate of properly constructed pervious asphalt and base generally exceeds the design storm peak rainfall rate; the subsoil infiltration rate and base storage capacity are the factors determining storm water detention potential. Table 2 provides monitored reductions in storm water volumes via storage and infiltration.

Table 4 – Volume Retention of Permeable Pavements

Application	Location	Soil Type	Underdrain	Volume Retention
Porous Asphalt				
Street	France	--	--	96.7%
Parking lot	State College, PA	--	--	Retained the 25 yr - 24 hr storm
Park Lot*	Durham, NH	Clay	Underdrain	25%
Permeable Interlocking Concrete Pavers				
Residential street	Auckland, New Zealand	Clay	Yes	60%
Driveway	Cary, NC	Clay	Yes	66%
Field and laboratory tests	Guelph, Ontario, Canada	--	--	90%
Parking lot	Swansboro, NC	Sandy soil	No	100%
Parking lot	United Kingdom	Impermeable liner installed	Yes	34% - 45%
Parking lot	Renton, WA	---	No	100%
Parking lot	Kinston, NC	Clay	No	55%
Pervious Concrete				
Residential streets and sidewalk	Sultan, WA	--	--	100%
Parking lot	Kingston, NC	Clay	No	99.9%
*System designed to collect infiltrated storm water in underdrain for monitoring purposes. (Legret, M. & Colandini, 1999)(Cahill et al., 2003)(Roseen and Ballestero, 2008)(Fassman and Blackbourn, 2006)(Bean, et al., 2007a)(Bean et al., 2007b)(Pratt, 1999)(Booth and Leavitt, 1999)(Brattebo and Booth, 2003)(Collins, et al., 2008)(WA Aggregates & Concrete Association, 2006)(Collins, et al., 2008)				

Permeable pavement reduces pollutant concentrations through several processes. The aggregate filters the storm water and slows it sufficiently to allow sedimentation to occur. The subgrade soils are also a major factor in treatment. Sandy soils will infiltrate more storm water but have less treatment capability. Clay soils have a high cation exchange capacity and will capture more pollutants but will infiltrate less. Also, studies have found that in addition to beneficial treatment bacteria in the soils, beneficial bacteria growth has been found on established aggregate bases. In addition, permeable pavement can process oil drippings from vehicles (Pratt et al., 1999). Table 3 provides measured pollutant removals from pervious pavement structures.

Table 5 – Monitored Pollutant Removals of Permeable Pavement

Application	Location	TSS	Metals	Nutrients
Porous Asphalt				
Highway (friction course only)	Austin, TX	94%	76-93%	43%
Parking lot	Durham, NH	99%	Zn: 97%	TP: 42%
Permeable Interlocking Concrete Pavers				
Driveways	Jordan Cove, CT	67%	Cu: 67% Pb: 67% Zn:71%	TP: 34% NO_3-N: 67% NH_3-N: 72%
Parking lot	Goldsboro, NC	71%	Zn: 88%	TP: 65% TN: 35%
Parking lot	Renton, WA	---	Cu: 79% Zn: 83%	--
Parking lot	King College, ON	81%	Cu: 13% Zn: 72%	TP: 53% TKN: 53%
Pervious Concrete				
Parking lot	Tampa, FL	91%	75-92%	--
(Barrett et al., 2006)(UNHSC, 2007)(Bean, et al., 2007b)(Clausen and Gilbert, 2006)(Van Seters/TRCA 2007)(Rushton, 2001)				

Permeable pavement water quantity and pollutant reduction characteristics such as 80 percent total suspended solids reductions can qualify it to earn credits under green or sustainable building evaluation systems such as Leadership in Energy and Environmental Design (LEED®) and Green Globes. Credits also can be earned for water conservation and conservation of materials by utilizing some recycled materials and regional manufacturing and resource use.

Chapter B5

Inspection, Maintenance, and Record Keeping

5.1 Introduction

The permanent BMPs are designed to reduce pollutant loadings into receiving waters. To ensure that the performance of BMP meets the design criteria and they serve the intended purpose, the following activities are essential:

- Regular site inspections;
- Acceptance of final BMP construction & As-built certification;
- Proper BMP maintenance; and
- Good record keeping.

5.2 Site Inspection During Construction

Regular inspections shall be conducted and documented at the stages listed in the following subsections:

Vegetative Swales

- During excavation to subgrade;
- During placement and backfill of under drain systems for dry swales; and
- Upon completion of final grading and establishment of permanent stabilization.

Infiltration Facilities

Infiltration Trenches

- During excavation to subgrade;
- During placement and backfill of underdrain systems and observation wells;
- During placement of geotextiles and all filter media; and
- During construction of appurtenant conveyance systems such as diversion structures, pre-filters and filters, inlets, outlets, and flow distribution structures.

Infiltration Basins

- At the stages specified for pond construction in the pond description portion of this section and during placement and backfill of underdrain systems.

Storm Water Wetlands

- At the stages specified for pond construction in the pond description portion of this section;
- During and after wetland reservoir area planting; and
- During the second growing season to verify a vegetation survival rate of at least 50 percent.

Storm Water Ponds

• Upon completion of excavation to sub-foundation and when required, installation of structural supports or reinforcement for structures, including but not limited to:

o Core trenches for structural embankments,

o Inlet and outlet structures, anti-seep collars or diaphragms, and watertight connectors on pipes, and

o Trenches for enclosed storm drainage facilities;

• During placement of structural fill, concrete, and installation of piping and catch basins;
• During backfill of foundations and trenches;
• During embankment construction; and
• Upon completion of final grading and establishment of permanent stabilization.

Filtering Systems

• During excavation to subgrade;
• During placement and backfill of underdrain systems;
• During placement of geotextiles and all filter media;
• During construction of appurtenant conveyance systems such as flow diversion structures, pre-filters and filters, inlets, outlets, orifices, and flow distribution structures; and
• Upon completion of final grading and establishment of permanent stabilization.

Proprietary "Hydrodynamic" Type BMPs

• During excavation to subgrade;
• During placement and backfill of underdrain systems;
• During placement of geotextiles and all filter media;
• During construction of appurtenant conveyance systems such as flow diversion structures, pre-filters and filters, inlets, outlets, orifices, and flow distribution structures;
• Other critical stages as per manufacturer's recommendations; and
• Upon completion of final grading and establishment of permanent stabilization.

5.3 As-Built Certification and Acceptance of Permanent BMPs

Once construction is complete, as-built plan certification shall be submitted to the District by either a registered professional engineer or professional land surveyor licensed in BC to ensure that constructed BMPs and associated conveyance systems comply with the specifications contained in the approved plans. At a minimum, as-built plan certification shall include a set of drawings comparing the approved permanent BMPs plan with what was constructed. The District may require additional information.

5.4 BMP Inspections After Construction

Permanent BMPs are to be inspected at least once a year and within fourteen (14) days after each storm event that produces 25mm or more precipitation. Inspections after a storm event provide an evaluation of the effectiveness of the BMPs and early detection of potential damages as a result of the storm. The after-storm inspection also aid in identifying maintenance activities needed. The result of the inspection and evaluation must be written in the latest inspection form as provided by the District. If deficiencies are observed during the inspections, follow-up procedures must be performed to ensure that the required repair, maintenance, or modification activity is completed in a timely manner.

5.5 BMP Maintenance

General maintenance tasks that are to be performed periodically, as specified in the BMP description or determined by site inspection include the following:

- Removal of the sediment and debris;
- Removal of grease and oil;
- Replacement or repair of worn or damaged geotextile fabrics;
- Reseeding or replanting of damaged vegetated areas;
- Re-mulching of damaged stabilized areas; and
- Replacement or repair of damaged flow control structure or devices. Specific maintenance tasks are identified in Chapter 4 of this manual for each BMP description. Maintenance related to a storm event must be completed within 14 days of the inspection. A maintenance schedule shall be developed for the life of the permanent BMP facility and shall state the maintenance to be completed, the time period for completion, and who shall perform the maintenance. This maintenance schedule shall be printed on the approved permanent BMP plan.

5.6 Record Keeping

Records of all inspections and follow-up activities for deficiencies in the conditions of the BMPs are to be retained for a minimum of five years. This record information can be used to improve the BMP performance for future applications. In addition to the inspection form, records of maintenance activities shall also be kept. These records are to indicate specific maintenance activities that have been completed, record observations of maintenance personnel, and provide useful information regarding future maintenance requirements for a particular BMP. It is the District's goal to develop and implement a system to compile a database of permanent BMPs. The database will include the BMP type and location, as well as all inspection and maintenance records. The database will be made part of the District's storm water asset management system.

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