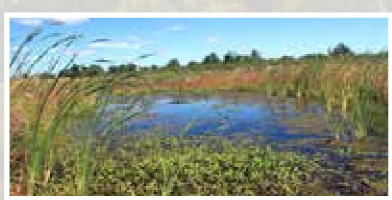
stormwater procedures manual

city of winchester and clark county

specifications for streets, drainage, landscaping, erosion protection and sediment control, and low impact development



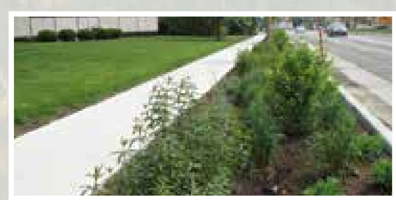


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TABLE OF CONTENTS

INTRODUCTION 1
PART I STORMWATER 1
- A. Storm Drainage 1
- B. Drainage Requirements (Grading) 3
- C. Drainage System Requirements 4
- D. Road Drainage System 4
- E. Off-Road Drainage Systems 4
- F. Easements 4
- G. Protection of Drainage Systems 5
- H. Material Specifications 5

PART II PERMITTING COMPLIANCE 5
- A. Planning Commission Procedures 6
- B. County Requirements for EPSC and PC 6
- C. City Requirements for EPSC and PC 6
- D. EPSC BMPs and Control Measures 8

PART III LOW IMPACT DEVELOPMENT BEST MANAGEMENT PRACTICES 9
- A. General Information 9
- B. Select Green Infrastructure Specifications 9
- C. Permeable Pavement 10
- D. Vegetated Roofs 34
- E. Manufactured BMP Systems 48
- F. Roof Downspout System 52
- G. Vegetated Filter Strip 55
- H. Grassed Swale 64
- I. Infiltration Trench 77
- J. Bioretention Basin/Rain Garden 86
- K. Infiltration Basin 115

LIST OF TABLES

Table 1 Summary of Stormwater Functions Provided by Permeable Pavement 12
Table 2 Comparative Properties of the Three Major Permeable Pavement Types 13
Table 3 Permeable Pavement Design Criteria 14
Table 4 The Three Design Scales for Permeable Pavement 17
Table 5 Material Specifications for Underneath the Pavement Surface 25
Table 6 Different Permeable Pavement Specifications 26
Table 7 Summary of Stormwater Functions Provided by Vegetated Roofs 35
Table 8 Green Roof Design Guidance 36
Table 9 Ground Covers for Vegetated Roofs in Clark County 43
Table 10 Extensive Vegetated Roof Material Specifications 45
Table 11 Typical Maintenance Activities Associated with Green Roofs 48
Table 12 Stone or Riprap Sizes for Gabion Baskets 74
Table 13 Pollutant Removal Efficiencies for Bioretention Basins 89
Table 14 Pretreatment Filter Strip Sizing Guidance 96
Table 15 Pretreatment Grass Channel Sizing Guidance for a 1.0 acre Drainage Area 96
Table 16 Popular Native Plant Materials for Bioretention Basins 103
Table 17 Recommended Tree and Shrub Spacing 105
Table 18 Example Maintenance Schedule for Bioretention Basins 113

LIST OF FIGURES

Figure 1 Cross Section of Typical Permeable Pavement....10
Figure 2 Permeable Pavement Typical Detail....11
Figure 3 Photos of Vegetated Roof Cross-Sections....36
Figure 4 Typical Section – Extensive Vegetated Roof....37
Figure 5 Typical Section – Intensive Vegetated Roof....38
Figure 6 Roof Downspout System with a Pretreatment Sump Basin....54
Figure 7 Vegetated Filter Strip....61
Figure 8 Level Spreader....62
Figure 9 USDA Plant Hardiness Zones....63
Figure 10 Typical Grassed Swale Configuration....65
Figure 11 Typical Water Quality Swale Configuration....66
Figure 12 Typical Check Dam Configurations....76
Figure 13 Manning's n Values for Varying Depths of Flow....77
Figure 14 Infiltration Trench – Section....78
Figure 15 Filter Fabric Placement....81
Figure 16 Observation Well....82
Figure 17 Bioretention Basin....87
Figure 18 Bioretention Basin at Edge of Parking Lot with Curb....90
Figure 19 Bioretention basin in a Planting Island in a Parking Lot....91
Figure 20 Bioretention Basin Adjacent to a Drainage Swale....92
Figure 21 Bioretention Basin at Edge of Parking Lot Without Curb....93
Figure 22 Upflow Inlet for Bioretention Basin....97
Figure 23 Grading Plan for Bioretention Basin....101
Figure 24 Sample Planting Plan for Bioretention Basin....106
Figure 25 Infiltration Basin – Plan and Section....116

LIST OF APPENDICES

APPENDIX A Land Disturbance Permitting Process (Flow Chart)
APPENDIX B Post Construction Stormwater Management (Flow Chart)
APPENDIX C Annual Inspection Checklists
APPENDIX D Erosion Protection and Sediment Control BMPs

INTRODUCTION:

In 1972, Congress passed The Clean Water Act establishing the basic structure for regulating discharges of pollutants into the waters of the United States. The Water Quality Act of 1987, amended the Clean Water Act by creating the National Pollution Discharge Elimination System (NPDES). This program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Over the years point discharges have been defined to include many types of discharges. Included in these discharges are construction runoff and runoff from storm drainage systems.

Under the program, states that meet certain criteria have the authority and responsibility to regulate discharges into these waters. In Kentucky this authority and responsibility lies with the Division of Water (DOW) in the Environmental and Public Protection Cabinet. The DOW regulates these discharges under Kentucky's version of the NPDES, the Kentucky Pollution Discharge Elimination System (KPDES).

The City of Winchester operates under the requirements of KPDES general stormwater permit for small municipal separate storm sewer systems (MS4). The City has six (6) minimum control measures that are required for implementation in order to be compliant with the MS4 stormwater permit. The intent of this manual is to provide property owners, developers, builders, and the general public a standardized stormwater and infrastructure manual for streets, drainage, erosion protection and sediment control, and low impact development. This manual shall be used in conjunction with the current development regulations and the ordinances for erosion prevention and sediment control and post-construction storm water runoff requirements.

PART 1 STORMWATER DRAINAGE

A drainage system shall be designed and constructed by the developer/owner developer/owner to provide for the proper drainage of the surface water of the development and the drainage area of which it is a part. Storm sewer design shall be made a part of the plans and the details thereon shall be adhered to except as otherwise stated herein. All storm sewer pipe shall be fifteen inches (15") or greater in diameter and shall meet Kentucky Standard Specifications for Road and Bridge Construction (latest addition), Supplemental Specifications to the Standard Specifications, and current version of Kentucky Transportation Cabinet's (KYTC) Drainage Manual. Stormwater drainage design criteria and specifications are listed below.

A. Storm Drainage

A development plan shall not be considered for approval until the developer/owner submits to the Office of Planning & Community Development City of Winchester a drainage report by a professional engineer as to the ability of existing water course channels, storm sewers, culverts, and other improvements pertaining to drainage or flood control within the development to handle the additional run-off for the storms noted below which would be generated by the planned future development of the land within the area according to long range plan. There shall be no increase in the rate of run-off as a result of new construction. Additional information shall be submitted to adequately indicate that provision has been made for disposal of surface water without any damage to the developed or undeveloped land downstream or below the proposed development. This report shall also include:

1. Estimates of the quantity (cubic feet) of storm water entering the development naturally from area outside of the development subject parcel on each inlet.

2. Calculation of Stormwater Runoff Water Quality Treatment Standard
   In urban areas the first flush of runoff pollutants carries a heavy load of pollutants from impervious areas such as streets and parking areas that can negatively impact receiving streams by altering the water chemistry and water quality. Capturing the "First Flush" of pollutants is one way to improve water quality leaving the MS4. The goal of this stormwater runoff quality treatment standard is establish the water quality volume (WQ_v) metric and provide treatment for the WQ_v.

   The water quality volume (WQ_v) can be calculated using the formula below:

$$WQ_V = \left(\frac{A * d}{43560\, ft^2 * 0.6in} \right)$$

   WQ_v = Ac*ft
   A = Impervious area (ft^2) d = 0.6 (in)

   The calculated WQ_v shall be treated in combination or alone, by management measures that are designed, built, and maintained to treat, filter, flocculate, infiltrate, screen, evapotranspire, harvest and reuse stormwater runoff, or otherwise manage the stormwater runoff quality.

3. Standards for Protection of High Quality Water (HQW)
   Areas of development and/or re-development that result in new or expanded discharge from MS4 shall:

   - Provide sufficient detention, storage, or infiltration BMPs to maintain or improve upon pre-construction flow in order to protect the existing in-stream designated water uses; and

   - Provide the necessary BMPs that focus on removal of pollutants most common to the type of development occurring in order to maintain the level of water quality that protects existing uses. BMPs selected for the site shall be accepted by the City of Winchester of their designee.

   - Areas of redevelopment will be required to meet the same water quantity criteria as new development, and will need to provide water quality treatment at a level equivalent to 20% of the requirement for the new development. BMPs will be accepted on a case-by-case basis by the City of Winchester authority to provide reasonable assurance that the BMPs selected are appropriate for the site and pollutants of concern.

4. Peak flow rates (cfs) at each pick-up point (inlet).

5. The preliminary plan shall record the location, size and elevations of all stormwater features and other required appurtenances including the following design calculations:

   - Drainage Areas (acres)
   - Calculated WQ_v
   - Design flow for each structure (Q_{ex} existing and Q_{post} post-construction)

- Imperviousness of Drainage Area-C_{ex} and C_{post}
- Intensity of Rainfall-I (10 year, 25 year, and 100 year storms for a 24 hour event);
- Time Conc,-TC

6. The basic standard for design of drainage systems for a development will be to keep run-off characteristics after development at the same level as existed prior to development. No excess stormwater runoff is permitted to occur. To achieve these objectives, storm water retention and/or detention systems will be required in most cases. The analysis used for the design of the required retention/detention systems shall consider impact on downstream properties for a 10-year/24-hour storm, a 25-year/24-hour storm, and a 100-year/24-hour storm. Likewise, where conditions and engineering calculations indicate benefit would not occur storm drainage detention facilities may be deleted from the development requirements in favor of channel improvements, off-site improvements to improve flow, or other alternative wherein the alternate is less burdensome to the developer than providing detention facilities. In computing storm water run-off and designing the drainage system, the developer's engineer shall use standard engineering practice which shall be accepted by the City of Winchester.

B. Drainage Requirements (Grading)

No site development work shall commence on a subject parcel including but not limited to: rough grading, final grading, sidewalk, pavement construction or installation of utilities until the Development Plan has been approved and all plan submittals have been accepted by the Winchester/Clark County Planning Commission and the City of Winchester.

The developer/owner shall grade each development in order to establish street, block, and a lot grades in proper relation to each other and to topography as follows:

1. **Street Grading Plan**: A grading plat shall be prepared for the streets along with street improvement details. The grading of the roadway shall extend the full width of the right-of-way. Planting strips shall be graded at a gradient of not less than two (2) percent upward from the curb to the sidewalk or property line except where green infrastructure BMPs are used.

2. **Lot Grading**: Lots shall be graded so that water drains away from each building at a minimum grade of two (2) percent except where green infrastructure BMPs are used. Surface drainage swales shall meet the standards and specifications of the Clark County Conservation District and shall be designed so that the surface water will drain into a driveway, street gutter, storm sewer, drain inlet or natural drainage way. Contractors shall return lots to approved grade if disturbed during building construction.

3. **Top Soil**: If grading results in the stripping of top soil, the top soil shall not be removed from the site or used as spoil and shall be uniformly spread over the lots as grading is finished.

4. **Trees**: As many trees as can be reasonably utilized in the final development plan shall be retained and the grading adjusted to the existing grade of the trees where practicable.

C. Drainage System Requirements

The design criteria for storm drainage systems shall be based on information from the current version of KYTC's Drainage Manual.

Culverts shall be designed for fifty (50) year storm frequency unless the culvert is a part of the stormwater retention/detention system. Storm sewers in all streets shall be designed for a twenty-five (25) year storm frequency.

For curbs and gutters, curb and gutter inlets and open channels an intensity of four (4) inches per hour shall be used in all computations.

A minimum of "TC" of 8 minutes shall be used as well as the "C" value shall be based on the planned future development of the watershed area according to the Comprehensive Plan.

D. Road Drainage System

All roadways shall be provided with an adequate storm drainage system.

The road storm sewer shall serve as the primary drainage system and shall be designed to carry roadway, adjacent land, and building storm water drainage. No storm water shall be permitted to be run into the sanitary sewer system within the proposed development. Since the road drainage is a major contributing factor to excess surface runoff, it must be routed through the storm water retention facilities.

Curb drainage box inlets shall be type A or B (unless otherwise approved by the Commission) and provided at intervals along roadways. Inlet spacing shall be adequate to limit the spread of water to two (2) feet into the roadway. Storm drain inlets will be placed so that crosswalks will not be flooded during the storm intensity of four (4) inches per hour.

E. Off-Road Drainage Systems

The design of the off-road drainage system shall include the watershed affecting the development and shall be extended to a watercourse or ditch adequate to receive the storm drainage.

1. When the drainage system is outside of the road right-of-way, the developer/owner shall make provisions for dedicating of an easement to provide for the future maintenance of said system per City of Winchester's Code of Ordinance Chapter 2, Article VI, Division 11, Sections 2-321 to 2-340.

2. If a watercourse or ditch is left open it may be required to be protected by a fence as determined by the City of Winchester. The water course or ditch easement shall be wide enough to contain said ditch slope with ample clearance for the operation of maintenance equipment. The side slopes of the ditch shall not be greater than 3:1.

F. Easements

1. An easement for the purpose of stormwater drainage is an area set aside for stormwater flow that cannot be filled in or altered without prior approval from the City of Winchester and is maintained by the property owner. Drainage easements shall be a

minimum of twenty (2) feet on each side of the stream. For smaller streams (less than 5 feet in width from top of bank to top of bank), the storm water easement or drainage right-of-way shall be included on the plat that is inclusive of the area flooded by the 100 year event. Easements shall be shown on the record plat and shall cover all existing or reconstructed watercourses.

2. All permanent stormwater management facilities shall have an easement that allows access to the facility for monitoring and maintenance. Easements for the purpose of maintaining permanent stormwater management facilities shall be binding on all subsequent owners of the land served by stormwater management facility, provide access to the facility for periodic inspections by the City, and shall be recorded on a plat.

G. Protection of Drainage Systems

The developer/owner shall adequately protect all open drainage features to the satisfaction of the City of Winchester. Ditches and open channels shall be seeded, sodded or paved depending on grades (slopes) and types of soils. As a general rule, ditches and channels with grades up to one (1) percent shall be seeded, with grades from one (1) to four (4) percent shall be sodded and with grades over four (4) percent shall be paved. Paving operations shall be in compliance with the Kentucky Standard Specifications for Road and Bridge Construction (latest addition). Seeding and sodding operations shall be in accordance to the recommendations of the *Kentucky Erosion Prevention and Sediment Control Field Guide.*

H. Material Specifications

Material and construction specifications for all drainage projects (i.e., pipe, tile, seed, sod) shall be in compliance with the Kentucky Standard Specifications for Road and Bridge Construction (latest addition) or KYTC Drainage Manual, as applicable.

PART II PERMITTING COMPLIANCE

In the event that any person intends to make changes to the contour of the land proposed to be subdivided, developed, or changed in use by grading, excavating or the removal of destruction of the natural topsoil, trees, or other vegetative covering, the owner of said land or his agent shall be in compliance with Kentucky Pollutant Discharge Elimination System (KPDES) General Permit for Stormwater Discharges Associated with construction Activities (KYR10), current version. If within the MS4 jurisdictional boundary of the City of Winchester, the owner of said land or his agent shall also be in compliance with the City of Winchester's Code of Ordinances 5-2011 for Erosion Prevention and Sediment Control (EPSC).

Compliance with KYR10 and/or Ordinance 5-2011 requires the development of a Stormwater Pollution Prevention Plan (SWPPP) and lists a series of Best Management Practices (BMP) for erosion prevention and sediment control. This applies to land disturbances of one (1) acre or more or any that are part of a larger common plan of development that will ultimately disturb one acre or more. Local regulations may also exist and applicability considerations are described in this section of the manual. Under no conditions shall soil or other construction products be allowed to exit the site under development onto adjacent roadways or public or private property. BMPs selected shall follow the guidelines and policies contained herein and at a minimum meet the recommendations of the *Kentucky Erosion Prevention and Sediment Control Field Guide*.

The City of Winchester is regulated by KYG20, which is the state general KPDES permit for Small Municipal Separate Storm Sewer Systems (MS4). Projects that disturb one (1) acre or more or are part of a larger common plan of development shall also comply with the City of Winchester's Code of Ordinances 14-2011 for Post-Construction (PC) Stormwater Runoff Requirements. Compliance with KYG20 and the City of Winchester's Code of Ordinances 14-2011 requires the development of Stormwater Management Plan (SWMP) that outlines the on-site stormwater management practices to control the peak flow rates of stormwater discharge and treat the water quality volume (Part 1 Section A).

A. Planning Commission Procedures

1. Article III of the Development and Subdivision Regulations for Winchester/Clark County fully explains the Development Plan Procedures followed by the Office of Planning & Community Development.

2. The Planning Commission has jurisdiction and control over all development and development of land within the City of Winchester and Clark County.

3. Development Plans may be submitted to the Office of Planning & Community Development as "Preliminary Development Plans" or "Final Development Plans". Preliminary Development Plans are conceptual and do not flow for any site related activities to commence prior to approval of the Final Development Plan and acceptance of all plans related to the development.

B. County Requirements for EPSC and PC

The following guidelines are under the jurisdiction of Kentucky Division of Water (KDOW) and apply to all construction projects with land disturbance activities located outside of the City of Winchester MS4 boundary.

1. All projects disturbing one acre or more are less than one acre and are part of a larger common plan of development shall be in compliance with the current version of KYR10 and must obtain an eNOI from the state. It is the responsibility of the permittee (i.e. NOI holder) to maintain compliance with all provisions of KYR10.

2. Construction Site Inspections – The site shall be self-policing; correcting or remedying any EPSC measures that are not effective or functioning properly at all times during the various phases of construction. A SWPPP shall be developed per KYR10 specifications and available on-site. The developer shall perform site inspections once every seven (7) days or within 24 hours of a rain event 0.5 inches or greater and every fourteen (14) days.

C. City Requirements for EPSC and PC

The following guidelines apply to all construction projects with land disturbance activities located within the City of Winchester MS4 boundary and are under the jurisdiction of the City of Winchester. The Grading Permit Application, EPSC Land Disturbance From, Permitting Fees Schedule, and Operation and Maintenance Agreement (Post-Construction) are available online at the City of Winchester's website. Templates for completing a SWPPP and Stormwater Management Plan (SWMP) are also available on the City's website. For any additional information on the requirements listed below please call the City of Winchester.

1. Grading Permit Submittals are defined by Winchester's Code of Ordinances including but not limited to the following:
   a. Land Disturbance Activities < 1 acre
      - Completed EPSC Land Disturbance Form
   b. Land Disturbance Activities > 1 acre
      - Grading Permit Application
      - SWPPP – Four (4) copies (Section C.2 below)
      - Stormwater Management Plan (SWMP), if applicable – Two (2) copies (Section C.3 below)
      - Copy of eNOI
      - Fees according to the Permitting Fee Schedule

2. Components of a SWPPP – Per Chapter 14, Article VI, Division 1, Sect. 14-305 of Winchester's Code of Ordinances for EPSC
   a. Site description
   b. Project site map/drawing
   c. All BMPs selected shall be equally or more effective than the practices described in the *Kentucky Erosion Prevention and Sediment Control Manual and Field Guide*.
   d. The SWPPP shall be signed in accordance with the signatory requirements in 401 KAR 5:056, Section 2(1).
   e. The current SWPPP shall be kept on-site during construction.

   <u>The Land Disturbance Permitting Process is further explained in Appendix A by a flow chart illustrating the steps associated with obtaining a Grading Permit and release of the permit.</u>

   Components of a SWMP – Per Chapter 14, Article VI, Division 3, Section 14-351 of the Winchester's Code of Ordinances for Post-Construction.
   a. Contact information
   b. Topographic base map
   c. Calculations (i.e. water quality, quantity, EPSC)
   d. Soils information
   e. SWPPP
   f. Landscaping plan
   g. Maintenance and repair plan for selected BMPs (Annual Inspection checklists are available in Appendix C for Post-Construction BMPs)
   h. Maintenance easements (recorded per requirements of Part 1 Section F)
   i. Operation and Maintenance agreement
   k. Stormwater management costs

3. Construction Site Inspections
   a. Responsible Party: The development shall be self-policing; correcting or remedying EPSC measures that are not effective or functioning properly at all times during the various phases of construction. The developer shall perform site inspections once every seven (7) days or within 24 hours of a rain event 0.5

inches or greater and every fourteen (14) days. These reports shall be available for review by the City of Winchester.

b. Responsible Official: To ensure compliance with the EPSC measures identified in the approved plan, the City of Winchester or duly authorized representatives shall have the power to inspect any site with land disturbance activities.

c. Authority and Duties of Inspectors: Inspectors employed by the City shall be authorized to inspect all work done and all materials furnished. Such inspection may extend to all or any part of the work and to the preparation, fabrication, or manufacture of the materials to be used. The inspector shall not be authorized to revoke, alter, or waive any requirements or the specifications of plans. The inspector shall be authorized to call the attention of the contractor to any failure of the work or materials to conform to the specifications and contract.

d. Final Inspections: Upon completion of all the improvements, the permittee shall request, in writing, a final inspection by the City of Winchester. If final stabilization has been established, a Certificate of Stabilization will be issued.

4. Post-Construction Requirements if applicable
   a. It shall be the responsibility of the contractor to conduct regular inspections of stormwater management system BMPs by qualified inspectors.
   b. “As-built” plans must be submitted for any stormwater management BMPs after final construction is completed and be certified by a professional engineer.

D. EPSC BMPs and Control Measures

A selection of Best Management Practices for EPSC is provided in Appendix D. This list is not all inclusive of allowable practices for EPSC. Each BMP selected shall be suitable to the site and use for which it is needed. Below is a list of control measures that should be utilized for an effective erosion and sediment control plan along with selected BMPs:

1. The smallest practical area of land should be exposed at any one time during development.

2. When land is exposed during development, the exposure should be kept to the shortest practical period of time.

3. Where necessary, temporary vegetation, erosion fencing, and/or mulching should be used to protect areas exposed during development.

4. Sediment basins (debris basins, desilting basins, or silt traps) should be installed and maintained to remove sediment from run-off waters from land disturbing activities.

5. Provisions should be made to effectively accommodate the increased runoff caused by changed soil and surface conditions during and after development.

6. The permanent final vegetation and structures should be installed as soon as practical in the development.

7. The development plan should be fitted to the topography and soils so as to create the least erosion potential.

8. Wherever feasible, natural vegetation should be retained and protected.

PART III LOW IMPACT DEVELOPMENT BEST MANAGEMENT PRACTICES

A. General Information

Green Infrastructure (GI): an integrated systems approach to stormwater management that mimic natural processes in order to infiltrate evaporate, and/or reuse stormwater. Green infrastructure uses soils, topography, and vegetation in a way that minimizes the impacts of anthropogenic disturbance and maintains the pre-development hydrology and water quality of urban environments.

The goal of GI is to design a built environment that remains a functioning part of an ecosystem rather than existing apart from it. This is an innovative approach to urban stormwater management that strategically integrates stormwater controls throughout the urban landscape and does not rely solely on conventional end-of-pipe structural practices. LID techniques can offer many benefits to a variety of stakeholders.

Developers:
- Reduce land clearing and grading costs
- Potentially reduce infrastructure costs (streets, curbs, gutters)
- Reduce storm water management costs
- Potentially reduce impact fees and increase lot yield
- Increase lot and community marketability

Municipalities
- Protects the health and safety of a community by reducing stormwater impacts
- Reduces or eliminates nonpoint source pollutants from reaching waterways
- Protect regional flora and fauna by reducing stream bank erosion
- Balance growth needs with environmental protection
- Reduces municipal infrastructures and utility maintenance costs (streets, curbs, gutters, storm sewer)
- Enhances both physical health (by increasing an individual's opportunity to walk and exercise outside) and mental health (by improving the visual quality of the environment and thereby reducing stress and mental fatigue)
- Increase collaborative public/private partnerships

Environment:
- Preserve integrity of ecological and biological systems
- Protect site and regional water quality by reducing sediment, nutrient, and toxic loads to water bodies
- Reduce impacts to local terrestrial and aquatic plants and animals
- Preserve trees and natural vegetation

B. Select Green Infrastructure Specifications

Green Infrastructure practices have the potential to address one, two or all three of the following stormwater related issues: reduce volume runoff, reduce peak discharge and improve water quality for residential, commercial and industrial projects. Green Infrastructure relies on a systems approach model to address stormwater runoff. As a result, an individual site or project may contain two, three or more GI practices operating in a treatment train format to capture, infiltrate or harvest rain water. Some features can be used as pre-treatment so that the pollutants can be captured as quickly as possible in the treatment train, thus eliminating adverse effects further downstream. Some of these pre-treatment options include solids, traps, oil and water separators, forebays, etc.

This manual provides additional information on select BMP practices. The BMPs listed in this manual does not limit the use of other BMPs suitable for your construction site. It is important to know that one BMP is not suitable for all situations. Select appropriate BMP's which respond accordingly to the natural environment. BMPs may require certified installers that must approve and oversee the installation of the BMP.

C. Permeable Pavement

1. Description

   Permeable pavements are alternative paving surfaces that allow stormwater runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. A variety of permeable pavement surfaces are available, including pervious concrete (PC), porous asphalt (PA) and permeable interlocking concrete pavers (IP). While the specific design may vary, all permeable pavements have a similar structure, consisting of a surface pavement layer, an underlying stone aggregate reservoir layer and a filter layer or fabric installed on the bottom (See Figures 1 and 2).

Figure 1. Cross Sections of Typical Permeable Pavement
(Source: Hunt & Collins, 2008)

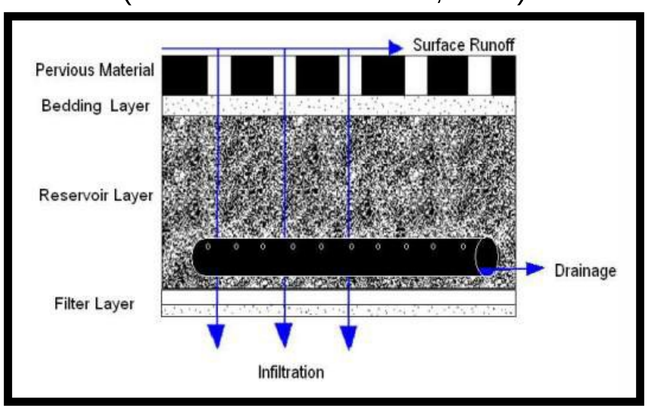
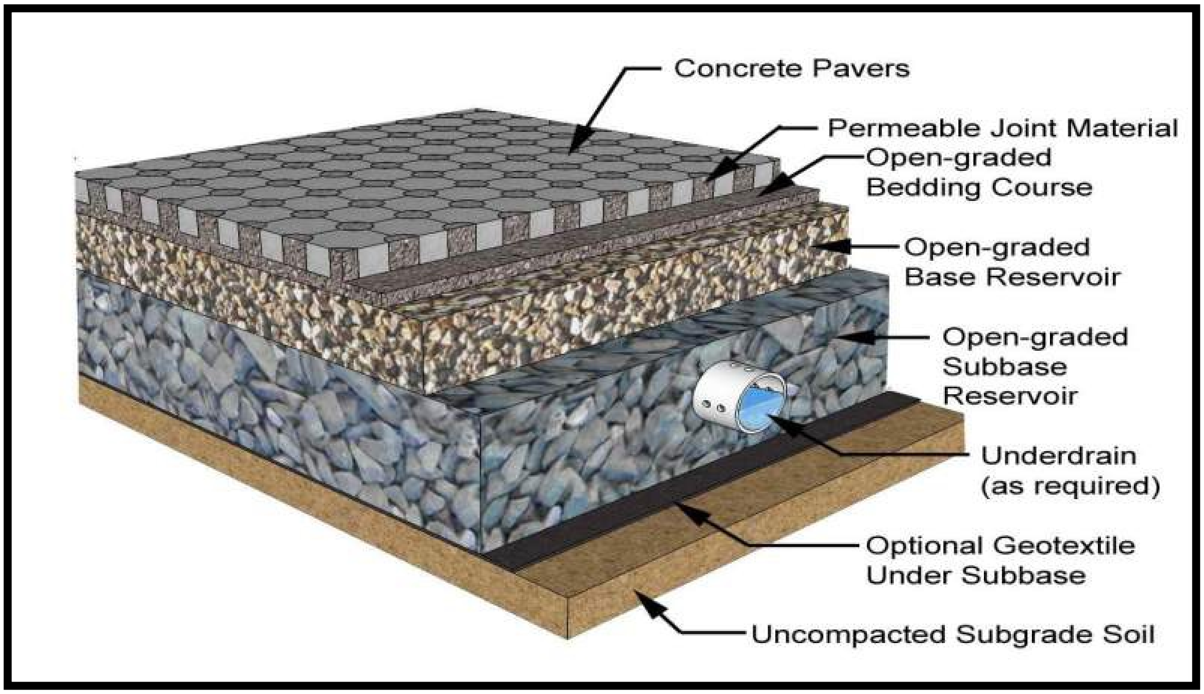


Figure 2. Permeable Pavement Typical Detail
(Source: Smith 2009)



The thickness of the reservoir layer is determined by both a structural and hydrologic design analysis. The reservoir layer serves to retain stormwater and also supports the design traffic loads for the pavement. In low-infiltration soils, some or all of the filtered runoff is collected in an underdrain and returned to the storm drain system. If infiltration rates in the native soils permit, permeable pavement can be designed without an underdrain, to enable full infiltration of runoff. A combination of these methods can be used to infiltrate a portion of the filtered runoff.

Permeable pavement is typically designed to treat stormwater that falls on the actual pavement surface area, but it may also be used to accept run-off from small adjacent impervious areas, such as impermeable driving lanes or rooftops. Careful sediment control of these adjacent areas is needed to avoid clogging of the down-gradient permeable pavement. Permeable pavement has been used at commercial, institutional, and residential sites in spaces that are traditionally impervious. Permeable pavement promotes a high degree of runoff volume reduction and nutrient removal, and it can also reduce the effective impervious cover of a development site.

2. Performance

The overall stormwater functions of permeable pavement are shown in Table 1.

Table 1. Summary of Stormwater Functions Provided by Permeable Pavement

<table>
<tr><th>Stormwater Function</th><th>Level 1 Design</th><th>Level 2 Design</th></tr>
<tr><td>Annual Runoff Volume Reduction (RR)</td><td>45%</td><td>75%</td></tr>
<tr><td>Channel Protection</td><td colspan="2">○ Use RRM spreadsheet to calculate a Curve Number (CN) adjustment; OR
○ Design extra storage (optional, as needed) in the stone underdrain layer to accommodate larger storm volumes, and use NRCS TR-55 Runoff Equations[1] to compute CN adjustment</td></tr>
<tr><td>Flood Mitigation</td><td colspan="2">Partial. May be able to design additional storage into the reservoir layer by adding perforated storage pipe or chambers</td></tr>
<tr><td colspan="3">1 NRCS TR-55 Runoff Equations 2-1 thru 2-5 and Figure 201 can be used to compute a curve number adjustment for larger storm events based on the retention storage provided by the practice(s).</td></tr>
</table>

Sources: CWP and CSN (2008) and CWP (2007)

The choice of what kind of permeable pavement to use is influenced by site-specific design factors and the intended future use of the permeable surface. A general comparison of the engineering properties of the three major permeable pavement types is provided in Table 2, although designers should check with product vendors and their local review authority to determine their specific requirements and capabilities. Designers should also note that there are other paver options, such as concrete grid pavers and reinforced turf pavers that function in the same general manner as permeable pavement.

Table 2. Comparative Properties of the Three Major Permeable Pavement Types

Design Factor	Porous Concrete (PC)	Porous Asphalt (PA)	Interlocking Pavers (IP)
Scale of Application	Small and large scale paving applications	Small and large scale paving applications	Micro, small and large scale paving applications
Pavement Thickness[1]	5 to 8 inches	3 to 4 inches	3 inches[1, 8]
Bedding Layer [1, 8]	None	2 inches No. 57 stone	2 inches No. 8 stone
Reservoir Layer[2, 8]	No. 57 stone	No. 2 stone	No. 2 stone 3-4 inches of No. 57 stone
Construction Properties[3]	Cast in place, seven day cure, must be covered	Cast in place, 24 hour cure	No cure period; manual or mechanical installation of pre-manufactured units, over 5000 sf/day per machine
Design Permeability[4]	10 feet/day	6 feet/day	2 feet/day
Construction Cost Comparison	Middle	Lowest	Highest
Min. Batch Size	500 sq. t.		NA
Longevity[6]	20 to 30 years	15 to 20 years	20 to 30 years
Overflow	Drop inlet or overflow edge	Drop inlet or overflow edge	Surface, drop inlet or overflow edge
Temperature Reduction	Cooling in the reservoir layer	Cooling in the reservoir layer	Cooling at the pavement surface & reservoir layer
Colors/Texture	Limited range of colors and textures	Black or dark grey color	Wide range of colors, textures and patterns
Traffic Bearing Capacity[7]	Can handle all traffic loads, with appropriate bedding layer design		
Surface Clogging	Replace paved areas or install drop inlet	Replace paved areas or install drop inlet	Replace permeable stone jointing materials
Other Issues		Avoid seal coating	Snowplow damage
Design Reference	American Concrete Institute #522.1.08	Jackson (2007) NAPA	Smith (2206) ICPI

[1]Individual designs may depart from these typical cross-sections, due to site, traffic and design conditions.
[2]Reservoir storage may be augmented by corrugated metal pipes, plastic arch pipe, or plastic lattice blocks.
[3]ICPI (2008)
[4]NVRA (2008)
[6]Based on pavement being maintained properly, Resurfacing or rehabilitation may be needed after the indicated period.
[7]Depends primarily on on-site geotechnical considerations and structural design computations.
[8]Stone sizes correspond to ASMT D 448: *Standard Classification for Sizes of Aggregate for Road and Bridge Construction.*

3. Design Table

The major design goal of Permeable Pavement is to maximize nutrient removal and runoff reduction. To this end, designers may choose to use a baseline permeable pavement design (Level 1) or an enhanced design (Level 2) that maximizes nutrient and runoff reduction. To qualify for Level 2, the design must meet all design criteria shown in the right hand column of Table 3.

Table 3. Permeable Pavement Design Criteria

Level 1 Design	Level 2 Design
Tv = (0.64)(Rv)(A) / 12 – the volume reduced by an upstream BMP[1]	Tv = (0.75)(Rv)(A) / 12
Soil infiltration is less than 0.5 in./hr.	Soil infiltration rate exceeds 0.5 in./hr.
Underdrain required	Underdrain not required; ***OR*** If an underdrain is used, a 12-inch stone sump must be provided below the underdrain invert; ***OR*** The Tv has at least a 48-hour drain time, as regulated by a control structure.
CDA = The permeable pavement area plus Upgradient parking, as long as the ratio of external contributing area to permeable pavement does not exceed 2:1	CDA = The permeable pavement area
[1]The contributing drainage area to the permeable pavements should be limited to paved surfaces, to avoid sediment wash-on, and sediment source controls and/or a pre-treatment strip or sump should be used. When pervious areas are conveyed to permeable pavement, pre-treatment must be provided.	

4. Physical Feasibility & Design Applications

Since permeable pavement has a very high runoff reduction capability, it should always be considered as an alternative to conventional pavement. Permeable pavement is subject to the same feasibility constraints as most infiltration practices, as described below.

Available Space. A prime advantage of permeable pavement is that it does not normally require additional space at a new development or redevelopment site, which can be important for tight sites or areas where land prices are high.

Soils. Soil conditions do not constrain the use of permeable pavement, although they do determine whether an underdrain is needed. Impermeable soils in Hydrologic Soil Groups (HSG) C or D usually require an underdrain, whereas HSG A and B soils often do not. In addition, permeable pavement should never be situated above fill soils unless designed with an impermeable liner and underdrain.

If the proposed permeable pavement area is designed to infiltrate runoff without underdrains, it must have a minimum infiltration rate of 0.5 inches per hour. Initially, projected soil infiltration rates can be estimated from USDA-NRCS soil data, but they must be confirmed by an on-site infiltration measurement. Native soils must have silt/clay content less than 40% and clay content less than 20%.

Designers should also evaluate existing soil properties during initial site layout, and seek to configure the site to conserve and protect the soils with the greatest recharge and infiltration rates. In particular, areas of HSG A or B soils shown on NRCS soil surveys should be considered as primary locations for all types of infiltration.

External Drainage Area. Any external drainage area contributing runoff to permeable pavement should generally not exceed twice the surface area of the permeable pavement, and it should be as close to 100% impervious as possible. Some field experience has shown that an Upgradient drainage area (even if it is impervious) can contribute particulates to the permeable pavement and lead to clogging (Hirschman, et al., 2009). Therefore, careful sediment source control and/or a pre-treatment strip or sump (e.g., stone or gravel) should be used to control sediment run-of to he permeable pavement section.

Pavement Slope. Steep slopes can reduce the stormwater storage capability of permeable pavement and may cause shifting of the pavement surface and base materials. Designers should consider using a terraced design for permeable pavement in sloped areas, especially when the local slope is several percent or greater.

The bottom slope of a permeable pavement installation should be as flat as possible (i.e., 0% longitudinal slope) to enable even distribution and infiltration of stormwater. However, a maximum longitudinal slope of 1% is permissible if an underdrain is employed. Lateral slopes should be 0%.

Minimum Hydraulic Head. The elevation difference needed for permeable pavement to function properly is generally nominal, although 2 to 4 feet of head may be needed to drive flows through underdrains. Flat terrain may affect proper drainage of Level 1 permeable pavement design, so underdrains should have a minimum 0.5% slope.

Minimum Depth to Water Table. A high groundwater table may cause runoff to pond at the bottom of the permeable pavement system. Therefore, a minimum vertical distance of 2 feet must be provided between the bottom of the permeable pavement installation (i.e., the bottom invert of the reservoir layer) and the seasonal high water table.

Setbacks. Permeable pavement should not be hydraulically connected to structure foundations, in order to avoid harmful seepage. Setbacks to structures and roads vary, based on the scale of the permeable pavement installation (see Table 4 above0. At a minimum, small- and large-scale pavement applications should be located a minimum horizontal distance of 100 feet from any water supply well, 50 feet from septic systems, and at least 5 feet down-gradient from dry or wet utility lines. Setbacks can be reduced at the discretion of the local program authority for designs that use underdrains and/or liners.

Informed Owner. The property owner should clearly understand the unique maintenance responsibilities inherent with permeable pavement, particularly for parking lot applications. The owner should be capable of performing routine and long-term actions (e.g., vacuum sweeping) to maintain the pavement's hydrologic functions, and avoid future practices (e.g., winter sanding, seal coating or repaving) that diminish or eliminate them.

High Loading Situations. Permeable pavement is not intended to treat sites with high sediment or trash/debris loads, since such loads will cause the practice to clog and fail.

Groundwater Protection. Section 1.i of this specification presents a list of potential stormwater hotspots that pose a risk of groundwater contamination. Infiltration of runoff from designated hotspots is highly restricted or prohibited.

Limitations. Permeable pavement can be used as an alternative to most types of conventional pavement at residential, commercial and institutional developments, with two exceptions.

- Permeable pavement should not be used for high speed roads, although it has been successfully applied for low speed residential streets, parking lanes and roadway shoulders; and

- Permeable pavement should not be used to treat runoff from stormwater hotspots, as noted above.

Design Scales. Permeable pavement can be installed at the following three scales:

a. The smallest scale is termed ***Micro-Scale Pavements***, which applies to converting impervious surfaces to permeable ones on small lots and redevelopment projects, where the installations may range from 250 to 1000 square feet in total area. Where redevelopment or retrofitting of existing impervious areas result in a larger foot-print of permeable pavers (small-scale or large-scale, as described below), the designer should implement the Load bearing, Observation Well, Underdrain, Soil Test, and Building Setback criteria associated with the applicable scale.

b. ***Small-scale pavement*** applications treat portions of a site between 1,000 and 10,000 square feet in area, and include areas that only occasionally receive heavy vehicular traffic.

c. ***Large-scale pavement*** applications exceed 10,000 square feet in area and typically are installed within portions of a parking lot.

Table 4 outlines the different design requirements for each of the three scales of permeable pavement installation.

Table 4. The Three Design Scales for Permeable Pavement

Design Factor	Micro-Scale Pavement	Small-Scale Pavement	Large-Scale Pavement
Impervious Area Treated	250 to 1000 sq. ft.	1000 to 10,000 sq. ft.	More than 10,000 sq. ft.
Typical Applications	Driveways Walkways Court Yards Plazas Individual Sidewalks	Sidewalk Network Fire Lanes Road Shoulders Spill-Over Parking Plazas	Parking lots with more than 40 spaces Low Speed Residential Streets
Most Suitable Pavement	IP	PA, PC and IP	PA, PC and IP
Load Bearing Capacity	Foot traffic Light vehicles	Light vehicles	Heavy vehicles (moving & parked)
Reservoir Size	Infiltrate or detain some or all of the Tv	Infiltrate or detain the full Tv and as much of the CPv and design storms as possible	
External Drainage Area?	No	Yes, impervious cover up to twice the permeable pavement area may be accepted as long as sediment source controls and/or pretreatment is used	
Observation Well	No	No	Yes
Underdrain	Rare	Depends on the soils	Back-up underdrain
Required Soil Tests	One per practice	Two per practice	One per 5000 sq. ft. of proposed practice
Building Setbacks	5 feet down-gradient 25 feet up-gradient	10 feet down-gradient 50 feet up-gradient	25 feet down-gradient 100 feet up-gradient

Regardless of the design scale of the permeable pavement installation, the designer should carefully consider the expected traffic load at the proposed site and the consequent structural requirements of the pavement system. Sites with heavy traffic loads will require a thick aggregate based and, in the case of porous asphalt and pervious concrete, may require the addition of an admixture for strength or a specific bedding design. In contrast, most micro-scale applications should have little or no traffic flow to contend with.

5. Design Criteria

   a. Sizing of Permeable Pavement

      Structural Design. If permeable pavement will be used in a parking lot or other setting that involves vehicles, the pavement surface must be able to support the maximum anticipated traffic load. The structural design process will vary according to the type of pavement selected, and the manufacturer's specific recommendations should be consulted. The thickness of the permeable pavement and reservoir layer must be sized to support structural loads and to temporarily store the design storm volume (e.g., the water quality, channel protection, and/or flood control volumes). On most new development and redevelopment sites, the structural support requirements will dictate the depth of the underlying stone reservoir.

The structural design of permeable pavement involves consideration of four main site elements:

- Total traffic;
- In-situ soil strength;
- Environmental elements; and
- Bedding and Reservoir layer design.

The resulting structural requirements may include, but are not limited to, the thickness of the pavement, filter, and reservoir layer. Designers should note that if the underlying soils have a low California Bearing Ratio (CBR) (less than 4%), they may need to be compacted to at least 95% of the Standard Proctor Density, which generally rules out their use for infiltration.

Designers should determine structural design requirements by consulting transportation design guidance sources, such as the following:

- KYTC Standard specifications for Road and Bridge Construction, current edition;
- AASHTO Guide for Design of Pavement Structures, current edition, and,
- AASHTO Supplement to the Guide for Design of Pavement Structures, current edition.

Hydraulic Design. Permeable pavement is typically sized to store the Water Quality Treatment Volume (T_v) or another design storm volume in the reservoir layer. The infiltration rate typically will be less than the flow rate through the pavement, so that some underground reservoir storage will usually be required. Designers should initially assume that there is no outflow through underdrains, using **Equation 1** to determine the depth of the reservoir layer, assuming runoff fully infiltrates into the underlying soil:

Equation 1

$$d_p = \frac{\{(d_c \times R) + P - (i/2 \times t_f)}{V_r}$$

Where:

d_p = The depth of the reservoir layer (ft.)
d_c = The depth of runoff from the contributing drainage area (not including the permeable paving surface) for the Treatment of Volume (T_v/A_c), or other design storm (ft.)
R = A_c/A_p = The ratio of the contributing drainage area (A_c, not including the permeable paving surface) to the permeable pavement surface area (A_p)

[NOTE: With reference to Table 4, the maximum value for the Level 1 design is R = 2, (the external drainage area A_c is twice that of the permeable pavement area A_p; and for Level 2 design R = 0 (the drainage area is made up solely of permeable pavement A_p]

- P = The rainfall depth for the Treatment Volume (Level 1 =0.6 inch.; Level 2 = 0.75 inch), or other design storm (ft.)
- i = The field-verified infiltration rate for native soils (ft./day)
- t_f = The time to fill the reservoir layer (day) – typically 2 hours or 0.083 day
- V_r = The void ratio for the reservoir layer (0.4)

The maximum allowable depth of the reservoir layer is constrained by the maximum allowable drain time, which is calculated using **Equation 2.**

Equation 2

$$d_{p\text{-}max} = \frac{(i/2 x t_d)}{V_r}$$

Where:

- $d_{p\text{-}max}$ = The maximum depth of the reservoir layer (ft.)
- i = The field-verified infiltration rate of the native soils (ft./day)
- V_r = The void ratio for reservoir layer (0.4 – see assumptions, below)
- t_d = The maximum allowable time to drain the reservoir layer, typically 1 to 2 days (days)

The following design assumptions apply to **Equations 1 and 2:**

- The contributing drainage area (A_c) should not contain pervious areas.
- For design purposes, the native soil infiltration rate (i) should be field-tested soil infiltration rate dived by a factor of safety of 2. The minimum acceptable native soil infiltration rate is 0.5”/hr.
- The void ratio (V_r) for No. 57 stone = 0.4.
- Max. drain time for the reservoir layer should be not less than 24 nor more than 48 hours.

If the depth of the reservoir layer is too great (i.e. d_p exceeds $d_{p\text{-}max}$), or the verified soil infiltration rate is less than 0.5 inches per hour, then the design method typically changes to account for underdrains. The storage volume in the pavements must account for the underlying infiltration rate and outflow through the underdrain. In this case, the design storm should be routed through the pavement to accurately determine the required reservoir depth. Alternatively, the designer may use **Equations 3 through 5** to approximate the depth of the reservoir layer for designs using underdrains.

Equation 3 can be used to approximate the outflow rate from the underdrain. The hydraulic conductivity, *k*, of gravel media is very high (~17,000 ft./day). However the permeable pavement reservoir layer will drain increasingly slower as the storage volume decreases (i.e. the hydraulic head decreases). To account for this change, a conservative permeability coefficient of 100 ft./day can be used to approximate the average underdrain outflow rate.

Equation 3

$$q_u = k \times m$$

Where:

- q_u = Outflow through the underdrain (per outlet pipe, assumed 6-inch diameter) (ft./day)
- k = Hydraulic conductivity for the reservoir layer (ft./day – assume 100 ft./day)
- m = Underdrain pipe slope (ft./ft.)

Once the outflow rate through the underdrain has been approximated, **Equation 4** is used to determine the depth of the reservoir layer needed to store the design storm.

Equation 4

$$d_p = \frac{(d_c \times R) + P-(i/2 \times t_f) - q_u \times t_f)}{V_r}$$

Where:

- d_p = Depth of the reservoir layer (ft.)
- d_c = Depth of runoff from the contributing drainage area (not including the permeable pavement surface) for the Treatment Volume (T_v/A_c), or other design storm (ft.)
- R = A_c/A_p = The ratio of the contributing drainage area (A_c) (not including the permeable pavement surface) to the permeable pavement surface area (A_p)
- P = The rainfall depth for the Treatment Volume (Level 1 = 1 inch; Level 2 – 1.1 inch), or other design storm (ft.)
- i = The field-verified infiltration rate for the native soils (ft./day)
- t_f = The time to fill the reservoir layer (day) – typically 2 hours or 0.083 day
- V_r = The void ratio for the reservoir layer (0.4)
- q_u = Outflow through Underdrain (ft/day)

The maximum allowable depth of the reservoir layer is constrained by the maximum allowable drain time, which is calculated using, **Equation 5**.

Equation 5

$$d_{p\text{-}max} = \frac{\{(i/2 \times t_d) + (q_u \times t_d)\}}{V_r}$$

Where:

$d_{p\text{-}max}$ = The maximum depth of the reservoir layer (ft.)
i = The field-verified infiltration rate for the native soils (ft./day)
V_r = The void ratio for the reservoir layer (0.4)
t_d = The time to drain the reservoir layer (day – typically 1 to 2 days)
q_u = Outflow through underdrain (ft/day)

If the depth of the reservoir layer is still too great (i.e. d_p exceeds $d_{p\text{-}max}$), the number of underdrains can be increased, which will increase the underdrain outflow rate.

Permeable pavement can also be designed to address, in whole or in part, the detention storage needed to comply with channel protection and/or flood control requirements. The designer can model various approaches by factoring in storage within the stone aggregate layer, expected infiltration and any outlet structures used as part of the design. Routing calculations can also be used to provide a more accurate solution of the peak discharge and required storage volume.

Once runoff passes through the surface of the permeable pavement system, designers should calculate outflow pathways to handle subsurface flows. Subsurface flows can be regulated using underdrains, the volume of storage in the reservoir layer, the bed slope of the reservoir layer, and/or a control structure at the outlet.

Soil Infiltration Rate Testing

To design a permeable pavement system *without* an underdrain, the measured infiltration rate of subsoils must be 0.5 inch per hour or greater. A minimum of one test must be taken per 1,000 sq. ft. of planne4d permeable pavement surface area. In most cases, a single soil test is sufficient for micro-scale and small-scale applications. At least one soil boring must be taken to confirm the underlying soil properties *at the depth where infiltration is designed to occur* (i.e., to ensure that the depth to water table, or depth to bedrock is defined). Soil infiltration testing should be conducted within any confining layers that are found within 4 feet of the bottom of a proposed permeable pavement system.

Type of Surface Pavement

The type of pavement should be selected based on a review of the factors in Table 3 above, and designed according to the product manufacturer's recommendations.

Internal Geometry and Drawdowns

- ***Elevated Underdrain***. To promote greater runoff reduction for permeable pavement located on marginal soils, an elevated underdrain should be installed with a stone jacket that creates a 12 to 18 inch deep storage layer *below* the underdrain invert. The void storage in this layer can help qualify a site to achieve Level 2 design.

- ***Rapid Drawdown***. When possible, permeable pavement should be designed so that the target runoff reduction volume stays in the reservoir layer for at least 36 hours before being discharged through an underdrain.

- ***Conservative Infiltration Rates***. Designers should always decrease the measured infiltration rate by a factor of 2 during design, to approximate long term infiltration rates.

Pretreatment

Pretreatment for most permeable pavement applications is not necessary, since the surface acts as pretreatment to the reservoir layer below. Additional pretreatment may be appropriate if the pavement receives run-on from an adjacent pervious or impervious area. For example, a gravel filter strip can be used to trap coarse sediment particles before they reach the permeable pavement surface, in order to prevent premature clogging.

Conveyance and Overflow

Permeable pavement designs should include methods to convey larger storms (e.g., 2-yr, 10-yr) to the storm drain system. The following is a list of methods that can be used to accomplish this:

- Place a perforated pipe horizontally near the top of the reservoir layer to pass excess flows after water has filled the base. The placement and/or design should be such that the incoming runoff is not captured (e.g., placing the perforations on the underside only).

- Increase the thickness of the top of the reservoir layer by as much as 6 inches (i.e., create freeboard). The design computations used to size the reservoir layer often assume that no freeboard is present.

- Create underground detention within the reservoir layer of the permeable pavement system.

- Reservoir storage may be augmented by corrugated metal pipes, plastic or concrete arch structures, etc.

- Route excess flows to another detention or conveyance system that is designed for the management of extreme event flows.

- Set the storm drain inlets flush with the elevation of the permeable pavement surface to effectively convey excess stormwater runoff past the system (typically in remote areas). The design should also make allowances for relief of unacceptable ponding depths during larger rainfall events.

Reservoir layer

The thickness of the reservoir layer is determined by runoff storage needs, the infiltration rate of in situ soils, structural requirements of the pavement sub-base, depth to water table and bedrock, and frost depth conditions. A professional should be consulted regarding the suitability of the soil subgrade.

- The reservoir below the permeable pavement surface should be composed of clean, washed stone aggregate and sized for both the storm event to be treated and the structural requirements of the expected traffic loading.

- The storage layer may consist of clean washed No. 57 stone, although No. 2 stone is preferred because it provides additional storage and structural stability.

- The bottom of the reservoir layer should be completely flat so that runoff will be able to infiltrate evenly through the entire surface.

Underdrains

The use of underdrains is recommended when there is a reasonable potential for infiltration rates to decrease over time, when underlying soils have an infiltration rate of less than 1/2-inch per hour, or when soils must be compacted to achieve a desired Proctor density. Underdrains can also be used to manage extreme storm events to keep detained stormwater from backing up into the permeable pavement.

- An underdrain(s) should be placed within the reservoir and encased in 8 to 12 inches of clean, washed stone.

- The underdrain outlet can be fitted with a flow-reduction orifice as a means of regulating the stormwater detention time. The minimum diameter of any orifice should be 0.5 inch.

- An underdrain(s) can also be installed and capped at a downstream structure as an option for future use if maintenance observations indicate a reduction in the soil permeability.

Maintenance Reduction Features

Maintenance is a crucial element to ensure the long-term performance of permeable pavement. The most frequently cited maintenance problem is surface clogging caused by organic matter and sediment, which can be reduced by the following measures:

- ***Periodic Vacuum Sweeping***. The pavement surface is the first line of defense in trapping and eliminating sediment that may otherwise enter the stone base and soil subgrade. The rate of sediment deposition should be monitored and vacuum sweeping done once or twice a year. This frequency should be adjusted according to the intensity of use and deposition rate on the permeable pavement surface. At least one sweeping pass should occur at the end of winter.

- ***Protecting the Bottom of the Reservoir Layer***. There are two options to protect the bottom of the reservoir layer from intrusion by underlying soils. The first method involves covering the bottom with nonwoven, polypropylene geotextile that is permeable, although some practitioners recommend avoiding the use of filter fabric since it may become a future plane of clogging within the system. Permeable filter fabric is still recommended to protect the excavated sides of the reservoir layer, in order to prevent soil piping. The second method is to form a barrier of choker stone and sand. In this case, underlying native soils should be separated from the reservoir base/subgrade layer by a thin 2 to 4 inch layer of clean, washed, choker stone (ASTM D 448 No. 8 stone) covered by a layer of 6 two 8 inches of course sand.

- ***Observation Well***. An observation well, consisting of a well-anchored, perforated 4 to 6 inch (diameter) PVC pipe that extends vertically to the bottom of the reservoir layer, should be installed at the downstream end of all large-scale permeable pavement systems. The observation well should be fitted with a lockable cap installed flush with the ground surface (or under the pavers) to facilitate periodic inspection and maintenance. The observation well is used to observe the rate of drawdown within the reservoir layer following a storm event.

- ***Overhead Landscaping***. Most local communities now require from 5% to 10% (or more) of the area of parking lots to be in landscaping. Large-scale permeable pavement applications should be carefully planned to integrate this landscaping in a manner that maximizes runoff treatment and minimizes the risk that sediment, mulch, grass clippings, leaves, nuts, and fruits will inadvertently clog the paving surface.

Material Specifications

Permeable pavement material specifications vary according to the specific pavement product selected. Table 5 describes general material specifications for the component structures installed beneath the permeable pavement. Note that the size of stone materials used I the reservoir and filter layers may differ depending whether the system is PC, PA or IP (see Table 2 above). A general comparison of different permeable pavements is provided in Table 6 below, but designers should consult manufacturer's technical specifications for specific criteria and guidance.

Table 5. Material Specifications for Underneath the Pavement Surface

Specification		Note
Bedding Layer	PC: None PA: 2 in. depth of No. 8 stone IP: 2 in. depth of No. 8 stone Over 3 to 4 inches of No. 57	ASTM D448 size No. 8 stone (e.g. 3/8 to 3/16 inch in size). Should be double0washed and clean and free of all fines.
Reservoir Layer	PC: No. 57 stone PA: No. 2 stone IP: No. 57 stone	ASTM D448 size No. 57 stone (e.g. 1 1/2 to 1/2 inch in size); No. 2 Stone (e.g. 3 inch to 3/4 inch in size). Depth is based on the pavement structural and hydraulic requirements. Should be double-washed and clean and free of all fines.
Underdrain	Use 4 to 6 inch diameter perforated PVC (AASHTO M 252) pipe, with 3/8-inch perforations at 6 inches on center; each underdrain installed at a minimum 0.5% slope located 20 feet or less from the next pipe (or equivalent corrugated HDPE may be used for smaller load-bearing applications). Perforated pipe installed for the full length of the permeable pavement cell, and non-perforated pipe, as needed, is used to connect with the storm drain system. T's and Y's installed as needed, depending on the underdrain configuration. Extend cleanout pipes to the surface with vented caps at the T's and Y's.	
Filter Layer	The underlying native soils should be separated from the stone reservoir by a thin, 2 to 4 inch layer of choker stone (e.g. No. 8) covered by a 6 to 8 inch layer of coarse sand (e.g. ASTM C33, 0.02-0.04 inch).	The sand should be placed between the stone reservoir and the choker stone, which should be placed on top of the underlying native soils.
Filter Fabric (optional)	Use a needled, non-woven, polypropylene geotextile with Grab Tensile Strength equal to or grater than 120 lbs (ASTM D4632), with a Mullen Burst Strength equal to or greater than 225 lbs./sq. in. (ASTM D3786), with a Flow Rate greater than 125 gpm/sq. ft. (ASTM D4491), and an Apparent Opening Size (AOS) equivalent to a US #70 or #80 sieve (ASTM D4751). The geotextile AOS selection is based on the percent passing the No. 200 sieve in "A" Soil Subgrade, using FHWA or AASHTO selection criteria.	
Observation Well	Use a perforated 4 to 6 inch vertical PVC pipe (AASHTO M 252) with a lockable cap, installed flush with the surface.	

Table 6. Different Permeable Pavement Specifications

Material	Specification	Note
Permeable Interlocking Concrete Pavers	Surface open area: 5% to 15%. Thickness: 3.125 inches for vehicles. Compressive strength: 55 Mpa. Open void fill media: aggregate	Must conform to ASTM C936 specifications. Reservoir layer required to support the structural load.
Concrete Grid Pavers	Open void content: 20% to 50%. Thickness: 3.5 inches. Compressive strength: 35 Mpa. Open void fill media: aggregate, topsoil and grass, coarse sand.	Must conform to ASTM C 1319 specifications. Reservoir layer required to support the structural load.
Plastic Reinforced Grid Pavers	Void Content: depends on fill material. Compressive strength: varies, depending on fill material. Open void fill media: aggregate, topsoil and grass, coarse sand.	Reservoir layer required to support the structural load.
Pervious Concrete	Void content: 15% to 25%. Thickness: typically 4 to 8 inches. Compressive strength: 2.8 to 28 Mpa. Open void fill media: None	May not require a reservoir layer to support the structural load, but a layer may be included to increase the storage or infiltration.

6. Regional & Special Case Design Adaptations

The design adaptations described below permit permeable pavement to be used on a wider range of sites. However, it is important not to force this practice onto marginal sites. Other runoff reduction practices are often preferred alternatives for difficult sites.

Clay Soils

In areas where the underlying soils are not suitable for complete infiltration, permeable pavement systems with underdrains can still function effectively to reduce runoff volume and nutrient loads.

- If the underlying soils have an infiltration rate of less than 0.5 in./hr., an underdrain must be installed to ensure proper drainage from the system.
- Permeable pavement should not be installed over underlying soils with a high shrink/swell potential.
- To promote greater runoff reduction for permeable pavement located on marginal soils, an elevated underdrain configuration may be used.

Cold Climate and Winter Performance

In cold climates and winter conditions, freeze-thaw cycles may affect the structural durability of the permeable pavement system. In these situations, the following design adaptations may be helpful:

- To avoid damage caused by freezing, designs should not allow water to pond in or above the permeable pavement. Ensure complete drainage of the permeable pavement system within 24 hours following a rainfall event.

- Extend the filter bed and underdrain pipe below the frost line and/or oversize the underdrain by one pipe size, to reduce the freezing potential.

- Large snow storage piles should be located in adjacent grassy areas so that sediments and pollutants in snowmelt are partially treated before they reach the permeable pavement.

- Sand should never be applied for winter traction over permeable pavement or areas of standard (impervious) pavement that drain toward permeable pavement, since it will quickly clog the system.

- When plowing plastic reinforced grid pavements, snow plow blades should be lifted 1/2 inch to 1 inch above the pavement surface to prevent damage to the paving blocks or turf. Porous asphalt (PA), pervious concrete (PC) and interlocking pavers (IP) can be plowed similar to traditional pavements, using similar equipment and settings.

- Owners should be judicious when using chloride products for deicing over all permeable pavements designed for infiltration, since the salts will most assuredly be transmitted into the groundwater. Magnesium chloride should never be used on porous concrete.

7. Construction

Experience has shown that proper installation is absolutely critical to the effective operation of a permeable pavement system.

Necessary Erosion & Sediment Controls

- All permeable pavement areas should be fully protected from sediment intrusion by silt fence or construction fencing, particularly if they are intended to infiltrate runoff.

- Permeable pavement areas should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment. Permeable pavement areas should be clearly marked on all construction documents and grading plans. To prevent soil compaction, heavy vehicular and foot traffic should be kept out of permeable pavement areas during and immediately after construction.

- During construction, care should be taken to avoid tracking sediments onto any permeable pavement surface to avoid clogging.

- Any area of the site intended ultimately to be a permeable pavement area should generally not be used as the site of a temporary sediment basin. Where locating a sediment basin on an area intended for permeable pavement is unavoidable, the invert of the sediment basin must be a minimum of 2 feet above the final design, elevation of the bottom of the aggregate reservoir course. All sediment deposits in the excavated area should be carefully removed prior to installing the sub base, base and surface materials.

Permeable Pavement Construction Sequence

The following is a typical construction sequence to properly install permeable pavement, which may need to be modified to depending on whether Porous Asphalt (PA), Pervious Concrete (PC) or Interlocking Paver (IP) designs are employed.

Step 1. Construction of the permeable pavement shall only begin after the entire contributing drainage area has been stabilized. The proposed site should be checked for existing utilities prior to any excavation. Do not install the system in rain or snow, and do not install frozen bedding materials.

Step 2. As noted above, temporary erosion and sediment (E&S) controls are needed during installation to divert stormwater away from the permeable pavement area until it is completed. Special protection measures such as erosion control fabrics may be needed to protect vulnerable side slopes from erosion during the excavation process. The proposed permeable pavement area must be kept free from sediment during the entire construction process. Construction materials that are contaminated by sediments must be removed and replaced with clean materials.

Step 3. Excavators or backhoes should work from the sides, where possible, to excavate the reservoir layer to its appropriate design depth and dimensions. This practice will reduce compaction problems. For micro-scale and small-scale pavement applications, excavating equipment should have arms with adequate extensions so they do not have to work inside the footprint of the permeable pavement area (to avoid compaction). Contractors can utilize a cell 1000 sq. ft. temporary cells with a 10 to 15 foot earth bridge in between, so that cells can be excavated from the side. Excavated material should be placed away from the open excavation so as to not jeopardize the stability of the side walls.

Step 4. The native soils along the bottom and sides of the permeable pavement system should be scarified or tilled to a depth of 3 to 4 inches prior to the placement of the filter layer or filter fabric. In large scale paving applications with weak soils, the soil subgrade may need to be compacted to 95% of the Standard Proctor Density to achieve the desired load-bearing capacity. (NOTE: This effectively eliminates the infiltration function of the installation, and it must be addressed during hydrologic design.)

Step 5. Filter fabric should be installed on the bottom and the sides of the reservoir layer. In some cases, an alternative filter layer may be warranted. Filter fabric strips should overlap down-slope by a min8imum of 2 feet, and be secured a minimum of 4 feet beyond the edge of the excavation. Where the filter layer extends beyond the edge of the pavement (to convey runoff to the reservoir layer), install an additional layer of filter fabric 1 foot below the surface to prevent sediments from entering into the reservoir layer. Excess filter fabric should not be trimmed until the site is fully stabilized.

Step 6. Provide a minimum of 2 inches of aggregate above and below the underdrains. The underdrains should slope down toward s the outlet at a grade of 0.5% or steeper. The Upgradient end of underdrains in the reservoir layer should be capped. Where an underdrain pipe is connected to a structure, there shall be no perforations within 1 foot of the structure. Ensure that there are no perforations in clean-outs and observation wells within 1 foot of the surface.

Step 7. Moisten and spread 6-inch lifts of the appropriate clean, washed stone aggregate (usually No. 2 or No. 57 stone). Place at least 4 inches of additional aggregate above the underdrain, and then compact it using a vibratory roller in static mode until there is no visible movement of the aggregate. Do not crush the aggregate with the roller.

Step 8. Install the desired depth of the bedding layer, depending on the type of pavement, as follows:

- **Pervious Concrete**: No bedding layer is used.

- **Porous Asphalt**: The bedding layer for porous asphalt pavement consists of 1 to 2 inches of clean, washed ASTM D 448 No. 57 stone. The filter course must be leveled and pressed (choked) into the reservoir base with at least four (4) passes of a 10-ton steel drum static roller.

- **Interlocking Pavers**: The bedding layer for open-jointed pavement blocks should consist of 1-1/2 to 2 inches of washed ASTM D 448 No. 8 stone. The thickness of the bedding layer is to be based on the block manufacturer's recommendation or that of a qualified professional.

Step 9: Paving materials shall be installed in accordance with manufacturer or industry specifications for the particular type of pavement.

- **Installation of Porous Asphalt**: The following has been excerpted from various documents, most notably Jackson (2007).

    - Install porous asphalt pavement similarly to regular asphalt pavement. The pavement should be laid in a single lift over the filter course. The laying temperature should be between 230^{o} F and 260^{o} F, with a minimum air temperature of 50^{o} F, to ensure that the surface does not stiffen before compaction.
    - Complete compaction of the surface course when the surface is cool enough to resist a 10-ton roller. One or two passes of the roller are required for proper compaction. More rolling could cause a reduction in the porosity of the pavement.
    - The mixing plant must provide certification of the aggregate mix, abrasion loss factor, and asphalt content in the mix. Test the asphalt mix for its resistance to stripping by water using ASTM 1664. If the estimated coating area is not above 95%, additional anti-stripping agents must be added to the mix.
    - Transport a non-petroleum release agent. The mix shall be covered during transportation to control cooling.

- Test the full permeability of the pavement surface by application of clean water at a rate of at least five gallons per minute over the entire surface. All water must infiltrate directly, without puddle formation or surface runoff.
- Inspect the facility 189 to 30 hours after a significant rainfall (greater than 1/2 inch) or artificial flooding, to determine that the facility is draining properly.

- **Installation of Pervious Concrete**. The basic installation sequence for pervious concrete is outlined by the American Concrete Institute (2008). It is strongly recommended that concrete installers successfully complete a recognized pervious concrete installers training program, such as the Pervious Concrete Contractor Certification Program offered by the National Ready Mix Concrete Association (NRMCA). The basic installation procedure is as follows:

  - Drive the concrete truck as close to the project site as possible.
  - Water the underlying aggregate (reservoir layer) before the concrete is placed, so that the aggregate does not draw moisture from the freshly laid pervious concrete.
  - After the concrete is placed, approximately 3/8 to 1/2 inch is struck off, using a vibratory screed. This is to allow for compaction of the concrete pavement.
  - Compact the pavement with a steel pipe roller. Care should be taken so that over-compaction does not occur.
  - Cut joints for the concrete to a depth of 1/4 inch.
  - The curing process is very important for pervious concrete. Cover the pavement with plastic sheeting within 20 minutes of the strike-off, and keep it covered for at least seven (7) days. Do not allow traffic on the pavement during this time period.

- **Installation of Interlocking Pavers**: The basic installation process is described in greater detail by Smith (2006).

  - Place edge restraints for open-jointed pavement blocks before the bedding layer and pavement blocks are installed. Permeable interlocking concrete pavement (IP) systems require edge restraints to prevent vehicle loads from move the paver blocks. Edge restraints may be standard KYTC curbs or gutter pans, or precast or cast-in-place reinforced concrete borders a minimum of 6 inches wide and 18 inches deep, constructed with Class A3 concrete. Edge restraints along the traffic side of a permeable pavement block system are recommended.
  - Place the No. 57 stone in a single lift. Level the filter course and compact it into the reservoir course beneath with at least four (4) passes of a 10-ton steel drum static roller until there is no visible movement. The first two (2) passes are in vibratory mode, with the final two (2) passes in static mode. The filter aggregate should be moist to facilitate movement into the reservoir course.
  - Place and screed the bedding course material (typically No. 8 stone).
  - Fill gaps at the edge of the paved areas with cut pavers or edge units. When cut pavers are needed, cut the pavers with a paver splitter or masonry saw. Cut pavers no smaller than one-third (1/3) of the full unit size.
  - Pavers may be placed by hand or with mechanical installers. Fill the joints and openings with stone. Joint openings must be filled with KYTC No. 8 stone, although KYTC No. 8P or No. 9 stone may be used where needed to fill narrower joints. Remove excess stones from the paver surface.
  - Compact and seat the pavers into the bedding course with a minimum low-amplitude 5,000-lbf, 75- to 95-Hz plate compactor.
  - Do not compact within 6 feet of the unrestrained edges of the pavers.

- o The system must be thoroughly swept by a mechanicals weeper or vacuumed immediately after construction to remove any sediment or excess aggregate.
- o Inspect the area for settlement. Any blocks that settle must be reset and re-inspected.
- o Inspect the facility 18 to 30 hours after a significant rainfall (1/2 inch or greater) or artificial flooding to determine whether the facility drains properly.

Construction Inspection

Inspections before, during and after construction are needed to ensure that permeable pavement is built in accordance with these specifications. Use detailed inspection checklists that require sign-offs by qualified individuals at critical stages of construction, to ensure that the contractor's interpretation of the plan is consistent with the designer's intent.

Some common pitfalls can be avoided by careful construction supervision that focuses on the following key aspects of permeable installation:

- Store materials in a protected area to keep them free from mud, dirt, and other foreign materials.

- The contributing drainage area should be stabilized prior to directing water to the permeable pavement area.

- Check the aggregate material to confirm that it is clean and washed, meets specifications and is installed to the correct depth.

- Check elevations (e.g., the invert of the underdrain, inverts for the inflow and outflow points, etc.) and the surface slope.

- Make sure the permeable pavement surface is even, runoff evenly spread across it and the storage bed drains within 48 hours.

- Ensure that caps are placed on the upstream (but not the downstream) ends of the underdrains.

- Inspect the pretreatment structures (if applicable) to make sure they are properly installed and working effectively.

- Once the final construction inspection has been completed, log the GPS coordinates for each facility and submit them for entry into the local BMP maintenance tracking database.

It may be advisable to diver the runoff from the first few runoff producing storms away from larger permeable pavement applications, particularly when up-gradient conventional asphalt areas drain to the permeable pavement. This can help reduce the input of fine particles that are often produced shortly after conventional asphalt is laid down.

8. Maintenance

Maintenance Agreements

Section 6 of the Ordinance No. 12-51 specifies the circumstances under which a maintenance agreement must be executed between the owner and the local program. This section sets forth inspection requirements, compliance procedures if maintenance is neglected, notification of the local program upon transfer of ownership, and right-of-entry for local program personnel.

In addition, the maintenance agreements should also note which conventional parking lot maintenance tasks would be *avoided* (e.g., sanding, re-sealing, re-surfacing, power-washing). Signs should be posted on larger parking lots to indicate their stormwater function and special maintenance requirements.

When micro-scale or small-scale permeable pavement are installed on private residential lots, homeowners will need to (1) be educated about their routine maintenance needs, (2) understand the long-term maintenance plan, and (3) be subject to a deed restriction, drainage easement or other mechanism enforceable by the qualifying local program to help ensure that the permeable pavement system is maintained and functioning. The mechanism should, if possible, grant authority for local agencies to access the property for inspection or corrective action.

Maintenance Tasks

It is difficult to prescribe the specific types or frequency of maintenance tasks that are needed to maintain the hydrologic function of permeable pavement systems over time. Most installations work reasonably well year after year with little or no maintenance, whereas some have problems right from the start.

One preventative maintenance task for large-scale applications involves vacuum sweeping on a frequency consistent with the use and loadings encountered in the parking lot. Many consider an annual, dry-weather sweeping in the spring months to be important. The contract for sweeping should specify that a vacuum sweeper be used that does not use water spray, since spraying may lead to subsurface clogging. Vacuum settings for large-scale interlocking paver applications should be calibrated so they *do not* pick up the stones between pavement blocks.

Maintenance Inspections

It is highly recommended that a spring maintenance inspection and cleanup be conducted at each permeable pavement site, particularly at large-scale applications.

Maintenance of permeable pavement is driven by annual inspections that evaluate the condition and performance of the practice. The following are suggested annual maintenance inspection points for permeable pavements:

- The drawdown rate should be measured at the observation well for three (3) days following a storm event in excess of 1/2 inch in depth. If standing water is still observed in the well after three days, this is a clear sign that clogging is a problem.

- Inspect the surface of the permeable pavement for evidence of sediment deposition, organic debris, staining or ponding that may indicate surface clogging. If any signs of clogging are noted, schedule a vacuum sweeper (no brooms or water spray) to remove deposited material. Then, test sections by pouring water from a five gallon bucket to ensure they work.

- Inspect the structural integrity of the pavement surface, looking for signs of surface deterioration, such as slumping, cracking, spalling or broken pavers. Replace or repair affected areas, as necessary.

- Check inlets, pretreatment cells and any flow diversion structures for sediment buildup and structural damage. Note if any sediment needs to be removed.

- Inspect the condition of the observation well and make sure it is still capped.

- Generally inspect any contributing drainage area for any controllable sources of sediment or erosion.

Based on inspection results, specific maintenance tasks will be triggered and scheduled to keep the facility in operating condition.

9. Community & Environmental Concerns

Compliance with the Americans with Disabilities Act (ADA). Porous concrete and porous asphalt are generally considered to be ADA compliant. Most localities also consider interlocking concrete pavers to be compliant, if designers ensure that surface openings between pavers do not exceed 1/2 inch. However, some forms of interlocking pavers may not be suitable for handicapped parking spaces. Interlocking concrete pavers interspersed with other hardscape features (e.g., concrete walkways) can be used in creative designs to address ADA issues.

Groundwater Protection. While well-drained soils enhance the ability of permeable pavement to reduce stormwater runoff volumes, they may also increase the risk that stormwater pollutants might migrate into groundwater aquifers. Designers should avoid the use of infiltration-based permeable pavement in areas known to provide groundwater recharge to aquifers used for water supply. In these source water protection areas, designers should include liners and underdrains in large-scale permeable pavement applications (i.e., when the proposed surface area exceeds 10,000 square feet).

Stormwater Hotspots. Designers should also certify that the proposed permeable pavement area will not accept any runoff from a severe stormwater hotspots are operations or activities that are known to produce higher concentrations of stormwater pollutants and/or have a greater risk of spills, leaks or illicit discharges. Examples include certain industrial activities, gas stations, public work areas, petroleum storage areas. For potential hotspots, restricted infiltration means that a minimum of 50% of the total T_v must be treated by filtering or bioretention practice prior to the permeable pavement system. For known severe hotspots, the risk of groundwater contamination from spills, leaks or discharges is so great that infiltration of stormwater or snowmelt through permeable pavement is *prohibited*.

Underground Injection Control Permits. The Safe Drinking Water Act regulates the infiltration of stormwater in certain situations pursuant to the Underground Injection Control (UIC) Program, which is administered either by the EPA or a delegated state groundwater protection agency. In general, the EPA (2008) has determined that permeable pavement installations are not classified as Class V injection wells, since they are always wider than they are deep.

Cold Climate or Winter Time Operation. Experience has shown that permeable pavement can operate properly in snow and ice conditions, and there is evidence that a permeable surface increases meltwater rates compared to conventional pavement (thereby reducing the need for deicing chemicals). However, in larger parking lot applications certain snow management practices need to be modified to maintain the hydrologic function of the permeable pavement. These include not applying sand for traction and educating snowplow operators to keep blades from damaging the pavement surface. The jointing material for interlocking concrete paver systems (typically No. 8 stone) can be spread over surface ice to increase tire traction.

Air and Runoff Temperature. Permeable pavement appears to have some value in reducing summer runoff temperatures, which can be important in watersheds with sensitive cold-water fish populations. The temperature reduction effect is greatest when runoff is infiltrated into the sub-base, but some cooling may also occur in the reservoir layer, when underdrains are used. ICPI (2008) notes that the use of certain reflective colors for interlocking concrete pavers can also help moderate surface parking lot temperatures.

Vehicle Safety. Permeable pavement is generally considered to be a safer surface than conventional pavement, according to research reported by Smith (2006), Jackson (2007) and ACI (2008). Permeable pavement has less risk of hydroplaning, more rapid ice melt and better traction than conventional pavement.

D. Vegetated Roof

1. Description

Vegetated roofs (also known as *green roofs, living roofs or ecoroofs*) are alternative roof surfaces that typically consist of waterproofing and drainage materials and an engineered growing media that is designed to support plant growth. Vegetated roofs capture and temporarily store stormwater runoff in the growing media before it is taken up by plants, which helps reduce runoff volumes, peak runoff rates, and pollutant loads on development sites.

There are two different types of vegetated roof systems: *intensive* vegetated roofs and *extensive* vegetated roofs. Intensive systems have a deeper growing media layer that ranges from 6 inches to 4 feet thick, which is planted with a wider variety of plants, including trees. By contrast, extensive systems typically have much shallower growing media (2 to 6 inches), which is planted with carefully selected drought tolerant vegetation. Extensive vegetated roofs are much lighter and less expensive than intensive vegetated roofs and are recommended for use on most development and redevelopment sites.

NOTE: This specification is intended for situations where the primary design objective of the vegetated roof is stormwater management and, unless specified otherwise, addresses extensive roof systems.

Designers may wish to pursue other design objectives for vegetated roofs, such as energy efficiency, green building or LEED points, architectural considerations, visual amenities and landscaping features, which are often maximized with intensive vegetated roof systems. However, these design objectives are beyond the scope of this specification.

Vegetated roofs typically contain a layered system of roofing, which is designed to support plant growth and retain water for plant uptake while preventing ponding on the roof surface. The roofs are designed so that water drains vertically through the media and then horizontally along a waterproofing layer towards the outlet. Extensive vegetated roofs are designed to have minimal maintenance requirements. Plant species are selected so that the roof does not need supplemental irrigation or fertilization after vegetation is initially established.

2. Performance

The overall stormwater functions of permeable pavement are shown in Table 1.

Table 7. Summary of Stormwater Functions Provided by Vegetated Roofs[1]

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	45%	60%
Channel Protection & Flood Mitigation[2]	Use the following Curve Numbers (CN) for Design Storm events: 1-year storm = 64; 2-year storm = 66; 10-year storm = 72; and the 100 year storm = 74	
[1]Sources: CWP and CSN (2008) and CWP (2007) [2] See Miller (2008), NVRC (2007) and MDE (2008)		

3. Design Table

The major design goal for Vegetated Roofs is to maximize nutrient removal and runoff volume reduction. To this end, designers may choose to use a baseline design (Level 1) or an enhanced (Level 2) design that maximizes nutrient and runoff reduction. In general, most intensive vegetated roof designs will automatically qualify as being Level 2. Table 8 lists the design criteria for Level 1 and 2 designs.

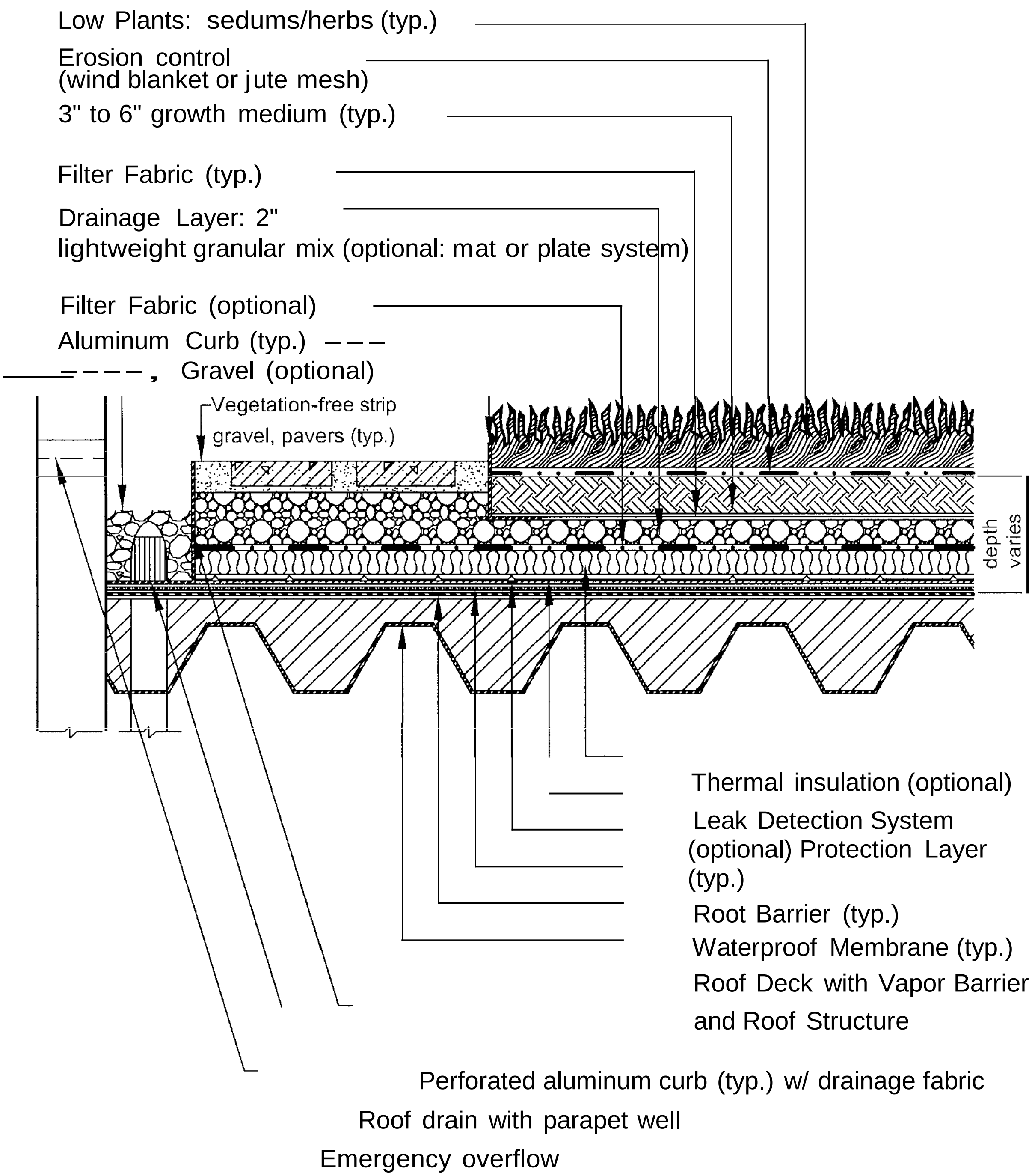
Table 8. Green Roof Design Guidance

Level 1 Design (RR:45; TP:0; TN:0)	Level 2 Design (RR: 60; TP:0; TN:0)
Tv =1.0 $(Rv)^1$ (A)/12	Tv = 1.1 $(Rv)^1$ (A)/12
Depth of media up to 4 inches	Media depth 4 to 8 inches
Drainage mats	2-inch stone drainage layer
No more than 20% organic matter in media	No more than 10% organic matter in media
All Designs: Must be in conformance to ASTM (20014) International Green (Vegetated) Roof Stds.	
[1]Rv represents the runoff coefficient for a conventional roof, which will usually be 0.914. The runoff reduction rate applied to the vegetated roof is for "capturing" the Treatment Volume (Tv) compared to what a conventional roof would produce as runoff.	

4. Typical Details

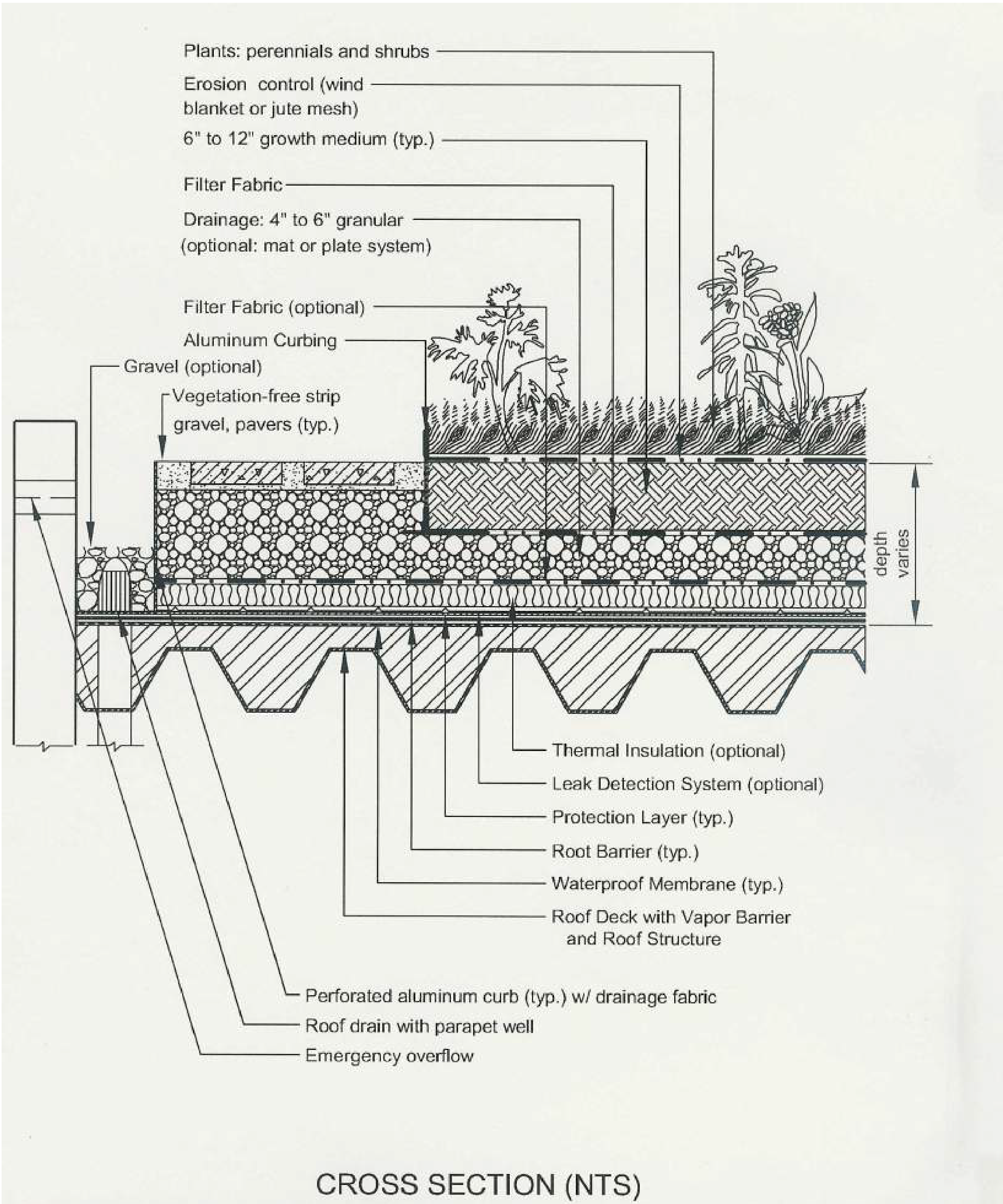
Figure 3 Photos of Vegetated Roof Cross-Sections (source: B. Hunt, NCSU)

Figure 4. Typical Section – Extensive Vegetated Roof
(Source: Northern VA Regional Commission)



CROSS SECTION VIEW (NTS)

Figure 5. Typical Section- Intensive Vegetated Roof
(Source: Northern VA Regional Commission)



5. Physical Feasibility & Design Applications

Typical applications

Vegetated roofs are ideal for use on commercial, institutional, municipal and multi-family residential buildings. They are particularly well suited for use on ultra-urban development and redevelopment sites: Vegetated roofs can be used on a variety of rooftops, including the following:

a. Non-residential buildings (e.g. commercial, industrial, institutional and transportation uses)
b. Multi-family residential buildings (e.g. condominiums or apartments)
c. Mixed-use buildings

Local regulations may also permit the use of vegetated roofs on single family residential roofs.

Common Site Constraints

Structural Capacity of the Roof. When designing a vegetated roof, designers must not only consider the stormwater storage capacity of the vegetated roof, but also its structural capacity to support the weight of the additional water. A conventional rooftop typically must be designed to support an additional 15 to 30 pounds per square foot (psf) for an extensive vegetated roof. As a result, a structural engineer, architect or other qualified professional should be involved with all vegetated roof designs to ensure that the building has enough structural capacity to support a vegetated roof.

Roof Pitch. Treatment volume (Tv) is maximize3d on relatively flat roofs (a pitch of 1 to 2%). Some pitch is needed to promote positive drainage and prevent ponding and/or saturation of the growing media. Vegetated roofs can be installed on rooftops with slopes up to 25% if baffles, grids, or strips are used to prevent slippage of the media. The effective treatment volume (Tv), however diminishes on rooftops with steep pitches (Van Woert et al, 2005).

Roof Access. Adequate access to the roof must be available to deliver construction materials and perform routine maintenance. Roof access can be achieved either by an interior stairway through a penthouse or by an alternating tread device with a roof hatch or trap door not less than 16 square feet in area and with a minimum dimension of 24 inches (NVRC, 2007). Designers should also consider how they will get construction materials up the roof (e.g., by elevator or crane), and how construction materials will be stockpiled in the confined space.

Roof Type. Vegetated roofs can be applied to most roof surfaces, although concrete roof decks are preferred. Certain roof materials, such as exposed treated wood and uncoated galvanized metal, may not be appropriate for vegetated rooftops due to pollutant leaching through the media (Clark et al, 2008).

Setbacks. Vegetated roofs should not be located near rooftop electrical and HVAC systems. A 2-foot wide vegetation-free zone is recommended along the perimeter of the roof, with a 1-foot vegetation-free zone around all roof penetrations, to act as a firebreak. The 2-foot setback may be relaxed to 1 foot for very small vegetated roof applications.

Retrofitting Green Roofs. Key feasibility factors to consider when evaluating a retrofit include the area, age and accessibility of the existing roof, and the capability of the building's owners to maintain it. Options for green roof retrofits are described in Profile Sheet RR-3 of Schueler et al (2007). The structural capacity of the existing rooftop can be a major constraint to a green roof retrofits.

Local Building Codes. Building codes often differ in each municipality, and local planning and zoning authorities should be consulted to obtain proper permits. In addition, the vegetated roof design should comply with the Kentucky Building Code with respect to roof drains and emergency overflow devices.

Construction Cost. When viewed strictly as stormwater treatment systems, vegetated roofs can cost between $12 and $25 per square foot, ranking them among the most costly stormwater practices available (Moran et al, 2004, Schueler et al 2007). These cost analyses, however, do not include life cycle cost savings relating to increased energy efficiency, higher rents due to green building scores, and increased roof longevity. These benefits over the life cycle of a vegetated roof may make it a more attractive investment. In addition, several communities may offer subsidies or financial incentives for installing vegetated roofs.

Risks of Leaky Roofs. Although well designed and installed green roofs have less problems with roof leaks than traditional roofs, there is a perception among property managers, insurers and product fabricators that this emerging technology could have a greater risk of problems. For an excellent discussion on how to properly manage risk in vegetated roof installations, see Chapter 9 in Weiler and Scholz-Barth (2009).

6. Design Criteria

Overall Sizing

Vegetated roof areas should be sized to capture a portion of the Treatment Volume (Tv). The required size of a vegetated roof will depend on several factors, including the porosity and hydraulic conductivity of the growing media and the underlying drainage materials. Site designers and planners should consult with vegetated roof manufacturers and material suppliers for specific sizing guidelines. As a general sizing rule, the following equation can be used to determine the water quality treatment storage volume retained by a vegetated roof.

$$\mathbf{Tv = (RA * D * P)/12}$$

Where Tv = storage volume (cu. ft.)
RA = vegetated roof area (sq. ft.)
D = media depth (in.)
P = media porosity (usually 0.3, but consult manufacturer specifications)

The resulting Tv can then be compared to the required Tv for the entire rooftop area (including all non-vegetated areas) to determine if it meets or exceeds the required Tv for Level 1 or Level 2 design, as shown in Table 8 above.

Guidance for selecting the appropriate post development CN for the vegetated roof of four different design storms is also provided in Table 9; in general, lower curve numbers are associated with more frequent design storms. In most cases, the maximum design storm is the 10-year event.

Structural Capacity of the Roof

Vegetated roofs can be limited by the additional weight of the fully saturated soil and plants, in terms of the physical capacity of the roof to bear structural loads. The designer should consult with a licensed structural engineer or architect to ensure that the building will be able to support the additional live and dead structural load and determine the maximum depth of the vegetated roof system and any needed structural reinforcement.

In most cases, fully-saturated extensive vegetated roofs have loads of about 15 to 25 lbs./sq. ft., which is fairly similar to traditional new rooftops (12 to 15 lbs./sq. ft.) that have a waterproofing layer anchored with stone ballast. For an excellent discussion of vegetated roof structural design issues, consult Chapter 9 in Weiler and Scholz-Bath (2009) and ASTM E-2397, *Standard Practice for Determination of Dead Loads and Live Loads Associated with Green (Vegetated) Roof Systems*

Functional Elements of a Vegetated Roof System

A vegetated roof is composed of up to eight different systems or layers, from bottom to top, that are combined together to protect the roof and maintain a vigorous cover. Designers can employ a wide range of materials for each layer, which can differ in cost, performance, and structural load. The entire system as a whole must be assessed to meet design requirements. Some manufacturers offer proprietary vegetated roofing systems, whereas in other cases, the designer or architect must assemble their own system, in which case they are advised to consult Weiler and Scholz-Barth (2009), Snodgrass and Snodgrass (2006) and Dunnett and Kingsbury (2004).

a. ***Deck Layer***. The roof deck layer is the foundation of a vegetated roof. It and may be composed of concrete, wood, metal, plastic, gypsum or a composite material. The type of deck material determines the strength, load bearing capacity, longevity and potential need for insulation in the vegetated roof system. In general, concrete decks are preferred for vegetated roofs, although other materials can be used as long as the appropriate system components are matched to them.

b. ***Waterproofing Layer***. All vegetated roof systems must include an effective and reliable waterproofing layer to prevent water damage through the deck layer. A wide range of waterproofing materials can be used, including built up roofs, modified bitumen, single-ply, and liquid-applied methods (see Weiler and Scholz-Barth, 2009 and Snodgrass and Snodgrass, 2006). The waterproofing layer must be 100% waterproof and have an expected life span as long as any other element of the vegetated roof system.

c. ***Insulation Layer***. Many vegetated rooftops contain an insulation layer, usually located above, but sometimes below, the waterproofing layer. The insulation increases the energy efficiency of the building and/or protects the roof deck (particularly for metal roofs). According to Snodgrass and Snodgrass (2006), the trend is to install insulation on the outside of the building, in part to avoid mildew problems.

d. ***Root Barrier***. The next layer of a vegetated roof system is a root barrier that protects the waterproofing membrane from root penetration. A wide range of root barrier options are described in Weiler and Scholz-Barth (2009). Chemical root barriers or physical root barriers that have been impregnated with pesticides, metals or other chemicals that could leach into stormwater runoff should be avoided.

e. ***Drainage Layer and Drainage System***. A drainage layer is the placed between the root barrier and the growing media to quickly remove excess water from the vegetation root zone. The drainage layer should consist of synthetic or inorganic materials (e.g. gravel, recycled polyethylene, etc.) that are capable of retaining water and providing efficient drainage. A wide range of prefabricated water cups or plastic modules can be used, as well as a traditional system of protected roof drains, conductors and roof leader. The required depth of the drainage layer is governed by both the required stormwater storage capacity and the structural capacity of the rooftop. ASTM E2396 and E2398 can be used to evaluate alternative material specifications.

f. ***Root-Permeable Filter Fabric***. A semi-permeable polypropylene filter fabric is normally placed between the drainage layer and the growing media to prevent the media from migrating into the drainage layer and clogging it.

g. ***Growing Media***. The next layer in an extensive vegetated roof is the growing media, which is typically 4 to 8 inches deep. The depth and composition of the media is described in the Filter Media Composition section in this Section.

h. ***Plant Cover***. The top layer of a vegetated roof consists of non-native, slow-growing, shallow-rooted perennial, succulent plants that can withstand harsh conditions at the roof surface. A mix of base ground covers (usually *Sedum* species) and accent plants can be used to enhance the visual amenity value of a green roof.

Filter Media Composition

The recommended growing media for extensive vegetated roofs is composed of approximately 80% to 90% lightweight inorganic materials, such as expanded slates, shales or clays, pumice, scoria or other similar materials. The remaining media should contain no more than 20% organic matter, normally well-aged compost. The percentage of organic matter should be limited, since it can leach nutrients into the runoff from the roof and clog the permeable filter fabric. The growing media should have a maximum water retention capacity of around 30%. It is advisable to mix the media in a batch facility prior to delivery to the roof. More information on growing media can be found in Weiler and Scholz-Barth (2009) and Snodgrass and Snodgrass (2006).

The composition of growing media for intensive vegetated roofs may be different, and it is often much greater in depth (e.g., 6 to 48 inches). If trees are included in the vegetated roof planting plan, the growing media must be at least 4 feet deep to provide enough soil volume for the root structure of mature trees.

Conveyance and Overflow

The drainage layer below the growth media should be designed to convey the 10-year storm without backing water up to into the growing media. The drainage layer should convey flow to an outlet or overflow system such as a traditional rooftop drainage system with inlets set slightly above the elevation of the vegetated roof surface. Roof drains immediately adjacent to the growing media should be boxed and protected by flashing extending at least 3 inches above the growing media to prevent clogging.

Vegetation and Surface Cover

A planting plan must be prepared for a vegetated roof by a landscape architect, botanist or other professional experienced with vegetated roofs, and it must be reviewed and approved by the local development review authority.

Plant selection for vegetated rooftops is an integral design consideration, which is governed by local climate and design objectives. The primary ground cover for most vegetated roof installations is a hardy, low-growing succulent, such as *Sedum, Delosperma, Talinum, Sempervium or Hieracium* that is matched to the local climate conditions and can tolerate the difficult growing conditions found on building rooftops (Snodgrass and Snodgrass, 2006). Winchester lies within USDA Plant Hardiness Zone 6 (AHS, 2003). A list of common vegetated roof plant species that work well in the Winchester watersheds can be found in Table 9 below.

a. Plant choices can be much more diverse for deeper intensive vegetated roof systems. Herbs, forbs, grasses, shrubs and even trees can be used, but designers should understand they have higher watering, weeding and landscape maintenance requirements.

b. The species and layout of the planting plan should reflect the location of the building, in terms of its height, exposure to wind, snow loading, heat stress, orientation to the sun, and shading by surrounding buildings. In addition, plants should be selected that are fire resistant and able to withstand heat, cold and high winds.

Table 9. Ground Covers for Vegetated Roofs in Winchester

Plant Hardiness Zone 6
Delosperma cooperi
Delosperma ecklonis var. latifolia
Hieracium villosum
Orostachys boehmeri
Sedum hispanicum
Sedum pluricaule var. ezawe
Sedum urvillei
Note: Landscape architects should choose species based on shade tolerance, ability to sow or not, foliage height, and spreading rate. See Snodgrass and Snodgrass (2006) for definitive list of green roof plants, including accent plants.

c. Designers should also match species to the expected rooting depth of the growing media, which can also provide enough lateral growth to stabilize the growing media surface. The planting plan should usually include several accent plants to provide diversity and seasonal color. For a comprehensive resource on vegetated roof plant selection, consult Snodgrass and Snodgrass (2006).

d. It is also important to note that most vegetated roof plant species will not be native to Kentucky (which is contrast to *native* plant recommendations for other stormwater practices, such as bioretention and constructed wetlands).

e. Given the limited number of vegetated roof plant nurseries in the region, designers should order plants 6 to 12 months prior to the expected planting date. It is also advisable to have plant materials contract-grown.

f. When appropriate species are selected, most vegetated roofs will not require supplemental irrigation, except for temporary irrigation during dry months as the vegetated roof is established. The planting window extends from spring to early fall, although it is important to allow plants to root thoroughly before the first killing frost.

g. Plants can be established using cuttings, plugs, mats, and, more rarely, seeding or containers. Several vendors also sell mats, rolls, or proprietary vegetated roof planting modules. For the pros and cons of each method, see Snodgrass and Snodgrass (2006).

h. The goal for vegetated roof systems designed for stormwater management is to establish a full and vigorous cover of low-maintenance vegetation that is self-sustaining and requires minimal mowing, trimming and weeding.

i. The vegetated roof design should include non-vegetated walkways (e.g., permeable paver blocks) to allow for easy access to the roof for weeding and making spot repairs.

Material Specifications

Standard specifications for North American vegetated roofs continue to evolve, and no universal material specifications exist that cover the wide range of roof types and system components currently available. The American Society for Testing and Materials (ASTM) has recently issued several overarching vegetated roof standards, which are described and referenced in Table 10 below.

Designers and reviewers should also fully understand manufacturer specifications for each system component listed, particularly if they choose to install proprietary “complete” vegetated roof systems or modules.

Table 10. Extensive Vegetated Roof Material Specifications

Material	Specification
Roof	Structural Capacity should conform to ASTM E-2397-014, *Practice for Determination of Live Loads and Dead Loads Associated with Green (Vegetated) Roof Systems*. In addition, use standard test methods ASTM E2398-014 for *Water Capture and Media Retention of Geocomposite Drain Layers for Green (Vegetated) Roof Systems*, and ASTM E2399-014 for *Maximum Media Density for Dead Load Analysis.*
Waterproof Membrane	See Chapter 6 of Weiler and Scholz-Barth (2009) for waterproofing options that are designed to convey water horizontally across the roof surface to drains or gutter. This layer may sometimes act as a root barrier.
Root Barrier	Impermeable liner that impedes root penetration of the membrane
Drainage Layer	1 to 2 inch layer of clean, washed granular material, such as ATM D448 size No. 8 stone. Roof drains and emergency overflow should be designed in accordance with VUSBC.
Filter Fabric	Needled, non-woven, polypropylene geotextile. Density (ASTM D3776) > 16 oz./sq. yd., or approved equivalent. Puncture resistance (ASTM D4833) > 220 lbs., or approved equivalent
Growth Media	80% lightweight inorganic materials and 20% organic matter (e.g. well-aged compost). Media should have a maximum water retention capacity of around 30%. Media should provide sufficient nutrients and water holding capacity to support the proposed plant materials. Determine acceptable saturated water permeability using ASTM E2396-014.
Plant Materials	Sedum, herbaceous plants, and perennial grasses that are shallow-rooted, self-sustaining, and tolerant of direct sunlight, drought, wind and frost. See ASTM E2400-06, *Guide for Selection, Installation and Maintenance of Plants for Green (Vegetated) Roof Systems*.

7. Regional & Special Case Design Adaptations

Cold Climate and Winter Performance

Several design adaptations may be needed for vegetated roofs. The most important is to match the plant species to the appropriate plant hardiness zone. In areas with colder climates, vegetated roofs should be designed so the growing media is not subject to freeze-thaw, and provide greater structural capacity to account for winter snow loads.

Acid Rain

Much of Kentucky experiences acid rain, with rainfall pH ranging from 3.9 to 4.1. Research has shown that vegetated roof growing media can neutralize acid rain (Berhage et al, 2007), but it is not clear whether acid rain will impair plant growth or leach minerals from the growing media.

8. Construction

Construction Sequence

Given the diversity of extensive vegetated roof designs, there is no typical step-by-step construction sequence for proper installation. The following general construction considerations are noted:

a. Construct the roof deck with the appropriate slope and material.

b. Install the waterproofing method, according to manufacturer's specifications.

c. Conduct a flood test to ensure the system is water tight by placing at least 2 inches of water over the membrane for 48 hours to confirm the integrity of the waterproofing system.

d. Add additional system components (e.g., insulation, root barrier, drainage layer and interior drainage system, and filter fabric), taking care not to damage the waterproofing. Drain collars and protective flashing should be installed to ensure free flow of excess stormwater.

e. The growing media should be mixed prior to delivery to the site. Media should be spread evenly over the filter fabric surface. The growing media should be covered until planting to prevent weeds from growing. Sheets of exterior grade plywood can also be laid over the growing media to accommodate foot or wheelbarrow traffic. Foot traffic and equipment traffic should be limited over the growing media to reduce compaction.

f. The growing media should be moistened prior to planting, and then planted with the ground cover and other plant materials, per the planting plan, or in accordance with ASTM E2400. Plants should be watered immediately after installation and routinely during establishment.

g. It generally takes 12 to 18 months to fully establish the vegetated roof. An initial fertilization using slow release fertilizer (e.g., 14-14-14) with adequate minerals is often needed to support growth. Temporary watering may also be needed during the first summer, if drought conditions persist. Hand weeding is also critical in the first two years (see Table 10.1 of Weiler and Scholz-Barth, 2009, for a photo guide of common rooftop weeds).

h. Most construction contracts should contain a Care and Replacement Warranty that specifies a 75% minimum survival after the first growing season of species planted and a minimum effective vegetative ground cover of 75% for flat roofs and 90% for pitched roofs.

Construction Inspection

Inspections during construction are needed to ensure that the vegetated roof is built in accordance with these specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction and confirm that the contractor's interpretation of the plan is consistent with the intent of the designer and/or manufacturer.

An experienced installer should be retained to construct the vegetated roof system. The vegetated roof should be constructed in sections for easier inspection and maintenance access to the membrane and roof drains. Careful construction supervision is needed during several steps of vegetated roof installation, as follows:

a. During placement of the waterproofing layer, to ensure that it is properly installed and watertight;

b. During placement of the drainage layer and drainage system;

c. During placement of the growing media, to confirm that is meets the specifications and is applied to the correct depth;

d. Upon installation of plants, to ensure they conform to the planting plan;

e. Before issuing use and occupancy approvals; and

f. At the end of the first or second growing season, to ensure desired surface cover specified in the Care and Replacement Warranty has been achieved.

9. Maintenance

Maintenance Inspections and Ongoing Operations

A vegetated roof should be inspected twice a year during the growing season to assess vegetative cover, and to look for leaks, drainage problems and any rooftop structural concerns (see Table 11 below). In addition, the vegetated roof should be hand-welded to remove invasive or volunteer plants, and plants/media should be added to repair bare areas (refer to ASTM E2400). Many practitioners also recommend an annual application of slow release fertilizer in the first five years after the vegetated roof is installed.

If a roof leak is suspected, it is advisable to perform an electric leak survey (i.e., Electrical Field Vector Mapping) to pinpoint the exact location, make localized repairs, and then reestablish system components and ground cover.

The use of herbicides, insecticides, and fungicides should be avoided, since their presence could hasten degradation of the waterproof membrane. Also, power-washing and other exterior maintenance operations should be avoided so that cleaning agents and other chemicals do harm the vegetated roof plant communities.

Written documentation between the local inspection authority and the property owner or manager should be required, in order to ensure adequate notification or authorization for access to conduct inspections.

Table 11. Typical Maintenance Activities Associated with Green Roofs

Activity	Schedule
- Water to promote growth and survival. - Inspect the vegetated roof and replace any dead or dying vegetation.	As Needed (Following Construction)
- Inspect the waterproof membrane for leaking or cracks. - Weeding to remove invasive plants. - Inspect roof drains, scuppers and gutters to ensure they are not overgrown or have organic matter deposits. Remove any accumulated organic matter or debris.	Semi-Annually
- Annual fertilization (first five years).	Annually

E. Manufactured BMP Systems

1. Description

There are two categories for this section. The first includes small structures for the purpose of collecting rainfall runoff for specific uses. Storage techniques may include cisterns, underground tanks, above-ground vertical storage tanks, rain barrels, rainwater harvesting or other similar systems. These techniques are for residential and small size commercial properties where the devices are placed for collecting water to provide additional sources to water plants, lawns, etc.

The second category is devoted to larger systems for non-residential designs. The rest of this document addresses those treatments.

The Manufactured BMP Systems mentioned in this standard are meant only to provide a frame of reference. The Winchester Planning Commission acknowledges that there may be additional Manufactured BMP Systems available that are not presented in this handbook. Presentation of the following products does not preclude the use of other available systems, nor does it constitute endorsement of any one system.

2. Definition

A Manufactured BMP system is a structural measure which is specifically designed and sized by the manufacturer to intercept stormwater runoff and prevent the transfer of pollutants downstream.

3. Purpose

Manufactured BMP systems are used solely for water quality enhancement in urban and ultra-urban areas where surface BMPs are not feasible. These are flow-through structures in that the design rate of flow into the structure is regulated by the inflow pipe or structure hydraulics as opposed to traditional BMPs designed to store the entire water quality volume. When the maximum design inflow is exceeded, the excess flow bypasses the structure or flows through the structure and bypasses the treatment with minimal turbulence and resuspension of previously trapped pollutants. Structures that rely on the inflow pipe to regulate the rate of flow into the treatment chamber typically cause stormwater to back up into the upstream conveyance system or associated storage facility. Depending on the type of structure and the configuration of the conveyance system, this excess flow will either bypass the treatment chamber or be attenuated and allowed to flow through the treatment chamber at the regulated rate.

Pollutant removal efficiencies presented in this standard are based upon currently available studies. Removal efficiencies are very variable, however, and highly dependant on storm size, influent pollutant concentrations, and rainfall intensity. Several monitoring studies are going and many products may be modified to improve pollutant removal performance. Therefore, the removal efficiencies presented may be subject to change. As more of these products are built and additional monitoring studies track their performance of these systems as water quality BMPs will become better established.

The discussion of each of the manufactured BMP systems presented in this standard includes the target pollutants for which the BMP was designed. Many of these systems were developed to remove a specific range of particulate pollutants, or total suspended solids (TSS), from stormwater runoff. Others, such as the filtering structures discussed below, were developed to capture a broad range of pollutants. The use of phosphorus as the target or "keystone" pollutant is recommended when using the performance-based water quality criteria to select a BMP. However, for stormwater "hot-spots", or areas from which a high concentration of urban pollutants can be expected, the primary pollutant of concern may be hydrocarbons (oil and grease), metals, or other compounds besides nutrients. Manufactured BMPs generally provide effective spill containment for material handling and transfer areas such as automobile fuel and service areas, and other urban hot-spots. Careful analysis of the proposed development project and intended uses help in selecting an appropriate BMP.

The manufactured BMP systems which have been evaluated at this time can be categorized as either:

- Hydrodynamic Structures – (Stormceptor, Vortechs Stormwater Treatment System, Downstream defender, BaySaver Separation System)

- Filtering Structures – (StormFilter, StormTreat System)

Hydrodynamic Structures

Hydrodynamic structures are those which rely on settling or separation of pollutants from the runoff. The hydrodynamic structures can be generally categorized as Chambered Separation Structures or Swirl Concentration Structures.

Chambered Separation Structures rely on settling of particles and, to a lesser degree centrifugal forces to remove pollutants from stormwater. These structures contain an upper bypass chamber and is channeled through a downpipe into the lower storage/separation, or treatment, chamber. The downpipe is configured such that when the rate of inflow into the structure exceeds its operating capacity, the flow simply "jumps" over the downpipe, bypassing the lower treatment chamber.

The outlet configuration of the downpipe forces the water to enter the lower treatment chamber in one direction, which encourages circular flow. This circular flow, as well as gravitational settling, traps the sediments and other particulate pollutants (as well as any pollutants which adsorb to the particulates) at the bottom of the chamber. The water leaves the treatment chamber through a return or riser pipe. The return or riser pipe extends below the water surface within the lower treatment chamber in order to prevent trapped floatables from exiting the structure. The hydraulic gradient of the structure prevents the inflow and the discharge from creating turbulent conditions within the lower treatment chamber. This feature helps prevent the resuspension of previously trapped particulate pollutants during high flow, or "bypass", storm events.

Swirl Separation Structures are characterized by an internal component that creates a swirling motion. This is typically accomplished by a tangential inflow location within a cylindrical chamber. The "swirl" technology is similar, if not identical to, the technology used in treating combined sewer overflows. The solids settle to the bottom and are trapped by the swirling flow path. Additional compartments or chambers act to trap oil and other floatables.

There is no bypass for larger flows prior to the treatment or swirl chamber. The larger flows simply pass through the structure untreated. However, due to the swirling motion within the structure, larger flows do not resuspend previously trapped particulates.

Filtering Structures

Filtering structures are characterized by a sedimentation chamber and a filtering chamber. The manufactured systems presented in this standard, the StormFilter and the StormTreat System, use very different configuration and filtering media. Both contain a primary settling chamber to remove heavy solids, floatable, oil, etc. The StormTreat System then directs the water through a series of screens and geotextile filters and into a containerized wetland system with soil and aquatic plants. The StormFilter, on the other hand, uses any one or combination of filter media cartridges. The filter media selected is typically based on the target pollutants to be removed or the desired efficiency. The number of cartridges is dependent on the project size, desired removal efficiency, and peak flow rates.

4. Conditions Where Practice Applies

Drainage Area

The sizing criteria for each manufactured BMP system should be obtained from the manufacturer to insure that the latest design and sizing criteria is used. In general, the flow-through configuration and treatment limitations will force drainage areas to remain relatively small.

Development Conditions

Manufactured BMP systems are ideal for use in ultra-urban areas since they are space efficient. Most of these systems can be placed under parking lots, or simply installed as a manhole junction box or inlet structure. Since other BMPs, such as sand filters and bioretention structures, are also suited for urban development, the designer must consider the type of pollutant load anticipated from the site, as well as other site factors, such as maintenance, aesthetics, etc., and select an appropriate BMP. In general, hydrodynamic and gross pollutant separate are recommended for the following:

- Pretreatment for other BMPs;
- Retrofit of existing development or Redevelopment; and
- Ultra-urban development areas.

Filtering structures are generally recommended for use in applications. In all cases, Manufactured BMP systems must be designed in accordance with the manufacturer's specifications.

5. Planning Considerations

The most significant feature of manufactured BMP systems is their small size and the ability to use them as retrofits underneath improved area. (It should be noted that other BMPs, such as sand filters, can also be placed under improved areas.) The fact these BMPs are underground requires the designer to locate an acceptable outfall or improved drainage system for discharging runoff. The vertical elevation of the inflow and outflow pipe connections may be critical to the choice, or design, of the BMP.

Overflow

All the manufactured BMP systems presented in this standard are flow-through structures that can be located on storm drainage systems that drain improved areas. Most manufactured systems, however, are designed to treat the first flush, or the water quality volume, of runoff. Therefore, an overflow, or bypass, is needed to divert flow that exceeds the design rate, or a storage facility is needed to store the appropriate volume of runoff for treatment. The discussion of each manufactured system will include the overflow or bypass provisions provided, or required.

6. Design Criteria

The design criteria for manufactured BMP systems should be obtained from the manufacturer. All designs should be reviewed by the manufacturer to insure that the system is appropriately designed and sized.

7. Maintenance and Inspections

All manufactured BMP systems require regular inspection and maintenance to maximize their effectiveness. The specific maintenance requirements and schedule should be prepared by the manufacturer and signed by the owner/operator. It should be noted that the frequency of maintenance is not only dependent on the type of manufactured system chose, but also the pollutant load from the contributing drainage area. The frequency of maintenance required may vary from after any major storm, to once a month, to up to twice a year.

A maintenance log should be required to keep track of routine inspections and maintenance. A maintenance log can also help facility owners establish the effectiveness of certain "housekeeping" practices, such as street sweeping. Failure to maintain any stormwater BMP may result in reduced efficiency, resuspension or mixing of previously trapped pollutants, or clogging of the system.

Many suppliers of manufactured BMP systems recommend service contracts to ensure that maintenance occurs on a regular basis. Lack of maintenance is widely acknowledged to be the most prevalent cause of failure of both structural and non-structural BMPs.

Another consideration with manufactured BMP systems is the possible contamination and toxicity of trapped sediments, especially in areas considered to be stormwater hot-spots. Care must be taken in the disposal of sediment that may contain accumulations of heavy metals. Sediment testing is recommended prior to sediment removal to assure proper disposal. Experience in other jurisdictions has indicated reluctance on the part of waste water utility operators to accept the pump-out material from these structures. Landowners are encouraged to research the disposal options as part of the planning process prior to selecting the BMP.

F. Roof Downspout System

1. Definition

A roof downspout system is an infiltration trench practice intended only for infiltrating rooftop runoff transported to the trench via roof downspout drains.

2. Purpose

The purpose of a roof downspout system is to provide water quality enhancement of rooftop runoff via infiltration of the water quality volume into the surrounding soils. This facility is not designed to infiltrate other surface water that could transport sediment or pollutants, such as from paved areas.

3. Conditions Where Practice Applies

Roof downspout systems may be used in any situation where disposing of rooftop runoff without direct connections to existing drainage systems or BMPs is acceptable and advantageous. Because of their small size, they are well suited for retrofitting in areas where runoff control of existing or new rooftop areas associated with building additions becomes necessary. As part of a low impact development strategy, roof downspout systems effectively disconnect the rooftop imperviousness from the drainage system which helps reduce the stormwater impact of the development. Use of roof downspout systems (or infiltration trenches in general) in residential areas should be used with caution due to concern for the potential lack of inspections and maintenance, and ultimate failure and abandonment of the facility.

4. Planning Considerations

The planning considerations for roof downspout systems are the same as those for infiltration trenches (see Section 7). The drainage area is limited to the rooftop areas of residential and/or commercial structures.

5. Design Criteria

This section provides recommendations and minimum criteria for the design of roof downspout systems intended to comply with the runoff quality requirements of the City of Winchester.

The design criteria for roof downspout systems are the same as those for infiltration trenches with the following exceptions and/or additions:

Distance from Structures

Roof downspout systems should be a minimum of 10 feet down-slope from any structure or property line, and 30 feet from any septic tank or drain field.

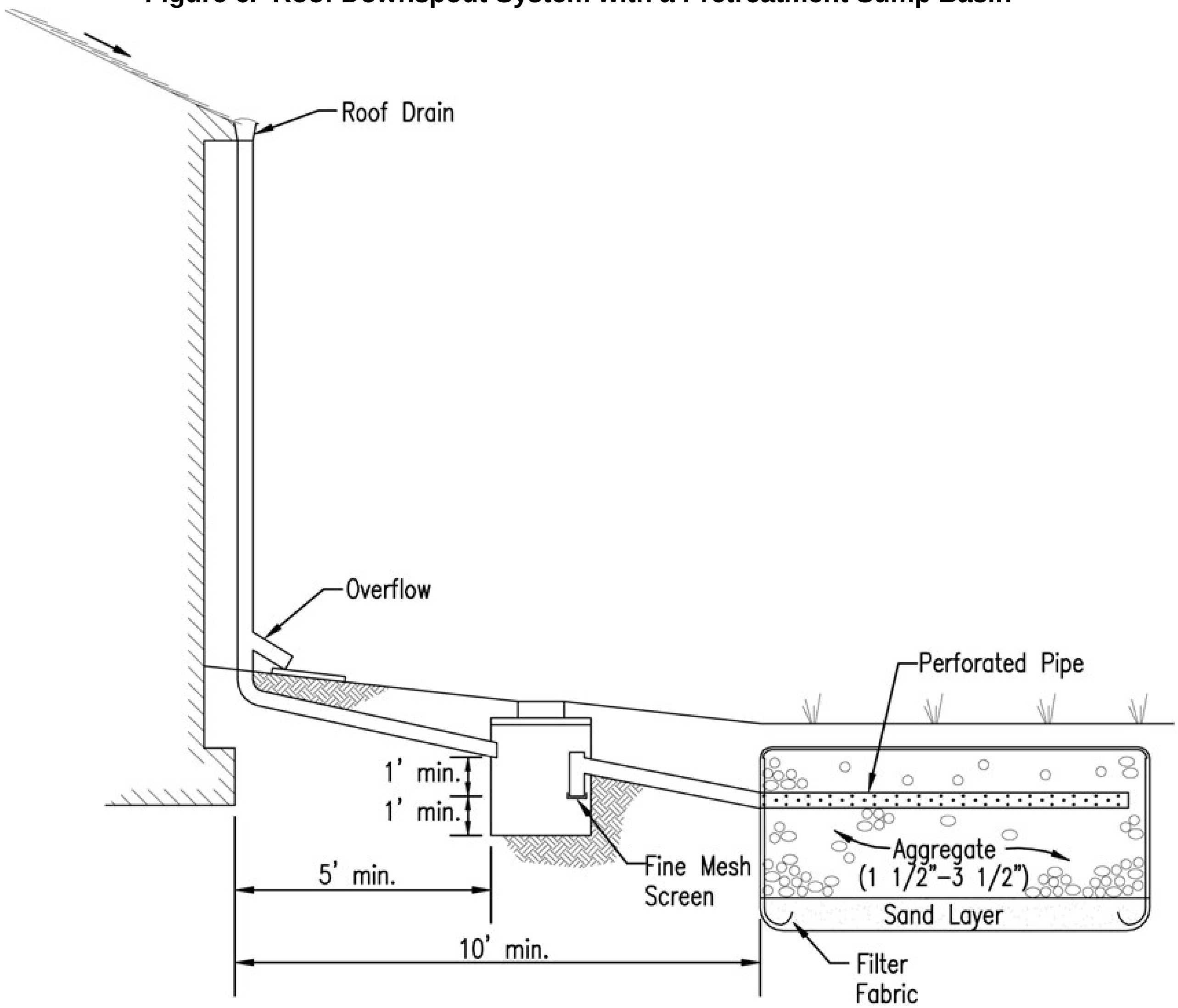
Runoff Pre-Treatment

Gutters should be fitted with mesh screens to prevent leaf litter and other debris from entering the system in areas where there is tree cover. The expected growth of newly planted trees should be considered. A pretreatment settling basin as shown in Figure 6 should be provided on all roof downspout systems.

Overflow

An overflow outlet should be provided on the downspout at the surface elevation to allow flow to bypass the infiltration facility when it is full or clogged (see Figure 6 below.) Adequate surface drainage away from the structure should be provided according to appropriate building codes.

Figure 6. Roof Downspout System with a Pretreatment Sump Basin



6. Construction Specifications

   The construction specifications for roof downspout systems are the same as those for infiltration trenches (see Section 1).

7. Maintenance and Inspection Guidelines

   Maintenance procedures are identical for those of an infiltration trench. Since these facilities are installed on individual buildings and other structures, provisions need to be made for their maintenance, especially when they are installed on single family dwellings. When flow is observed to be bypassing the facility, the system has clogged and should be evaluated for rehabilitation.

8. Design Procedures

   The following design procedure represents a generic list of steps typically required for the design of a roof downspout system.

   a. Determine if the anticipated development conditions and rooftop areas are appropriate for a roof downspout system.
   b. Determine if the soils (permeability, bedrock, water table, etc.) and topographic conditions (slopes, building foundations, etc.) are appropriate for a roof downspout system.
   c. Locate the roof downspout system on the site within site topographic constraints.
   d. Determine the roof area for each roof downspout system and calculate the required water quality volume.
   e. Design the roof downspout system:
      - design infiltration rate, $f_d = 0.5$ f
      - max. Storage time $T_{max} = 48$ hours
      - max. Storage depth, d_{max}
      - stone backfill of clean aggregate (1.5" to 3.5" diameter) – KYTC No. 1 Open-graded Course Aggregate
      - sand layer on trench bottom (8 inches)
      - runoff pretreatment – concentrated input: gutter screens, settling basin
      - filter fabric on trench sides and top (not on trench bottom) keyed into trench
      - overflow channel or large storm bypass
      - observation well
   f. Provide material specifications.
   g. Provide sequence of construction.
   h. Provide maintenance and inspection requirements.

G. Vegetated Filter Strip

1. Definition

   A vegetated filter strip is a densely vegetated strip of land engineered to accept runoff from upstream development as overland sheet flow. It may adopt any naturally vegetated form, from grassy meadow to small forest (See Figure 7 page 63).

2. Purpose

   The purpose of a vegetated filter strip is to enhance the quality of stormwater runoff through filtration, sediment deposition, infiltration and absorption.

   A vegetated filter strip may be used as a pretreatment BMP in conjunction with a primary BMP. This reduces the sediment and particulate pollutant load that could reach the primary BMP, which, in turn, reduces the BMP's maintenance costs and enhances its pollutant removal capabilities.

   Vegetated filter strips rely on their flat cross-slope and dense vegetation to enhance water quality. Their flat cross-slope assures that runoff remains as sheet flow while filtering through the vegetation. There is limited ponding or storage associated with these BMPs, so they are ineffective for reducing peak discharges. Vegetated filter strips may lower runoff velocities and, sometimes, runoff volume. Typically, however, the volume reduction is not adequate for controlling stream channel erosion or flooding.

3. Conditions Where Practice Applies

Drainage Area

A vegetated filter strip should not receive large volumes of runoff since such flows tend to concentrate and form channels. Channels within a filter strip allow runoff to short-circuit the BMP, rendering it ineffective. Therefore, the contributing drainage area for a vegetated filter strip is based on the linear distance behind it that is maintained as sheet flow. Runoff is assumed to change from sheet flow to shallow concentrated flow after traveling 150 feet over pervious surfaces and 75 feet over impervious surfaces (Center for Watershed Protection, 1996). A level spreader may be used to convert shallow concentrated flow from larger areas back to sheet flow before it enters the filter strip. In any event, the contributing drainage area should never exceed five acres.

Development Conditions

Vegetated filter strips have historically been used and proven successful on agricultural lands, primarily due to their low runoff volumes. In urban settings, filter strips are most effective in treating runoff from isolated impervious areas such as rooftops, small parking areas, and other small impervious area. Filer strips should not be used to control large impervious areas.

Since vegetated filter strips should not be used to treat concentrated flows, they are suitable only for low to medium-density development (16-21% impervious), or as a pretreatment component for structural BMPs in higher density developments.

4. Planning Considerations

Site Conditions

The following site conditions should be considered when selecting a vegetated filter strip as a water quality BMP:

a. **Soils** – Vegetated filter strips should be used with soils having an infiltration rate of 0.52 inches/hour; (sandy loam, loamy sand). Soils should be capable of sustaining adequate stands of vegetation with minimal fertilization.

b. **Topography** – Topography should be relatively flat to maintain sheet flow conditions. Filter strips function best on slopes 5 percent or less.

c. **Depth of Water Table** – A shallow or seasonally high groundwater table will inhibit the opportunity for infiltration. Therefore, the lowest elevation in the filter strip should be at least 2 feet above the water table.

If the soil's permeability and/or depth of water table are unsuitable for infiltration, the filer strip's primary function becomes the filtering and settling of pollutants. A modified design may be provided to allow ponding of the water quality volume at the filter's downstream end. The ponding area may be created by constructing a small permeable berm using a select soil mixture. The maximum ponding depth behind the berm should be 1 foot.

Water Quality Enhancement

Vegetated filer strips are occasionally installed as a standard feature in residential developments. To be used as a water quality BMP, however, filter strips must comply with certain design criteria. Vegetated filter strip designs should include specific construction, stabilization, and maintenance specifications. The most significant requirement is for runoff to be received as sheet flow. Certain enhancements may be necessary, such as added vegetation and grading specifications, or the use of level spreaders, to ensure that runoff enters the filter strip as sheet flow.

Sediment Control

A natural area that is designed to serve as a vegetated filter strip should not be used for temporary sediment control. Sediment deposition may have significant impacts on the existing vegetation. If a vegetated filter strip is proposed in a natural area marginally acceptable for use, due to topography or existing vegetation, then it may be appropriate to use the filter strip for temporary sediment control. However, when the project is completed, the sediment accumulation should be removed, the area should be regraded to create the proper design conditions (sheet flow), and the strip should be re-stabilized per the landscaping plan.

5. Design Criteria

This section provides recommendations and minimum design criteria for vegetated filter strips intended to enhance water quality. It is the designer's responsibility to decide which criteria are applicable to the each facility and to decide if any additional design elements are required. The designer must also provide for the long-term functioning of the BMP.

Hydrology

The hydrology of a filter strip's contributing drainage area shall be developed.

Filter Strip Geometry

Compliance with the following parameters will result in optimal filter strip performance (NVPDC):

a. **Length** – The minimum length of a filter strip should be 25 feet, at a maximum slope of 2 percent. The length should increase by 4 feet for any 1 percent increase in slope. The optimum filter strip length is 80 to 100 feet.

b. **Width** – The width of the filter strip (perpendicular to the slope) should be equal to the width of the contributing drainage area. When this is not practical, a level spreader should be used to reduce the flow width to that of the filter strip. The level spreader's width will determine the depth of flow and runoff velocity of the stormwater as it passes over the spreader lip and into the filter strip. A wide lip will distribute the flow over a longer level section, which reduces the potential for concentrated flow across the filter.

c. **Slope** – The slope of the filter strip should be as flat as possible while allowing for drainage. Saturation may occur when extremely flat slopes are used.

Level Spreader

A level spreader should be provided at the upper edge of a vegetated filter strip when the width of the contributing drainage area is greater than that of the filter (see Figure 8 page 64). Runoff may be directed to the level spreader evenly and flows over the level lip as uniformly as possible. The level spreader should extend across the width of the filter, leaving only 10 feet open on each end.

Pervious Berm

To force ponding in a vegetated filter strip, a pervious berm may be installed. It should be constructed using a moderately permeable soil such as ASTM ML, SM, or SC. Soils meeting USDA sandy loam or loamy sand texture, with a minimum of 25% clay, may also be used. Additional loam should be used on the berm (± 25%) to help support vegetation. An armored overflow should be provided to allow larger storms to pass without overtopping the berm. Maximum ponding depth behind a pervious berm is 1 foot.

Vegetation

A filter strip should be densely vegetated with a mix of erosion resistant plant species that effectively bind the soil. Certain plant types are more suitable than others for urban stormwater control. The selection of plants should be based on their compatibility with climate conditions, soils, and topography and their ability to tolerate urban stresses from pollutants, variable soil moisture conditions and ponding fluctuations.

A filter strip should have at least two of the following vegetation types:

- deep-rooted grasses, ground covers, or vines
- deciduous and evergreen shrubs
- under- and over-story trees

Native plant species should be used is possible. Non-native plants may require more care to adapt to local hydrology, climate, exposure, soil and other conditions. Also, some non-native plants may become invasive, ultimately choking out the native plant population. This is especially true for non-native plants used for stabilization.

Newly constructed stormwater BMPs will be fully exposed for several years before the buffer vegetation becomes adequately established. Therefore, plants which require full shade, are susceptible to winter kill or are prone to wind damage should be avoided.

Plant materials should conform to the American Standard for Nursery Stock, current issue, as published by the American Association of Nurserymen. The botanical (scientific) name of the plant species should be according to the landscape industry standard nomenclature. All plant material specified should be suited for USDA Plant Hardiness Zones 6 or 7 (see Figure 9, page 66).

6. Construction Specifications

Overall, widely accepted construction standards and specifications, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers, should be followed where applicable to construct a vegetated filter strip. The specifications should also satisfy all requirements of the local government.

Sequence of Construction

Vegetated filter strip construction should be coordinated with the overall project construction schedule. Rough grading of the filter strip should <u>not</u> be initiated until adequate erosion controls are in place.

Soil Preparation

Topsoil should be 8 inches thick, minimum. If grading is necessary, the topsoil should be removed and stockpiled. If the subsoil is either highly acidic or composed of heavy clays, ground dolomite limestone should be applied at an appropriate rate based on soil and slope conditions.

Subsoil should be tilled to a depth of at least 3 inches to adequately mix in soil additives and to permit bonding of the topsoil to the subsoil. If the existing topsoil is inadequate to support a densely vegetated filter strip, then suitable material should be imported. Proper specifications for imported topsoil should include the following:

a. The USDA textural triangle classification.
b. Requirements for organic matter content (not less than 1.5% by weight), pH (6 yo 7.5), and soluble salt (not greater than 500 parts per million).
c. Placement thickness and compaction. Topsoil should be uniformly distributed and compacted, and should have a minimum compacted depth of 6 to 8 inches.

7. Maintenance and Inspection Guidelines

Vegetated filter strips require regular maintenance. Field studies indicate that these BMPs usually have short life spans because of lack of maintenance, improper location, and poor vegetative cover.

The following maintenance and inspection guidelines are NOT all-inclusive. Specific facilities may require other measures not discussed here. It is the designer's responsibility to decide if additional measures are necessary.

Filter strips should be inspected regularly for gully erosion, density of vegetation, damage from foot or vehicular traffic, and evidence of concentrated flows circumventing the strip. The level spreader should also be inspected to verify that it is functioning as intended.

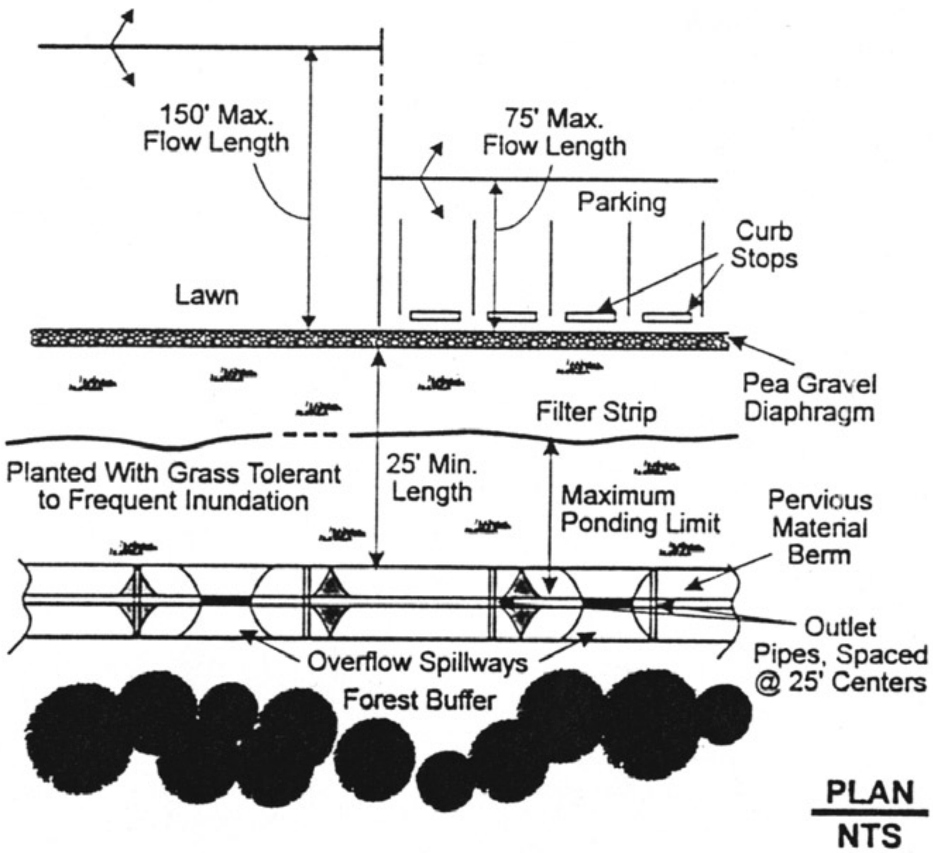
Inspections are critical during the first few years to ensure that the strip becomes adequately established. Maintenance is especially important during this time and should include watering, fertilizing, re-seeding or planting as needed.

Once a filter strip is well established and functioning properly, periodic maintenance, such as watering, fertilizing and spot repair, may still be necessary. However, fertilization efforts should be minimized. Natural selection allows certain species (usually native plants) to thrive while others decline. Excessive fertilization and watering to maintain individual plantings may prove costly, especially in abnormally dry or hot seasons. Overseeding and replanting should be limited to those species which have exhibited the ability to thrive.

To increase the functional longevity of a vegetated filter strip, the following practices are recommended:

- Regular removal of accumulated sediment,
- periodic reestablishment of vegetation in eroded areas or areas covered by accumulated sediment,
- periodic weeding of invasive species or weeds, and
- periodic pruning of woody vegetation to stimulate growth

Figure 7. Vegetated Filter Strip



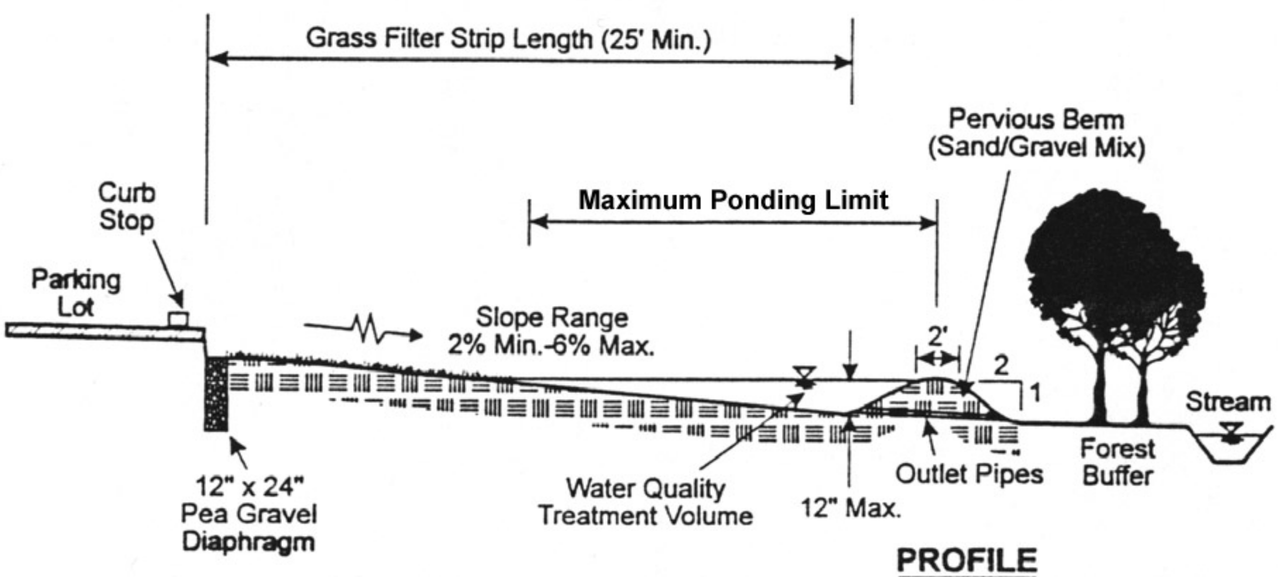


Figure 8. Level Spreader

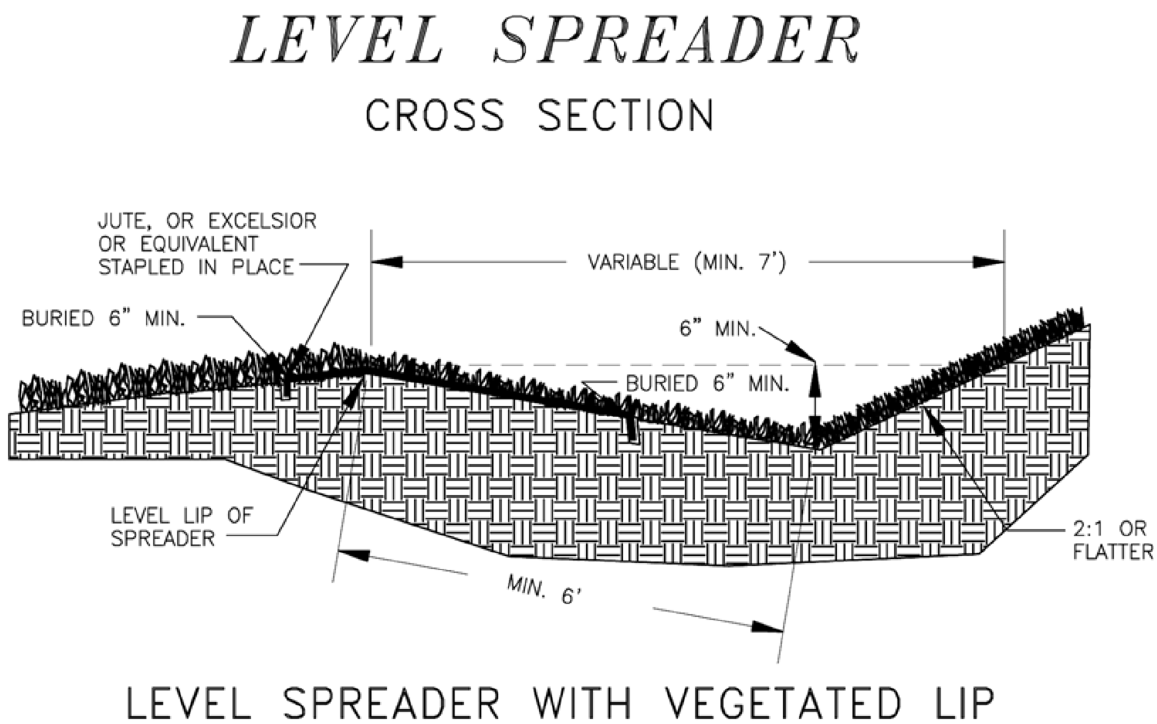
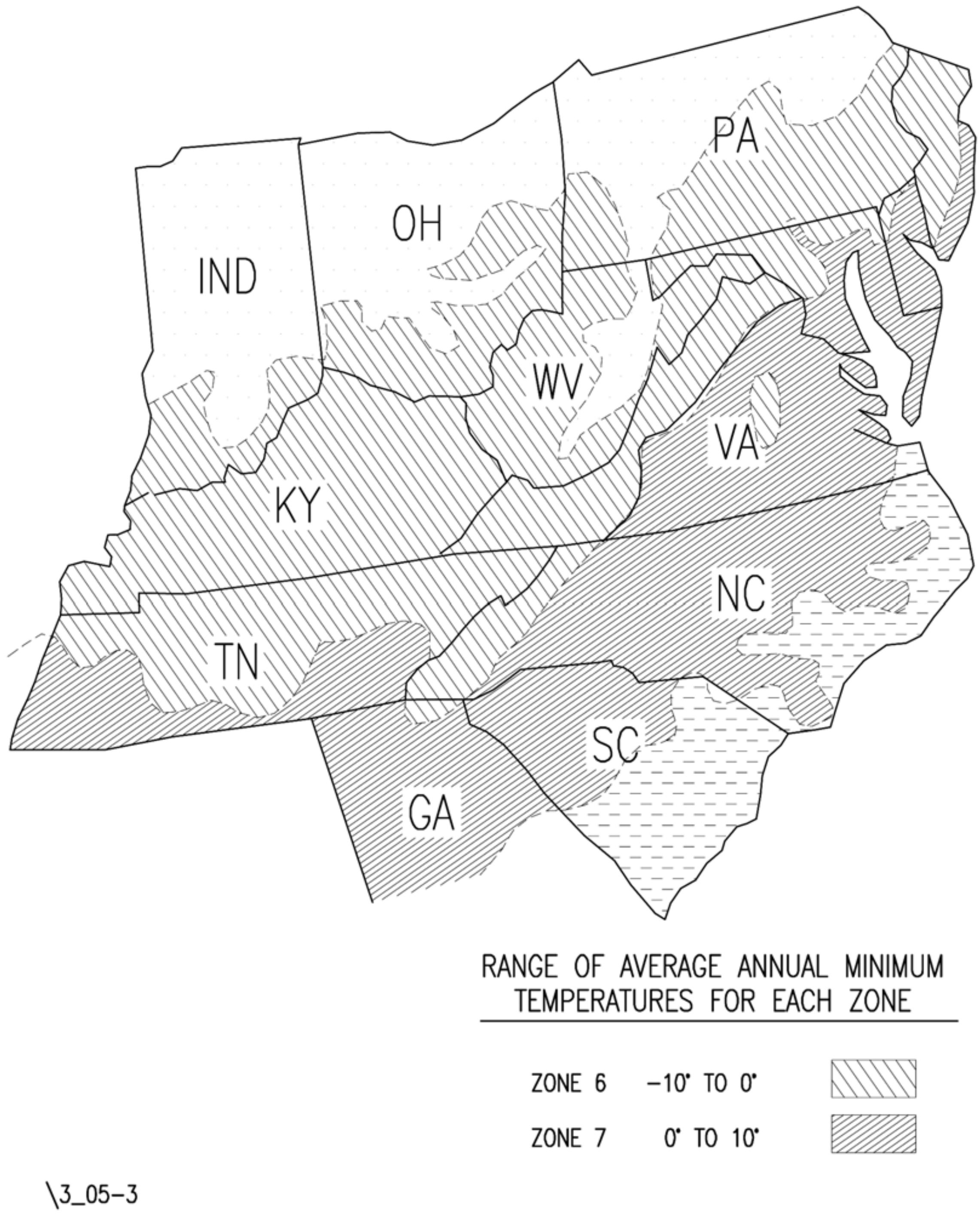


Figure 9. USDA Plant Hardiness Zones



H. Grassed Swale

1. Definition

A grassed swale is a broad and shallow earthen channel vegetated with erosion resistant and flood-tolerant grasses. Check dams are strategically placed in the swale to encourage ponding behind them. Figure 10, page 67, presents a grassed swale designed to hold small pockets of water behind each check dam. The water slowly drains through small openings in the check dam and/or infiltrates into the ground. Slow channel velocities allow the vegetation to filter out sediments and other particulate pollutants from the runoff and increases the opportunity for infiltration and adsorption of soluble pollutants.

A water quality swale is a broad and shallow earthen channel vegetated with erosion resistant and flood tolerant grasses, and underlain by an engineered soils media directly under the swale, with an underdrain. This design may be used in areas where the soils are not conducive to infiltration, or in developments where the swale is constructed beside a roadway using fill or compacted soils.

2. Purpose

The purpose of grassed swales and water quality swales is to convey stormwater runoff at a non-evasive velocity in order to enhance its water quality through infiltration, sedimentation, and filtration. Check dams are used within the swale to slow the flow rate and create small, temporary ponding areas. A water quality swale is appropriate where greater pollutant removal efficiency is desired.

Water Quality Enhancement

Grassed swales and water quality swales remove pollution through sedimentation, infiltration, and filtration. Water quality swales are specifically engineered to filter stormwater through an underlying soil mixture while grass swales are designed to slow the velocity of flow to encourage settling and filtering through the grass lining. Vegetation filters out the sediments and other particulate pollutants from the runoff and increases the opportunity for infiltration and adsorption of soluble pollutants. The flow rate becomes a critical design element, since runoff must pass through the vegetation slowly for pollutant removal to occur. Monitoring of grassed swales has indicated low to moderate removal of soluble pollutants (phosphorous and nitrogen) and moderate to high removal of particulate pollutants.

Flood Control

Grassed swales and water quality swales will usually provide some peak attenuation depending on the storage volume created by the check dams. However, flood control should be considered a secondary function of grassed swales since the required storage volume for flood control is usually more than they can provide.

Channel Erosion Control

Grassed swales and water quality swales may also provide some benefits relative to channel erosion by reducing the peak rate of discharge from a drainage area. However, the holding capacity of a grassed swale designed for water quality purposes is limited.

Figure 10. Typical Grassed Swale Configuration

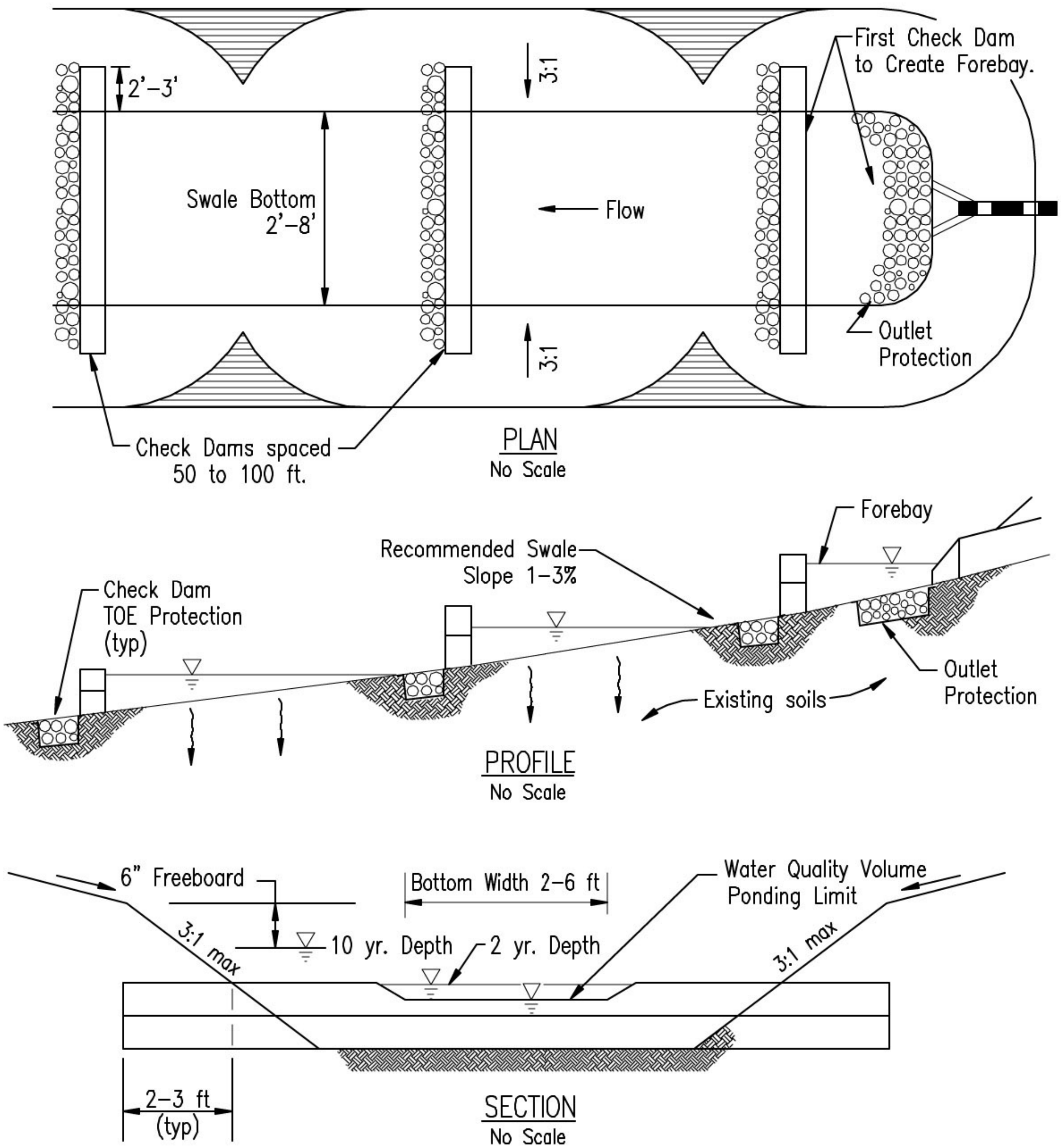
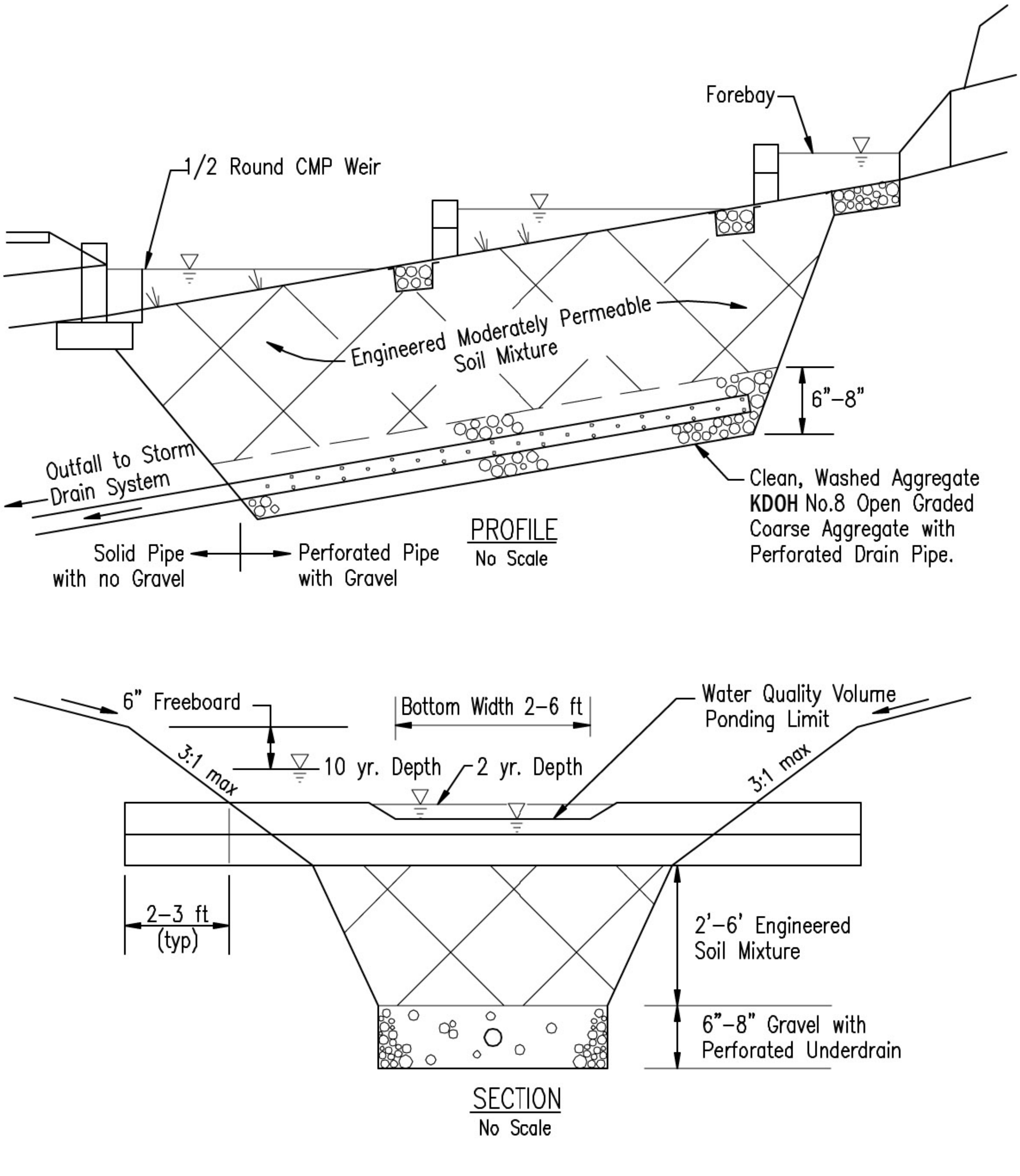


Figure 11. Typical Water Quality Swale Configuration



3. Conditions Where Practice Applies

Drainage Area

Grassed swales and water quality swales engineered for enhancing water quality cannot effectively convey large flows. Therefore, their contributing drainage areas must be kept small. The dimensions (length, width, and overall geometry) and slope of the swale, and its ability to convey the 10-year storm at a non-erosive velocity will set the size of the contributing drainage area.

Development Conditions

Grassed swales are commonly used instead of curb and gutter drainage systems in low- to moderate-density (16 to 21% impervious) single-family residential developments. Since grassed swales do not function well with high volumes or velocities of stormwater, they have limited application in highly urbanized or other highly impervious areas. However, swales may be appropriate for use in these areas if they are constructed in series or as pretreatment facilities for the BMPs.

Grassed swales are usually located within the right-of-way when used to receive runoff from subdivision or rural roadways. They may also be installed within drainage easements along the side or rear of residential lots. Grassed swales can be strategically located within the landscape to intercept runoff from small impervious surfaces (small parking lots, rooftops, etc.) as a component of a subdivision-wide or development-wide BMP strategy.

Water quality swales are appropriate for the same development conditions as those listed for grassed swales with the addition of higher densities of development (15 – 37% impervious) due to the increased pollutant removal capability.

4. Planning Considerations

Site Conditions

The following site conditions should be considered when selecting a grassed swale as a water quality BMP.

a. **Soils** – Grassed swales can be used with soils having moderate infiltration rates of 0.27 inches per hour (silt loam) or greater. Besides permeability, soils should support a good stand of vegetative cover with minimal fertilization.

   Water quality swales can be used in areas of unsuitable soil conditions for infiltration since the engineered soil mixture and underdrain system is used in place of the insitu soils.

b. **Topography** – The topography of the site should be relatively flat so that the swale can be constructed with a slope and cross-section that maintains low velocities and creates adequate storage behind the check dams.

c. **Depth of Water Table** – A shallow or seasonally-high groundwater table will inhibit the opportunity for infiltration. Therefore, the bottom of the swale should be at least 2 feet above the water table.

Sediment Control

Grassed swales may be used for conveyance of stormwater runoff during the construction phase of development. However, the swales should be maintained as required by the local program requirements. Before final stabilization, sediment must be removed from the swales and the soil surface prepared for final stabilization. Tilling of the swale bottom may be needed to open the surface pores and re-establish the soil's permeability. Water quality swales should be constructed after a majority of the drainage area has been stabilized.

This section presents minimum criteria and recommendations for the design of grassed swales used to enhance water quality. It is the designer's responsibility to decide which criteria are applicable to the particular swale being designed and to decide if any additional design elements are required. The designer must also provide for the long-term functioning of the facility by choosing appropriate structural materials.

5. Design Criteria

The design of a water quality grassed swale includes calculations for traditional swale parameters (flow rate, maximum permissible velocities, etc.) along with storage volume calculations for the water quality volume.

Hydrology

The hydrology of a grassed swale's contributing drainage area shall be developed.

Swale Geometry

A grassed swale should have a trapezoidal cross-section to spread flows across its flat bottom. Triangular or parabolic shaped sections will concentrate the runoff and should be avoided. The side slopes of the swale should be no steeper than 3H:1V to simplify maintenance and to help prevent erosion.

Bottom Width

The bottom width of the swale should be 2 feet minimum and 6 feet maximum in order to maintain sheet flow across the bottom and to avoid concentration of low flows. The actual design width of the swale is determined by the maximum desirable flow depth, as discussed below.

Flow Depth

The flow depth for a water quality grassed swale should be approximately the same as the height of the grass. An average grass height for most conditions is 4 inches. Therefore, the maximum flow depth for the water quality volume should be 4 inches (Center for Watershed Protection, 1996).

Flow Velocity

The maximum velocity of the water quality volume through the grassed swale should be no greater than 1.5 feet per second. The maximum design velocity of the larger storms should be kept low enough so as to avoid resuspension of deposited sediments. The 2-year storm recommended maximum design velocity if 4 feet per second and the 10-year storm recommended maximum design velocity of 7 feet per second.

Longitudinal Slope

The slope of the grassed swale should be as flat as possible, while maintaining positive drainage and uniform flow. The minimum constructable slope is between 0.75 and 1.0%. The maximum slope depends upon what is needed to maintain the desired flow velocities and to provide adequate storage for the water quality volume, while avoiding excessively deep water at the downstream end. Generally, a slope of between 1 and 3% is recommended. The slope should never exceed 5%.

Swale Length

Swale length is dependent on the swale's geometry and the ability to provide the required storage for the water quality volume.

Swale Capacity

The capacity of the grassed swale is a combined function of the flow volume (the water quality volume) and the physical properties of the swale such as longitudinal slope and bottom width. By using the Manning equation or channel flow nomographs the depth of flow and velocity for any given set of values can be obtained. The Manning's 'n' value, or roughness coefficient, varies with the depth of flow and vegetative cover. An 'n' value of 0.15 is appropriate for flow depths of up to 4 inches (equal to the grass height). The 'n' value decreases to a minimum of 0.03 for grass swales at a depth of approximately 12 inches (see Figure 13 below).

A grassed swale should have the capacity to convey the peak flows from the 10-year design storm without exceeding the maximum permissible velocities. (Note that a maximum velocity is specified for the 2-year and 10-year design storms to avoid resuspension of deposited sediments and other pollutants and to prevent scour of the channel bottom and side slopes. The swale should pass the 10-year flow over the top of the check dams with 6 inches, minimum, of freeboard. As an alternative, a bypass structure may be engineered to divert flows from the larger storm events (runoff greater than the water quality volume) around the grassed swale. However, when the additional area and associated costs for a bypass structure and conveyance system are considered, it may be more economical to simply increase the bottom width of the grassed swale. It should then be designed to carry runoff from the 10-year frequency design storm at the required permissible velocity.

The longitudinal slope and the bottom width may be adjusted to achieve the maximum allowable velocity according to the Manning equation:

$$Q = \left[\frac{1.49\ r^{2/3}\ s^{1/2}}{n}\right]A$$

Where: Q = peak flow rate, cfs
n = Manning's roughness coefficient
r = hydraulic radius, ft. = A / wp
s = longitudinal slope of the channel
A = cross-sectional area of the channel, ft^2

The portion of the equation within the brackets represents the velocity of flow. The previous equation can be rewritten as:

$$Q = VA$$

Where: Q = peak flow rate, cfs

V = flow velocity, ft/s = $\frac{1.49\ r^{2/3}}{n} S^{1/2}$

A = cross-sectional area of the channel, $ft.^2$

Water Quality Volume

If a grassed swale is used as a conveyance channel, its purpose is to transport stormwater to the discharge point. However, the purpose of a water quality grassed swale is to slow the water as much as possible to encourage pollutant removal.

The use of check dams will create segments of the swale which will be inundated for a period of time. The required total storage volume behind the check dams is equal to the water quality volume for the contributing drainage area to that point. However, the maximum ponding depth behind the check dams should not exceed 18 inches. To ensure that this practice does not create nuisance conditions, an analysis of the subsoil should be conducted to verify its permeability.

Underlying Soil Bed – Water Quality Swales

An underlying engineered soil bed and underdrain system may be utilized in areas where the soils are not permeable and the swale would remain full of water for extended periods of time (creating nuisance conditions). This soil bed should consist of a moderately permeable soil material with a high level of organic matter: 50% sand, 20% leaf mulch, 30% top soil. The soil bed should be 30 inches deep and should be accompanied by a perforated pipe and gravel underdrain system.

In residential developments with marginal soils, it may be appropriate to provide a soil bed and underdrain system in all grassed swales to avoid possible safety and nuisance concerns.

Check Dams

The use of check dams in a grassed swale should be per the following criteria (see Figure 12 below):

a. Height – A maximum height of 18 inches is recommended, and the dam height should not exceed one-half the height of the swale bank.

b. Spacing – Spacing should be such that the slope of the swale and the height of the check dams combine to provide the required water quality volume behind the dams.

c. Abutments – Check dams should be anchored into the swale wall a minimum of 2 to 3 feet on each side.

d. Toe Protection – The check dam toe should be protected with riprap placed over a suitable geotextile fabric. The size (D_{50}) of the riprap should be based on the design flow in the swale. Class A1 Riprap is recommended.

e. Overflow – A notch should be placed in the top of the check dam to allow the 2-year peak discharge to pass without coming into contact with the check dam abutments, or the abutments may be protected with a non-erodible material. Six inches of freeboard should be provided between the 10-year overflow and the top of the swale.

f. Riprap Check Dams – Riprap check dams should consist of a KYTC No. 1 Open-graded Coarse Aggregate core keyed into the ground a minimum of 6 inches, with a Class A riprap shell.

g. Filter Fabric – Filter fabric is required under riprap and gabion check dams.

h. Driveway Culvert Weirs – Where a driveway culvert is encountered, a 1/2 round corrugated metal pipe weir bolted to the concrete driveway headwall may be utilized as a check dam, or a timber check dam placed at least one foot upstream of the culvert opening.

Outlets

Discharges from grassed swales must be conveyed at non-erosive velocities to either a stream or a stabilized channel to prevent scour at the outlet of the swale.

Inflow Points

Swale inflow points should be protected with erosion controls as needed (e.g., riprap, flow spreaders, energy dissipators, sediment forebays, etc.)

Vegetation

A dense cover of water-tolerant, erosion-resistant grass or other vegetation must be established. Grasses used in swales should have the following characteristics:

- a deep root system to resist scouring,
- a high stem density, with well-branched top growth,
- tolerance to flooding,
- resistance to being flattened by runoff, and
- an ability to recover growth following inundation.

Recommended grasses include, but are not limited to, the following: Kentucky-31 tall fescue, reed canary grass, redtop, and rough-stalked blue grass. Note that these grasses can be mixed.

The selection of an appropriate vegetative lining for a grassed swale is based on several factors including climate, soils, and topography.

Erosion control matting should be used to stabilize the soil before seed germination. This protects the swale from erosion during the germination process. In most cases, the use of sod is warranted to provide immediate stabilization on the swale bottom and/or side slopes.

6. Construction Specifications

Specifications for the work should conform to the methods and procedures specified for earthwork, concrete, reinforcing steel, woodwork and masonry, as they apply to the site and the purpose of the structure. The specifications should also satisfy any requirements of the local government.

Sequence of Construction

The construction of grassed swales should be coordinated with the overall project construction schedule. The swale may be excavated during the rough grading phase of the project to permit use of the excavated material as fill in earthwork areas. Otherwise, grassed swales should not be constructed or placed into service until the entire contributing drainage area has been stabilized. Runoff from untreated, recently constructed areas may load the newly formed swale with a large volume of fine sediment. This could seriously impair the swale's natural infiltration ability.

The specifications for construction of a grassed swale should state the following:

- Earliest point in progress when storm drainage may be directed to the swale, and
- Means by which this delay in use will be accomplished.

Due to the wide variety of conditions encountered among project, each project should be evaluated separately to decide how long to delay use of the swale.

Excavation

Initially, the swale should be excavated to within one foot of its final elevation. Excavation to the finished grade should be deferred until all disturbed areas in the watershed have been stabilized or protected. The final phase of excavation should remove all accumulated sediment. When final grading is completed, the swale bottom should be tilled with rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.

Vegetation

Establishing dense vegetative cover on the swale side slopes and floor is required. This cover will not only prevent erosion and sloughing, but will also provide a natural means to maintain relatively high infiltration rates.

Materials

a. Check dams – Check dams shall be constructed of a non-erosive material such as wood, gabions, riprap, or concrete. All check dams shall be underlain by filter fabric.

   1) Wood – pressure treated logs or timers, or water-resistant tree species such as cedar, hemlock, swamp oak or locust.

   2) Gabions – hexagonal triple twist mesh with PVC coated galvanized steel wire. The maximum linear dimension of the mesh opening shall not exceed 4.5 inches. The area of the mesh opening shall not exceed 10 square inches.

      Stone or riprap for gabions shall be sized according to Table 12 below. It shall consist of field stone or rough unhewn quarry stone. The stone shall be hard and angular and of a quality that will not disintegrate with exposure to water or weathering. The specific gravity of the individual stones shall be at least 2.5. Recycled concrete may be used if it has a density of at least 150 pounds per cubic foot and does not have any exposed steel or reinforcing bars.

   3) Riprap – all riprap shall conform to KYTC Standards for open graded course aggregate.

   4) Concrete – All concrete shall conform to KYTC or SCS specifications.

b. Underlying soil medium – The underlying soils should consist of the following:

   1) Soil – USDA ML, SM, or SC.

   2) Sand – ASTM C-33 fine aggregate concrete sand; KYTC fine aggregate, grading A or B.

c. Pea Gravel – Pea gravel should consist of washed ASTM M-43; KYTC No. 8 Open-graded Course Aggregate.

d. Underdrain – An underdrain system below the swale bottom shall consist of the following:

   1) Gravel – AASHTO #7, ASTM M-43, KYTC No. 3 Open-graded Course Aggregate.

   2) PVC Pipe – AASHTO M-278, 4-inch rigid schedule 40, perforations of 3/8-inch diameter at 6-inch centers, 4 holes per row.

   3) Filter fabric – shall be 4 – 6 oz nonwoven needle – punched geotextile.

Table 12. Stone or Riprap Sizes for Gabion Baskets

Basket Thickness (in.)	Basket Thickness (mm.)	Stone Size (in.)
6	150	3 – 5
9	225	4 – 7
12	300	4 – 7
18	460	4 – 7
36	910	4 - 12

7. Maintenance and Inspection Guidelines

Maintenance of grassed swales includes upkeep of the vegetative cover and preservation of the swale's hydraulic properties. Individual land owners can usually carry out the suggested maintenance procedures for the swale or the portion of the swale on their property. To ensure continued long term maintenance, all affected landowners should be made aware of their maintenance responsibilities, and maintenance agreements should be included in land titles.

The following maintenance and inspection guidelines are not intended to be all-inclusive.

Specific swales may require other measures not discussed here. It is the engineer's responsibility for determining if any additional items are necessary.

Vegetation

A dense and vigorous grass cover should be maintained in a grassed swale. This will be simplified if the proper grass type is selected in the design. Periodic mowing is required to keep the swale operating properly. Grass should never be cut to a height less than 3 inches. Ideally, a grass stand of 6 inches is most effective. Stabilization and reseeding of bare spots should be performed, as needed.

Check Dams

Properly constructed check dams should require very little maintenance since they are made on non-erodible materials. Periodic removal of sediment accumulated behind the check dams should be performed, as needed.

Debris and Litter Removal

The accumulation of debris (including trash, grass clippings, etc.) in the swale can alter the hydraulics of the design and lead to additional maintenance costs. Debris can also alter the flow path along the swale bottom causing low flows to concentrate and result in erosion of the swale bottom. As with any BMP, frequent inspections by the land owner will help prevent small problems from becoming larger.

Sediment Removal

The sediment that accumulates within the swale should be manually removed and the vegetation reestablished. If accumulated sediment has clogged the surface pores of the swale, reducing or eliminating the infiltration capacity, then the surface should be tilled and restabilized. Drilling or punching small holes into the surface layer can be used instead of tilling, if desired.

8. Design Procedures

The following design procedure represents a generic list of the steps typically required for the design of a water quality grassed swale.

a. Determine if the anticipated development conditions and drainage area are appropriate for a water quality grassed swale BMP.

b. Determine if the soils (permeability, bedrock, etc.) topographic conditions (slopes, existing utilities, and environmental restrictions) are appropriate for a grassed swale BMP.

c. Determine any additional stormwater management requirements (channel erosion, flooding) for the project.

d. Locate the grassed swale BMP(s) on the site.

e. Determine the hydrology and calculate the 2-year and 10-year peak discharges (Part III) and the water quality volume for the contributing drainage area.

f. Approximate the geometry of the grassed swale and evaluate water quality parameters: water quality depth of flow (recommended maximum of 4 inches), and storage volume behind check dams (water quality volume). Adjust swale geometry and re-evaluate as needed.

g. Evaluate the grassed swale geometry for the 2-year design storm peak discharge velocity (4 feet per second), and capacity (check dam overflow), and the 10-year design storm peak discharge velocity (7 feet per second) and capacity (6 inches of freeboard). Adjust swale geometry and re-evaluate as needed.

h. Establish specifications for appropriate permanent vegetation on the bottom and side slopes of the grassed swale.

i. Establish specifications for sediment control.

j. Establish construction sequence and construction specifications.

k. Establish maintenance and inspection requirements.

Figure 12. Typical Check Dam Configurations

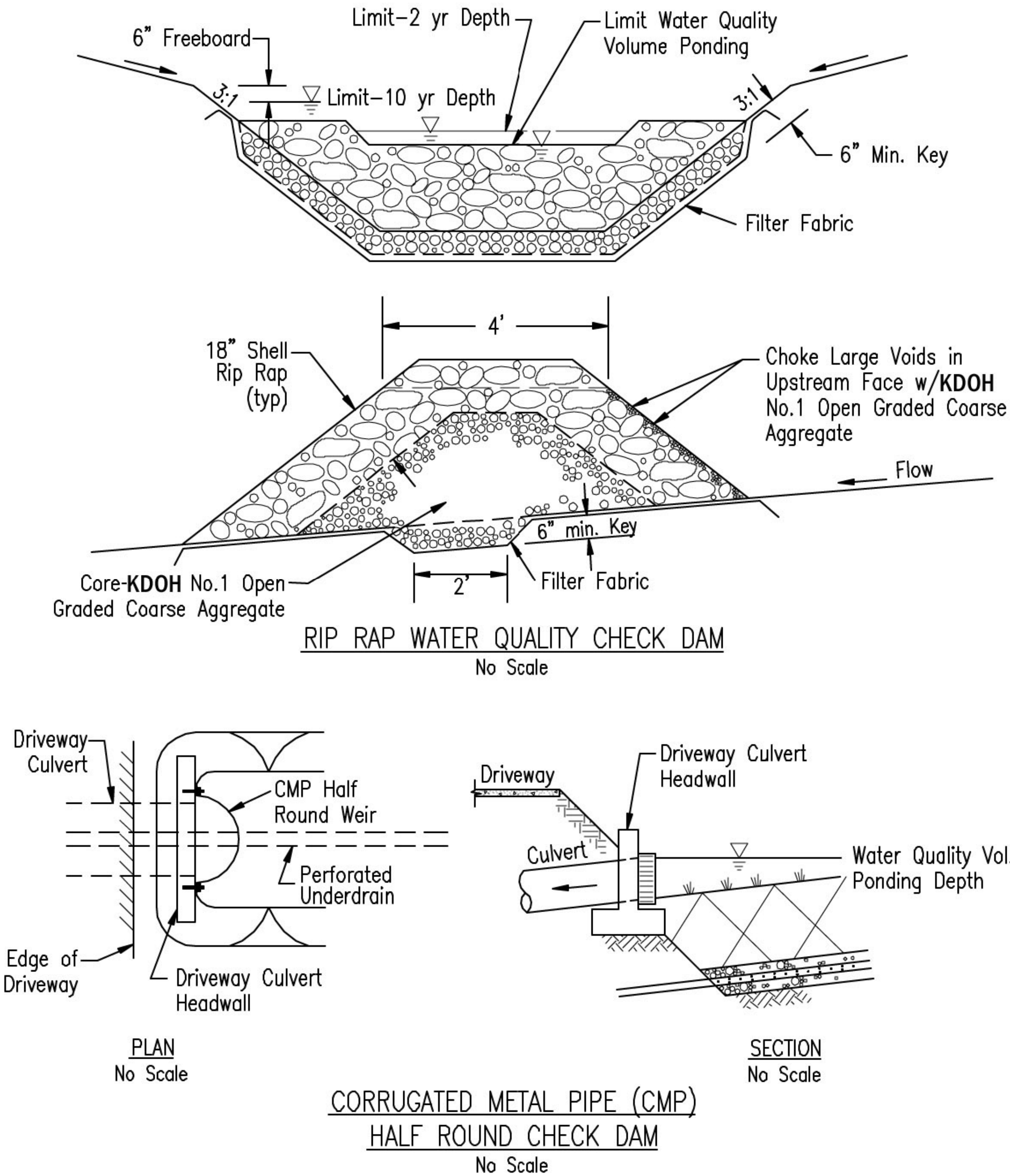
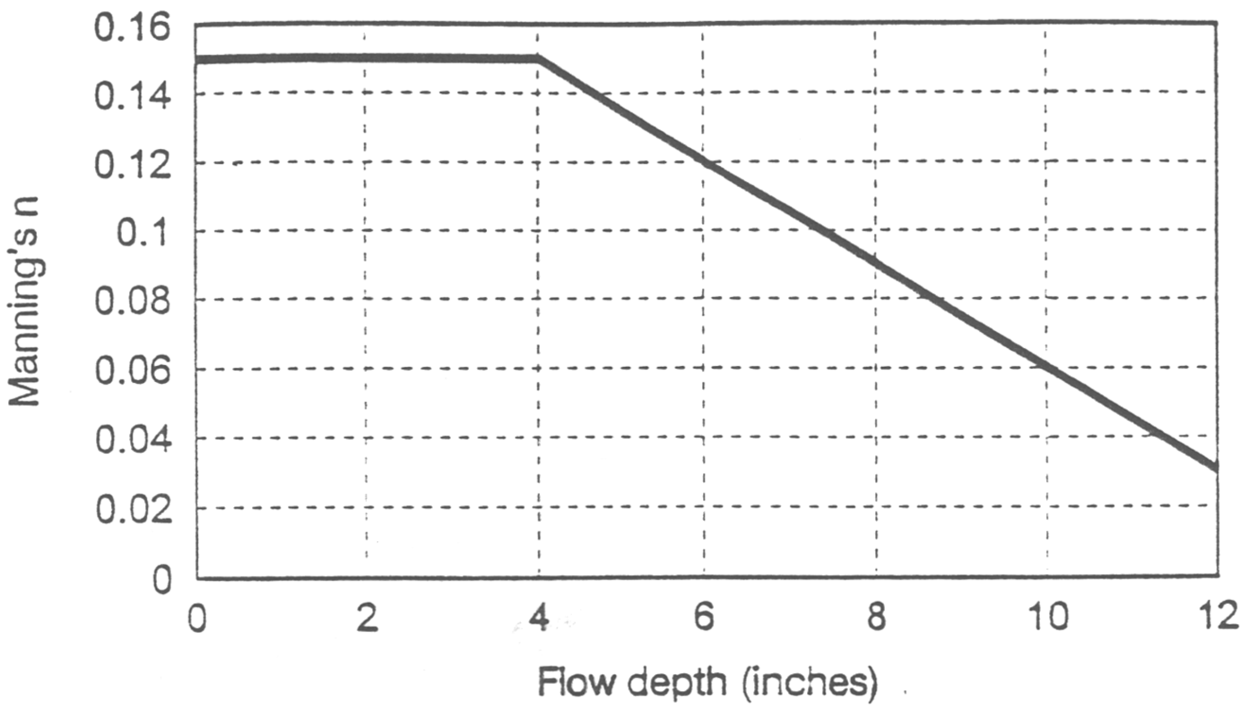


Figure 13. Manning's 'n' Values for Varying Depths of Flow



I Infiltration Trench

1. Definition

   An infiltration trench is a shallow, excavated trench backfilled with a coarse stone aggregate to create an underground reservoir. Stormwater runoff diverted into the trench gradually infiltrates into the surrounding soils from the bottom and sides of the trench. The trench can be either an open surface trench or an underground facility.

2. Purpose

   Infiltration trenches are used primarily as water quality BMPs. Trenches are generally 2 to 10 feet deep and are backfilled with a coarse stone aggregate, allowing for temporary storage of storm runoff in the voids between the aggregate material. Stored runoff gradually infiltrates into the surrounding soil. The surface of the trench can be covered with grating and/or consist of stone, gabion, sand, or a grassed areas with a surface inlet. Utilizing underground pipes within the trench can increase the temporary storage capacity of the trench and can sometimes provide enough storage for flooding and/or stream channel erosion control (see Figure 1.4 below).

3. Conditions Where Practice Applies

   An infiltration trench may be used where the subsoil is sufficiently permeable to provide a reasonable infiltration rate and where the water table is low enough to prevent pollution of groundwater.

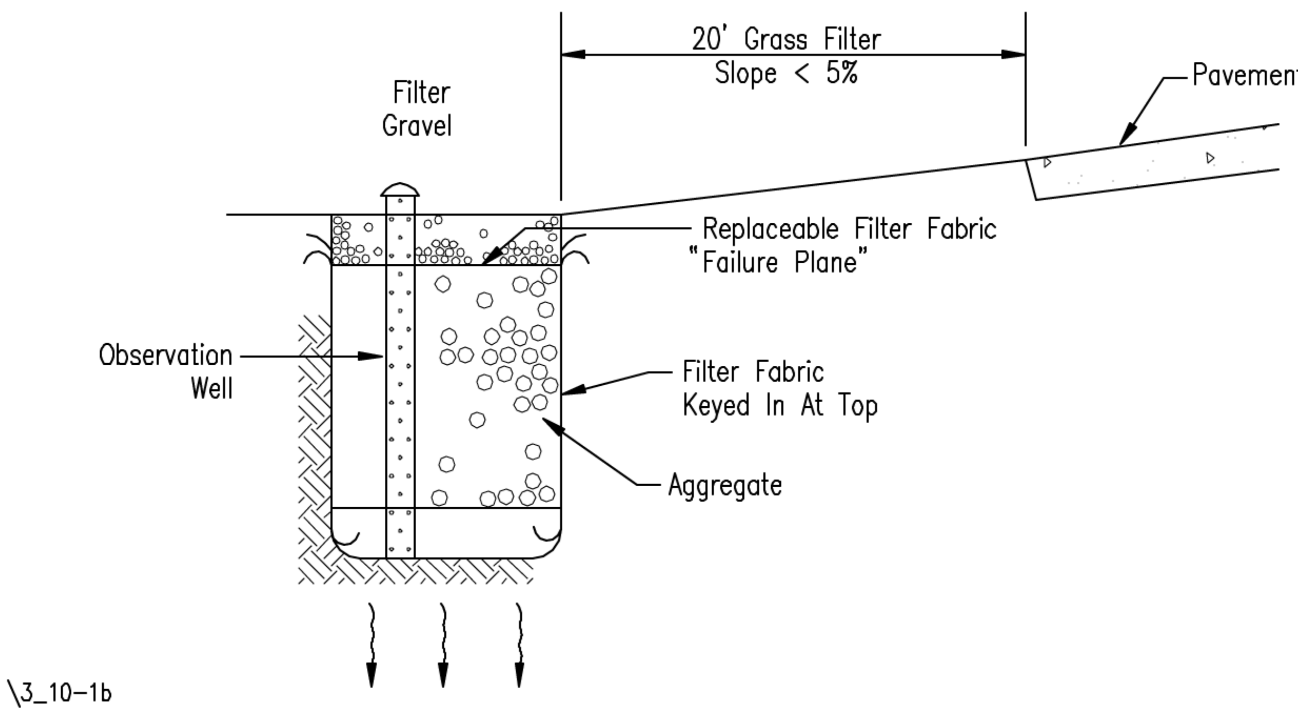
Drainage Area

Infiltration trenches are not practical for large drainage areas. Generally, the drainage area for infiltration trenches should be limited to 5 acres. Multiple trenches may be considered to control the runoff from a large site, but this also increases the associated maintenance responsibilities.

Development Conditions

Infiltration trenches are generally suited for low- to medium-density residential and commercial developments. They can be installed in multi-use areas, such as along parking lot perimeters, or in small areas that cannot readily support retention basins or similar structures. Unlike most BMPs, trenches can easily fit into the margin, perimeter, or other unused areas of developed sites, making them particularly suitable for retrofitting in existing developments or in conjunction with other BMPs. A trench may also be installed under a swale to increase the storage of the related infiltration system. In all cases, pretreatment of the stormwater runoff to remove course sediment and particulate pollutants prior to entering the infiltration trench should be provided.

Figure 14. Infiltration Trench – Section



4. Planning Considerations

Appropriate soil conditions and protection of groundwater are two important considerations when planning for an infiltration trench.

5. Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of infiltration trenches intended to comply with the runoff quality requirements of the Winchester Stormwater Management program.

General

Infiltration trenches are assumed to have rectangular cross-sections. Thus, the infiltration surface area (trench bottom) can be readily calculated from the trench geometry. The storage volume of the trench must be calculated using the void ratio of the backfill material that will be placed in it.

The same general criteria presented for the design of infiltration basins apply to trenches; the following information is provided for additional guidance.

Soils Investigation

A minimum of one soil boring log should be required for every 50 feet of trench length. A minimum of two soil boring logs should be required for each proposed trench location.

Topographic Conditions

Infiltration trenches should be located 20 feet down-slope and 100 feet up-slope from building foundations. An analysis should be completed to identify any possible adverse effects of seepage zones if there are nearby building foundations, basements, roads, parking lots or sloping sites. Developments on sloping sites often require the use of extensive cut and fill operations. The use of infiltration trenches on fill sites is not permitted.

Design Infiltration Rate

The design infiltration rate, f_d, should be set to equal one-half the infiltration rate obtained from the soil analysis. Therefore,

$$F_d = 0.5\ f$$

Maximum Storage Time and Trench Depth

All infiltration trenches should be designed to empty within 2 days following the occurrence of a storm event. Thus, a maximum allowable storage time, T_{max}, of 48 hours should be used.

The maximum depth for an infiltration trench may be defined as:

$$d_{max} = \frac{f_d T_{max}}{V_r}$$

where: d_{max} = maximum allowable depth of the facility, in ft;
f_d = design infiltration rate of the trench area soils, in ft/hr (f_d = 0.5f)
T_{max} = maximum allowable drain time = 48 hrs.;

V_r = void ratio of the stone reservoir expressed in terms of the percentage of porosity divided by 100 (0.4 typ.)

Refer to the KYTC's Road and Bridge Specifications, latest edition, for information and specifications for coarse aggregates. A void ratio of 0.40 is assumed for stone reservoirs using 1.5 to 3.5 inch stone – KYTC No. 1 Coarse-graded Aggregate.

The minimum surface area of the facility bottom may be defined as:

$$SA_{min} = \frac{Vol_{wq}}{F_d\ T_{max}}$$

where: SA_{min} = minimum trench bottom surface area, in ft.^{2};
Vol_{wq} = water quality volume requirements, in ft.^{3};
F_d = design infiltration rate of the trench area soils, in ft/hr (f_d = 0.5f);
T_{max} = maximum allowable drain time = 48 hrs.

Runoff Pretreatment

Infiltration trenches should always be preceded by a pretreatment facility. Grease, oil, floatable organic materials, and settleable solids should be removed from the runoff before it enters the trench. Vegetated filters, sediment traps or forbays, water quality inlets are just a few of the available pretreatment strategies. To reduce both the frequency of turbulent flow-through and the associated scour and/or resuspension of residual material, infiltration trenches and associated pretreatment facilities should be installed off-line (MWCOG, 1992).

A grass strip or other type of vegetated buffer at least 20 feet wide should be maintained around trenches that accept surface runoff as sheet flow. The slope of the filter strip should be approximately 1% along its entire length and 0% across its width. A recent study by MWCOG (Galli, 1992) concluded that for areas receiving high suspended solid loads, a minimum filter length of 50 feet is desirable.

All trenches with surface inlets should be engineered to capture sediment from the runoff before it enters the stone reservoir. Any pretreatment facility design should be included in the design of the trench, complete with maintenance and inspection requirements.

Backfill Material

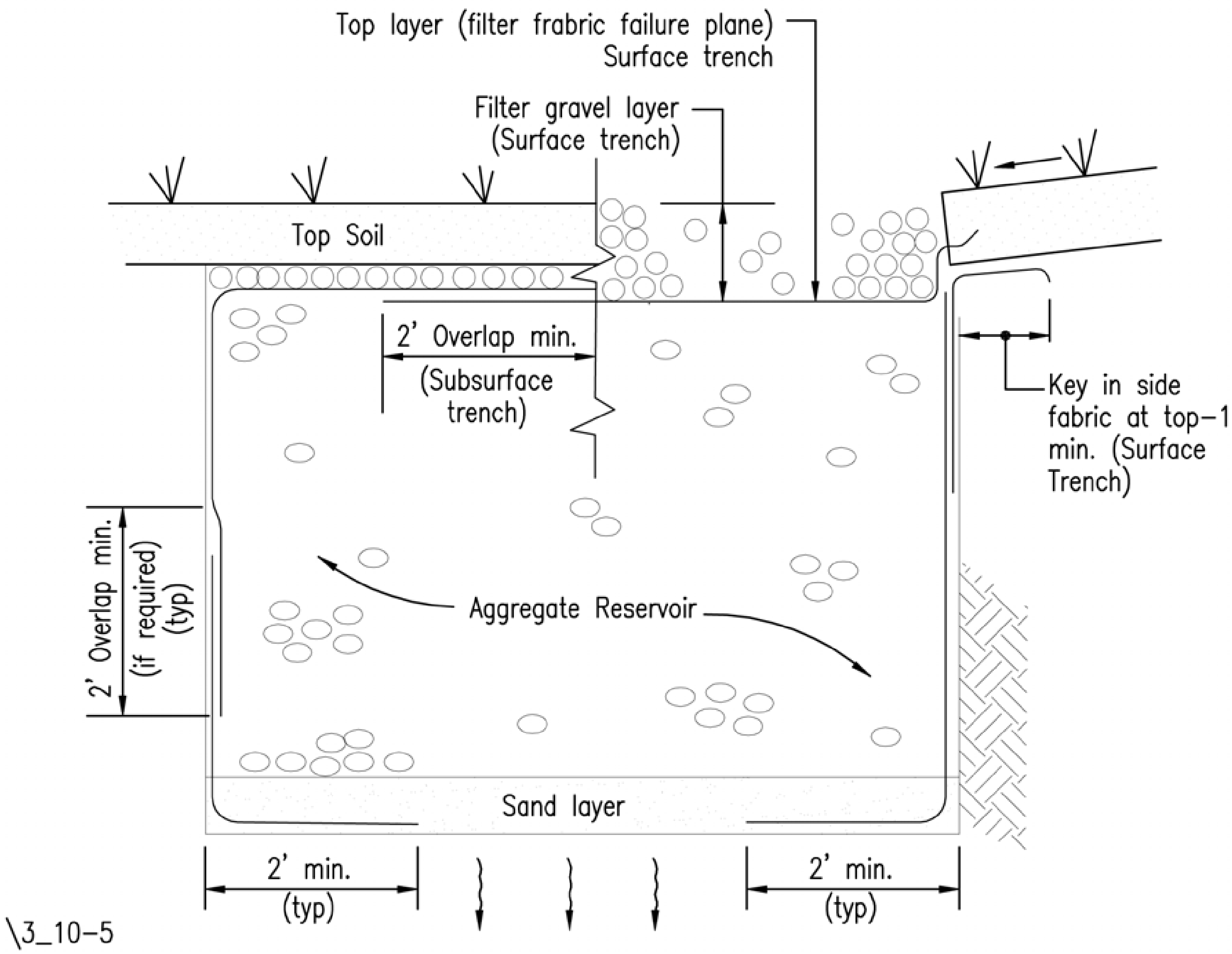
Backfill material for the infiltration trench should be clean aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches (i.e. KYTC No. 1 Open-graded Coarse Aggregate or equivalent). The aggregate should contain few aggregates smaller than the selected size. A void space for KYTC No. 1 aggregate is assumed to be 40 percent.

An 8 inch deep bottom sand layer (KYTC Fine Aggregate, Grading A or B) is required for all trenches to promote better drainage and reduce the risk of soil compaction when the trench is backfilled with stone (MWCOG, 1992).

Filter Fabric

The aggregate fill material should be surrounded with an engineering filter fabric as shown in Figure 15. For an aggregate surface trench, filter fabric should surround all of the aggregate fill material except the top one foot. A separate piece of fabric should be used for the top layer to act as a failure plane. This top piece can then be removed and replaced upon clogging. Note, however that filter fabric should not be placed on the trench bottom.

Figure 15. Filter Fabric Placement



Water Quality Volume

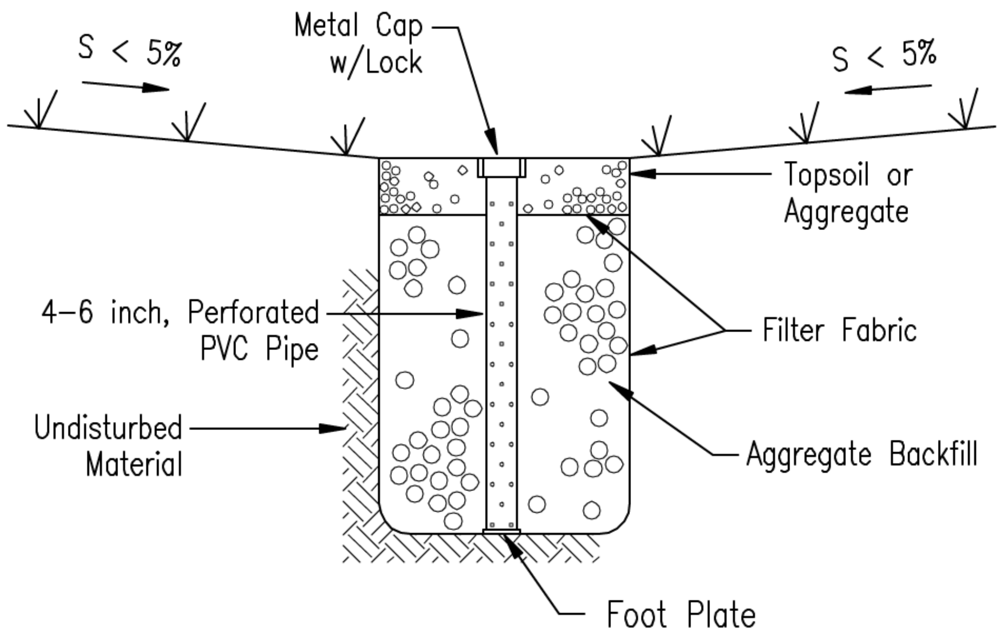
Usually, because of the small drainage areas controlled by an infiltration trench, an emergency spillway is not necessary. However, the overland flow path taken by the surface runoff, when the capacity of the trench is exceeded, should always be evaluated. A nonerosive overflow channel leading to a stabilized watercourse should be provided, as necessary, to insure that uncontrolled, erosive, concentrated flow does not develop.

Observation Well

An observation well should be installed for every 50 feet of infiltration trench length. The observation well will show how quickly the trench dewaters following a storm, as well as providing a means of determining when the filter fabric is clogged and maintenance is needed.

The observation well should consist of perforated PVC pipe, 4 to 6 inches in diameter. It should be installed in the center of the structure, flush with the ground elevation of the trench. Putting the observation well in a non-parking or traffic area to simplify inspections is best. The top of the well should be capped to discourage vandalism and tampering (See Figure 16).

Figure 16. Observation Well



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6. Construction Specifications

Overall, widely accepted construction standards and specifications, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers, should be followed where applicable. Further guidance can be found in the Soil Conservation Service's Engineering Field Manual. Specifications for the work should conform to the methods and procedures indicated for installing earthwork, concrete, reinforcing steel, pipe, water gates, metal work, woodwork and masonry, as they apply to the site and purpose of the structure. The specifications should also satisfy any requirements of the local government.

Construction of an infiltration trench should also be in conformance with the following:

Sequence of Construction

An infiltration trench should not be constructed or placed into service until all of the contributing drainage area has been stabilized. Runoff from untreated, recently constructed areas within the drainage area may load the newly formed trench and/or pretreatment facility with a large volume of fine sediment.

The specifications for the construction of an infiltration trench should state the following: 1) the earliest point at which storm drainage may be directed to the trench, and 2) the means by which this delay in use is to be accomplished. Due to the wide variety of conditions encountered among development projects, each project should be evaluated separately to postpone trench use for as long as possible.

Trench Preparation

Trench excavation should be limited to the specific trench dimensions. Excavated materials should be placed away from the trench sides to avoid impacting the trench wall stability.

The trench should be excavated with a backhoe or similar device that allows the equipment to stand away from the trench bottom. This bottom surface should be scarified with the excavator bucket teeth on the final pass to eliminate any smearing or shearing of the soil surface. Similarly, the sand filter material should be placed on the trench bottom so that it does not compact or smear the soil surface. The sand must be deposited ahead of the loader so the equipment is always supported by a minimum of 8 inches of sand.

Large tree roots must be trimmed flush with the trench sides to prevent the fabric from puncturing or tearing during subsequent installation procedures. No voids between the filter fabric and the excavation walls should be present. If boulders or similar obstacles are removed from the excavated walls, natural soils should be placed in these voids before the filter fabric is installed. The side walls of the trench should be roughened where sheared and sealed by heavy equipment.

Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft cohesive or cohesionless soils predominate. These conditions may require that the side slopes be laid back to maintain stability; trapezoidal rather than rectangular cross sections may result.

Fabric Laydown

The roll of filter fabric should be cut to the proper width before installation. The width should allow for perimeter irregularities plus a minimum 12-inch overlap at the top. When a fabric overlap is required elsewhere, the upstream section should overlap the downstream section by a minimum of 2 feet to ensure that the fabric conforms to the excavation surface during aggregate placement. Note that filter fabric should not be placed on the trench bottom.

Stone Aggregate Placement Compaction

The crushed stone aggregate should be placed in a the trench in loose lifts of about 12 inches using a backhoe or front-end loader with a drop height near the bottom of the trench, and should be lightly compacted with plate compactors. Aggregate should not be dumped into the trench by a truck.

Backfill material for the infiltration trench should be clean, washed aggregate 1.5 to 3.5 inches in diameter (KYTC No. 1 Open-graded Coarse Aggregate or equivalent). The aggregate should contain few aggregates smaller than the selected size.

The 8 inch deep bottom sand layer should consist of KYTC Fine Aggregate, Grading A or B.

Overlapping and Covering

Following the stone aggregate placement, the filter fabric should be folded over the stone aggregate to form a 12-inch minimum longitudinal overlap. The desired fill soil or stone aggregate should be placed over the lap at sufficient intervals to maintain the lap during subsequent backfilling.

Potential contamination

Clean aggregate should not be mixed with natural or fill soils. All contaminated aggregate should be removed and replaced with clean aggregate.

Traffic Control

To prevent or reduce compaction of the soil, heavy equipment and traffic should not travel over the infiltration trench.

Observation Well

Observation well should be provided as specified in the design criteria. The depth of the well at the time of installation should be clearly marked on the well cap.

7. Maintenance and Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all-inclusive. Specific facilities may require other measures not discussed here.

Inspection Schedule

The observation well and pretreatment facility should be monitored quarterly and after every large storm event. It is recommended that a log book be maintained showing the depth of water in the well at each observation in order to determine the rate at which the facility dewaters after runoff producing storm events. Once the performance characteristics of the structure have been verified, the monitoring schedule can be reduced to an annual basis, unless the performance data suggest that a more frequent schedule is required.

Sediment Control

Sediment buildup in the top foot of stone aggregate or the surface inlet should be monitored on the same schedule as the observation well. A monitoring well in the top foot of stone aggregate should be provided when the trench has a stone surface. Sediment deposited should not be allowed to build up to the point where it will reduce the infiltration rate into the trench.

It is recognized that infiltration facilities are subject to clogging. Once a trench facility has clogged, very little can be done to correct it, short of excavating the facility. Maintenance efforts, therefore, should focus on the measures used for pretreatment of runoff, in addition to facility itself.

Vegetation Maintenance

Any vegetated buffers associated with an infiltration trench should be inspected regularly and maintained as needed. Regular maintenance of the buffer is necessary to promote dense turf with extensive root growth, which subsequently enhances runoff filtering, prevents erosion and sedimentation, and deters invasive weed growth. Bare spots should be immediately stabilized and revegetated. Fertilizers should be applied only as necessary and in limited amounts to avoid contributing to pollution problems which the infiltration basin helps to mitigate.

8. Design Procedures

The following design procedure represents a generic list of the steps typically required for the design of an infiltration trench.

a. Determine if the anticipated development conditions and drainage area are appropriate for an infiltration trench application.

b. Determine if the soils (permeability, bedrock, water table, etc.) and topographic conditions (slopes, building foundations, etc.) are appropriate for an infiltration trench application.

c. Locate the infiltration trench on the site within topographic constraints.

d. Determine the drainage area for each infiltration trench and calculate the required water quality volume.

e. Evaluate the hydrology of the contributing drainage area to determine the peak rates of runoff.

f. Design the infiltration trench:
   - Design infiltration rate, $f_d = 0.5\ f$
   - max. storage time $T_{max} = 48$ hours
   - max. storage depth, d_{max}
   - stone backfill of clean aggregate (1.5” to 3.5”) KYTC No. 1 Open-Graded Course
   - Aggregate
   - sand layer on trench bottom (8 inches)

- runoff pretreatment – concentrated input, sheet flow input
- vegetated buffer around trench to filter surface runoff
- filter fabric on trench sides and top (not on trench bottom) keyed into trench
- overflow channel or large storm bypass
- observation well

g. Provide material specifications.

h. Provide sequence of construction.

i. Provide maintenance and inspection requirements.

j. Establish maintenance and inspection requirements.

J. Bioretention Basin / Rain Gardens

1. Definition

The following information is drawn from the Prince George's County, Maryland Department of Environmental Protection Design Manual for Use of Bioretention in Stormwater Management (P. G. County, 1993) unless otherwise noted. This technology is also referred to as "Rain Gardens."

Figure 17 illustrates a bioretention (Rain Garden) concept as adapted for use in Winchester. There are seven major components to the bioretention area: 1) the grass buffer strip; 2) the ponding area; 3) the surface mulch and planting soil; 4) the sand bed (optional); 5) the organic layer; 6) the plant material, and 7) the infiltration chambers. Each component is critical to sustaining a properly functioning BMP.

2. Purpose

Bioretention basins are used primarily for water quality control. However, since they capture and infiltrate part of the stormwater from the drainage shed, they may provide partial or complete control of streambank erosion and partial protection from flooding (depending on the volume of water being captured and filtrated).

Bioretention facilities are planting area installed in shallow basins in which the stormwater runoff is treated by filtering through the bed components, biological and biochemical reactions within the soil matrix and around the root zones of the plants, and infiltration into the underlying soil strata. Properly constructed bioretention areas replicate the ecosystem of an upland forest floor through the use of specific shrubs, trees, ground covers, mulches and deep, rich soils. Since almost all bioretention basins are intended to be visual landscape amenities as well as stormwater BMPs, aesthetic considerations may be equally as important in their use as proper engineering. Bioretention design requires participating by a person with appropriate design skills and a working knowledge of indigenous horticultural practices, preferably a Landscape Architect.

Water Quality Enhancement

Bioretention basins enhance the quality of stormwater runoff through the processes of adsorption, filtration, volitization, ion exchange, microbial and decomposition prior to exfiltration into the surrounding soil mass. Microbial soil processes, evapotranspiration, and nutrient uptake in plants also come into play (Bitter and Bowers, 1995).

Figure 17. Bioretention Basin

The grass buffer strip filters particles from the runoff and reduces its velocity. The sand bed further slows the velocity of the runoff, spreads the runoff over the basin, filters part of the water, provides for positive drainage to prevent anaerobic conditions in the planting soil and enhances exfiltration from the basin. The ponding area functions as storage of runoff awaiting treatment and as presettling basin for particulates that have not been filtered out by the grass buffer. The organic or mulch layer acts as a filter for pollutants in the runoff, protects the soil from eroding, and provides an environment for microorganisms to degrade petroleum-based solvents and other pollutants. The planting soil layer nurtures the plants with stored water and nutrients. Clay particles in the soil adsorb heavy metals, nutrients, hydrocarbons, and other pollutants. The plant species are selected based on their documented ability to cycle and assimilate nutrients, pollutants, and metals through the interactions among plants, soil, and the organic layer. By providing a variety of plants, monoculture susceptibilities to insect and disease infestation are avoided, and evapotranspiration is enhanced. The vented infiltration chambers provide unobstructed exfiltration through the open-bottomed cavities, decrease the ponding time above the basin, and aerate the filter media between storms through the open chamber cavities and vents to grade, preventing the development of anaerobic conditions. By providing a valve equipped drawdown drain to daylight, the basin can be converted into a soil media filter should exfiltration surface failures occur.

Perforated underdrain systems are recommended for facilities placed in residential areas and in all areas where the in-situ soils are questionable. Refer to 9A – Bioretention Filter.

The minimum width for a bioretention area is usually 10 feet, although widths as narrow as 4 feet may be used if the runoff arrives as dispersed sheet flow along the length of the facility from a properly sized vegetated strip. The minimum length should be 15 feet (for lengths greater than 20 feet, the length should be at least twice the width to allow dispersed sheet flow). As an infiltration BMP, the maximum ponding depth is restricted to six inches to restrict maximum ponding time to preclude development of anaerobic conditions in the planting soil (which will kill the plants) and to prevent the breeding of mosquitoes and other undesirable insects in the ponded water. The planting soil must have sufficient depth to provide appropriate moisture capacity, create space for the root systems, and provide resistance from wind throw (Minimum depth equal to the diameter of the largest plant root ball plus 4 inches).

Table 13 contains the target removal efficiencies once a mature plant community is created in the bioretention areas based on the volume of runoff to be captured and infiltrated.

Flood Control and Channel Erosion

The amount of flood and channel erosion control provided by bioretention basins depends on the local rainfall frequency spectrum, the amount of pre-development (or pre-redevelopment) impervious cover, the amount of post-development imperious cover, and the volume of runoff captured and infiltrated by the basins(s). The effect of the BMPs on peak flow rates from the drainage shed must be examined. As with other infiltration practices, bioretention basins tend to reverse the consequences of urban development by reducing peak flow rates and providing groundwater discharge.

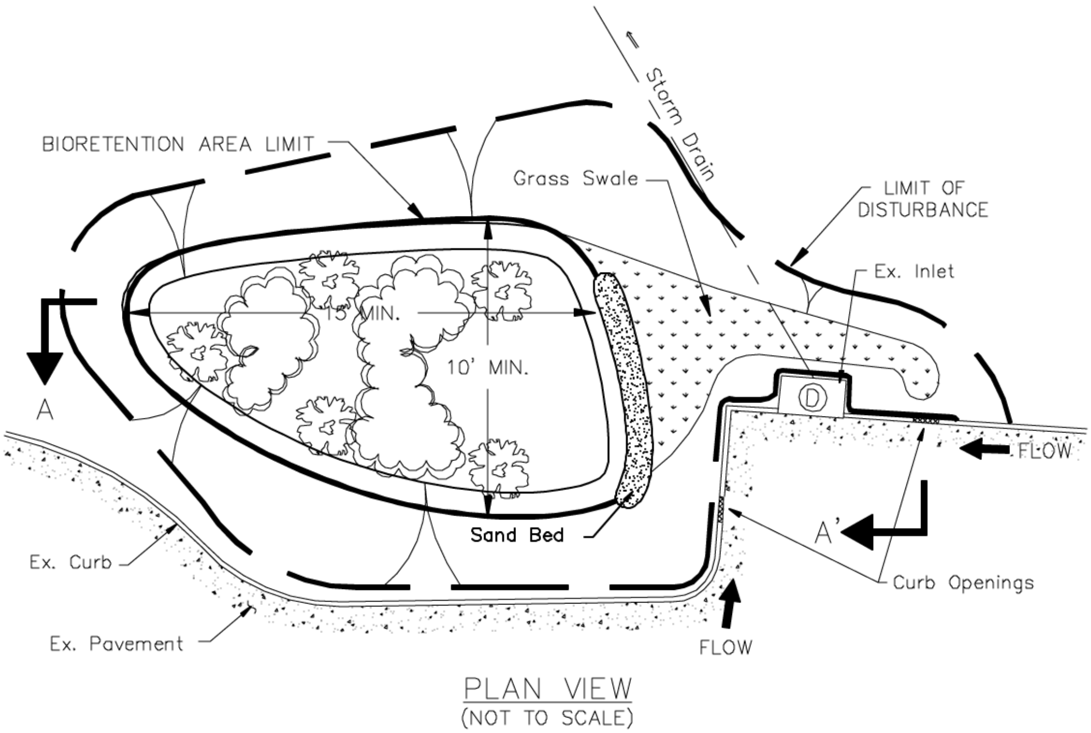
Table 13 Pollutant Removal Efficiencies for Bioretention Basins

BMP Description	Target Phosphorus Removal Efficiency
Bioretention basin with capture and treatment volume equal to 0.5 inches of runoff from the impervious area.	50%
Bioretention basin with capture and treatment volume equal to 1.0 inches of runoff from the impervious area.	65%

3. Conditions Where Practice Applies

Bioretention basins are suitable for use on any project where the subsoil is sufficiently permeable to provide a reasonable rate of infiltration and where the water table is sufficiently lower than the design depth of the facility to prevent pollution of the groundwater. Bioretention basins are generally suited for almost all types of development, from single-family residential to fairly high density commercial projects. They are attractive for higher density projects because of their relatively high removal efficiency. Figures 18 through 21 illustrate several applications. For large applications, several bioretention basins are preferable to a single, massive basin.

Figure 18. Bioretention Basin at Edge of Parking Lot with Curb



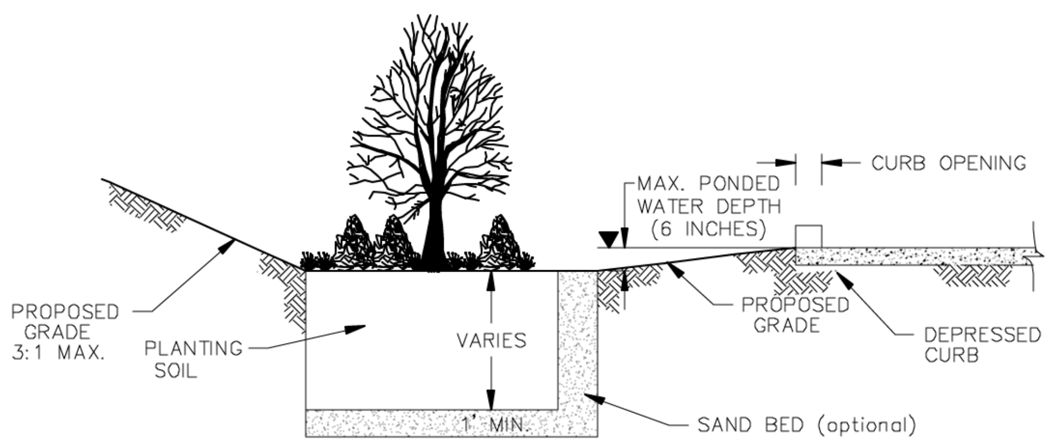
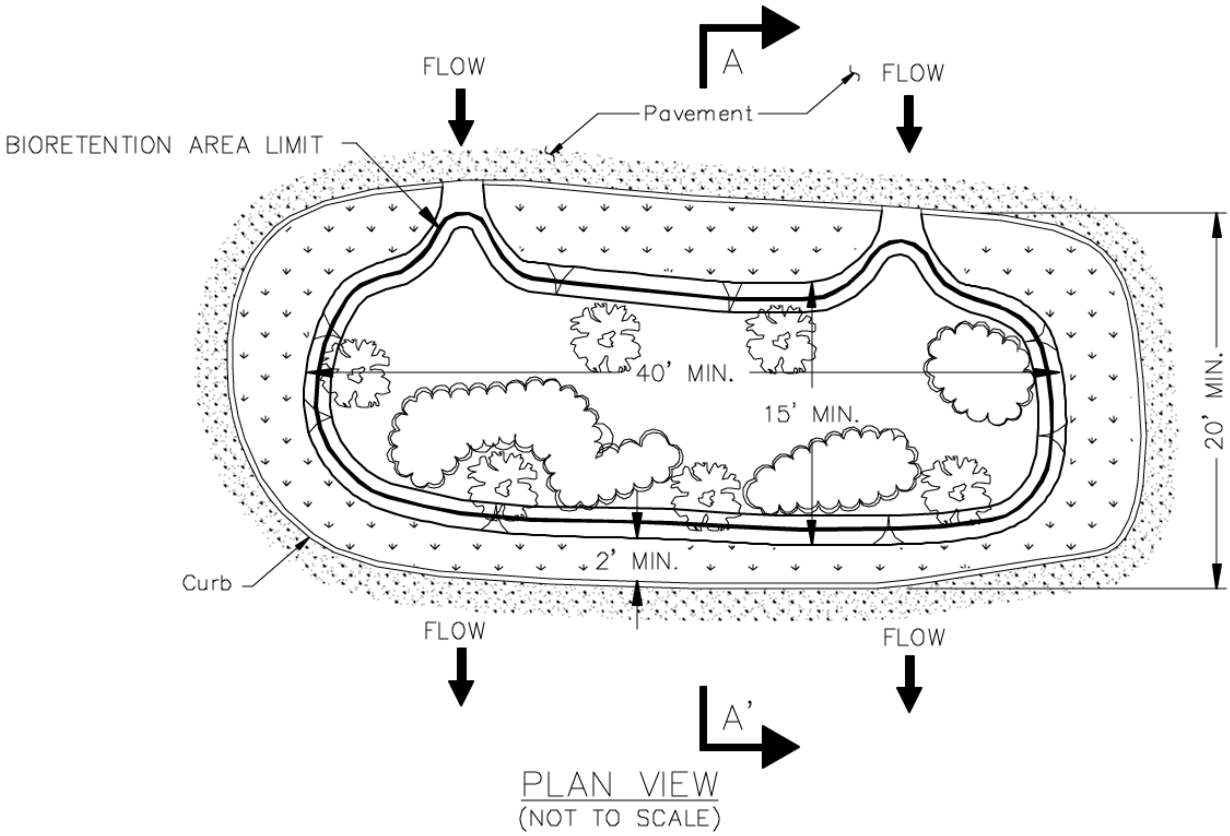


Figure 19. Bioretention Basin in a Planting Island in a Parking Lot



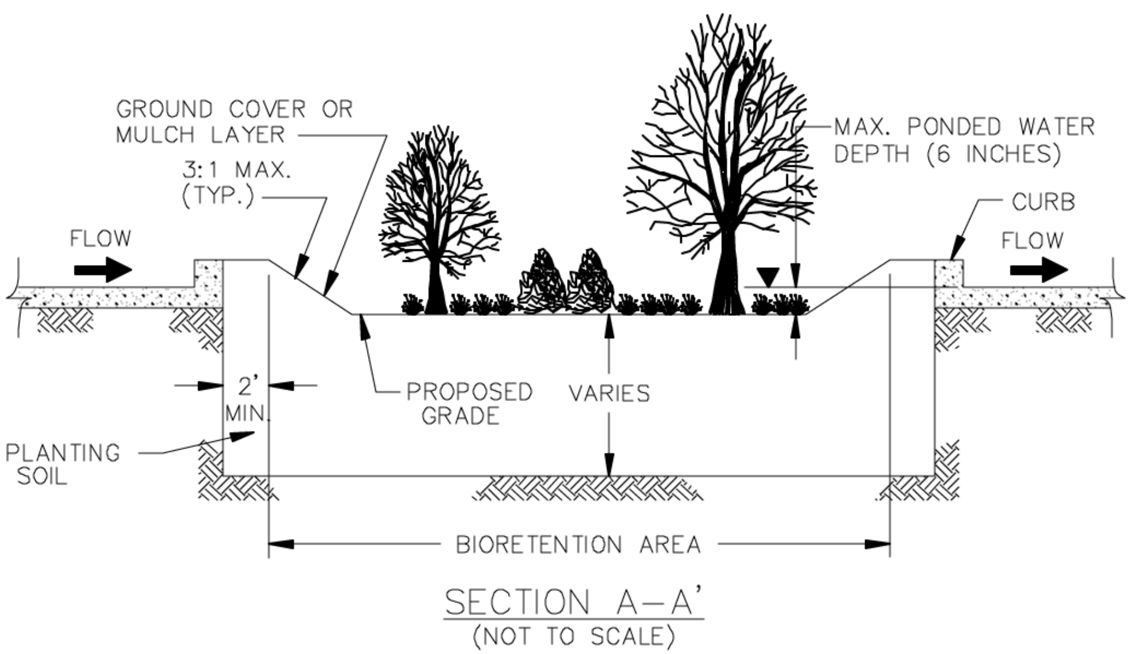
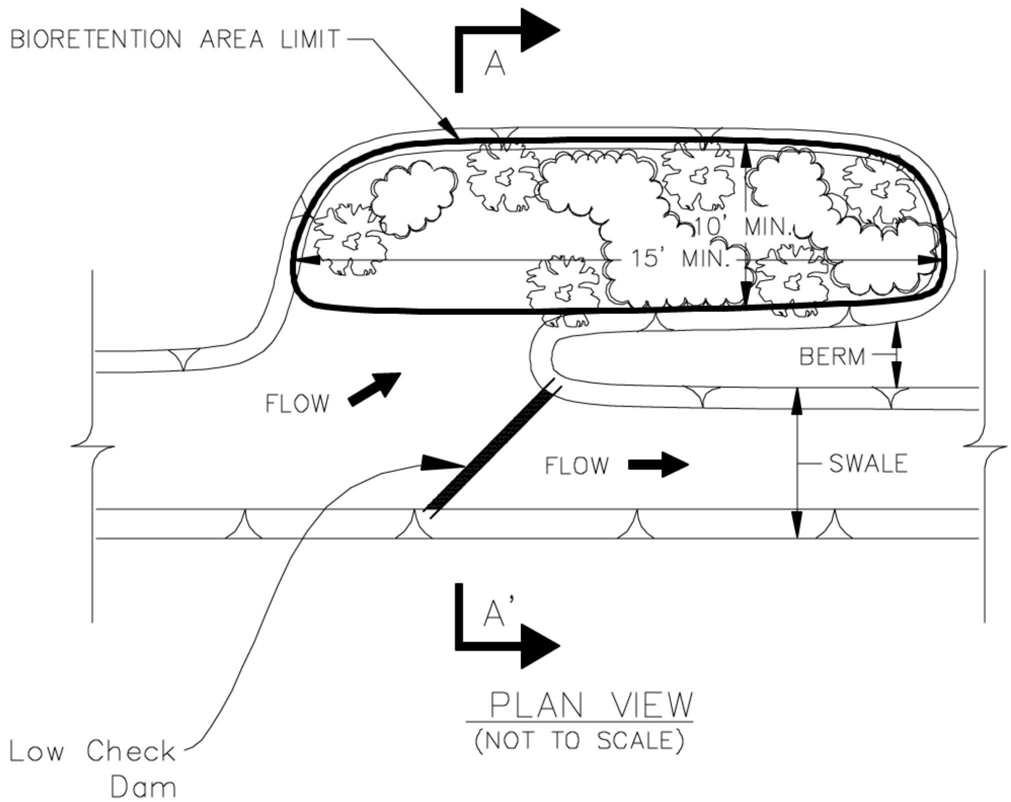


Figure 20. Bioretention Basin Adjacent to a Drainage Swale



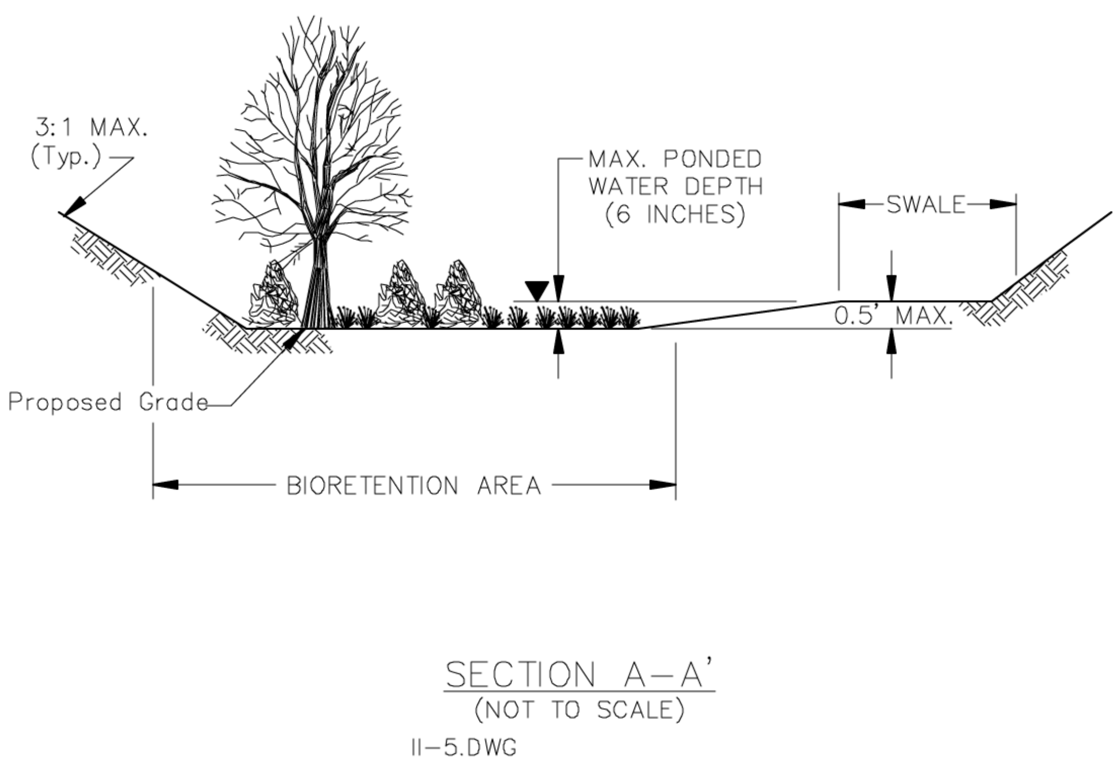
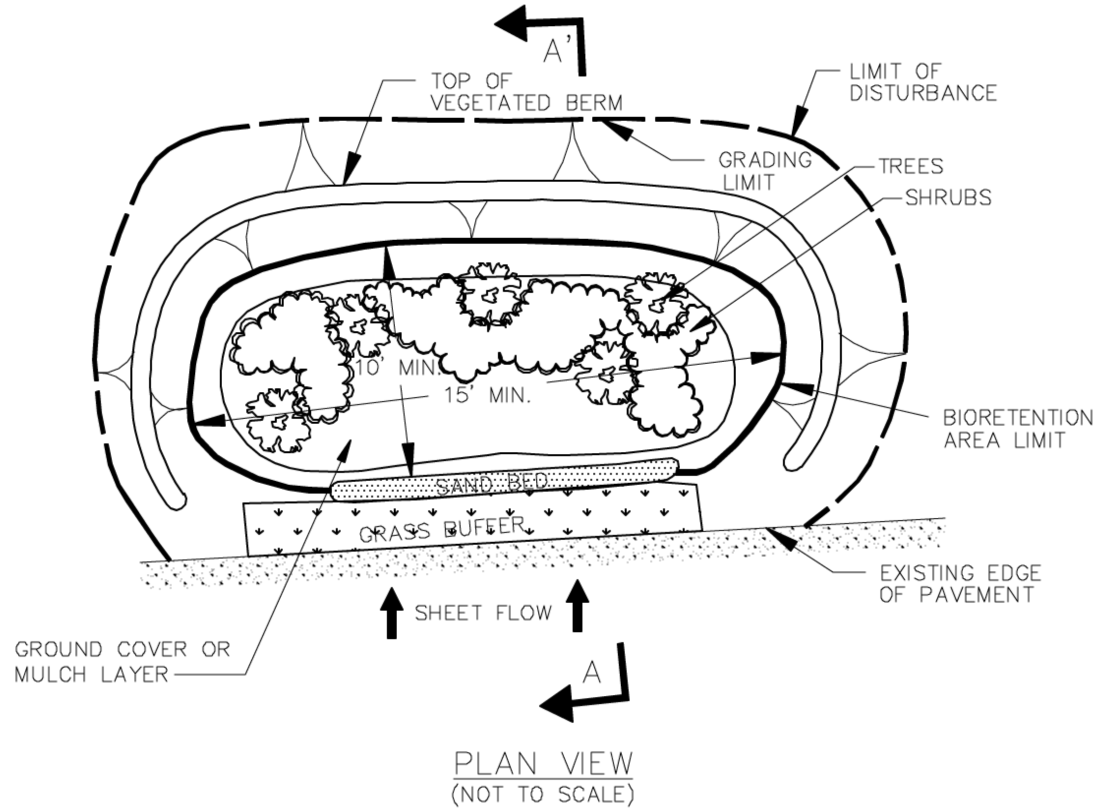
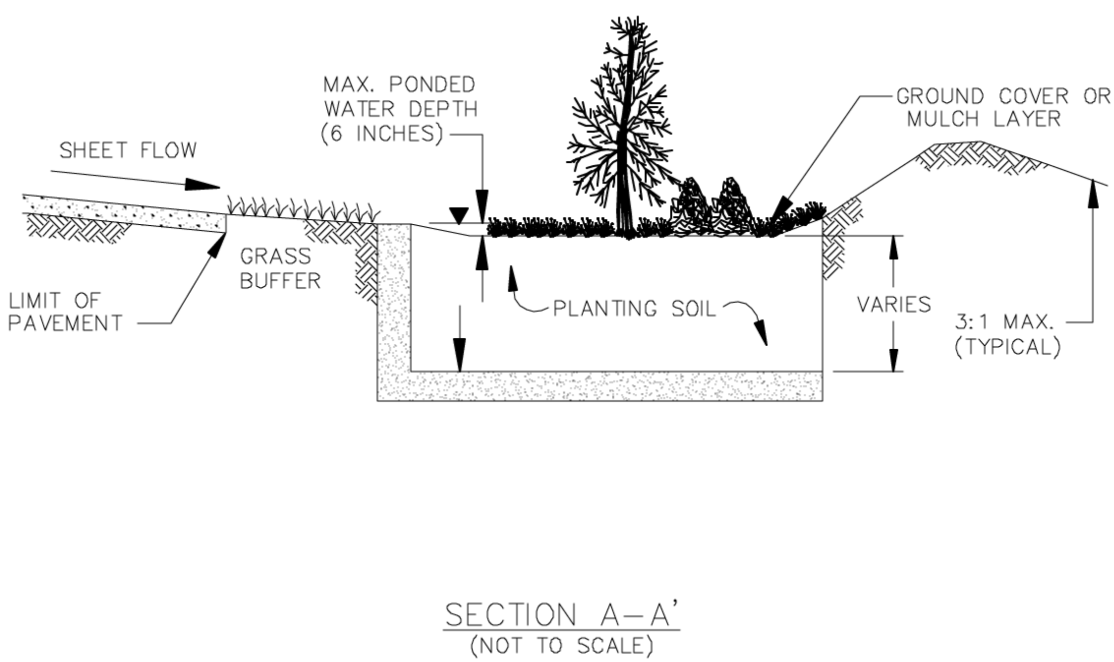


Figure 21. Bioretention Basin at Edge of Parking Lot Without Curbs





4. Planning Considerations

Site Conditions

In addition to site conditions affecting infiltration practices in general, the following apply specifically to bioretention basins. The application of individual bioretention basins will usually be limited to drainage areas from 0.25 to 1 acre. Generally, commercial or residential drainage areas exceeding 1 acre in size will discharge sheet flows greater than 5 cfs.

a. Location Guidelines

Preferable locations for bioretention basins include 1) areas upland from inlets or outfalls that receive sheet flow from graded areas, and 2) areas of the site that will be excavated or cut. When available, areas of loamy sand soils should be used since these types of soils comprise the planting soils for bioretention basins. Locating the BMP in such natural locations would eliminate the cost of importing planting soils (see soil and organic specification under Design Considerations). BMP location should be <u>integral</u> with preliminary planning studies.

The following areas would be <u>undesirable</u> for bioretention basins: 1) areas that have mature trees which would have to be removed for construction of the bioretention basin, 2) areas that have existing slopes of 20% or greater, and 3) areas above or in close proximity to an unstable soil strata such as marine clay.

b. Sizing Guidelines

For planning purposes, assume that the floor area of the bioretention basin will be a minimum of 25% of the impervious area draining to the basin if the first 0.6 inches of runoff is to be treated and a minimum of 4.0% of the impervious area on the drainage shed if the first 1.0 inches of runoff is to be treated. Derivation of these values is discussed below under Design Considerations. Note that small project such as single family residences will likely default to the minimum 150 square foot area (10’ x 15’).

c. Aesthetic Considerations

Aesthetic considerations of the bioretention basin must be considered early in the site planning process. While topography and hydraulic consideration may dictate the general placement of such facilities, overall aesthetics of the site and the bioretention basins must be integrated into the site plan and stormwater concept plan from their inception. Both the stormwater engineer and the Landscape Architect must participate during the layout of facilities and infrastructure to be placed on the site. Bioretention design must be an integral part of the site planning process.

Sediment Control

Like other infiltration practices, provisions for long-term sediment control must be incorporated into the design, as well as precautions during on-site construction activities. Careful consideration must be given in advance of construction to the effects of work sequencing, techniques, and equipment employed on the future maintenance of the practice. Serious maintenance problems can be averted, or in large part, mitigated, by the adoption of relatively simple measures during construction.

a. Construction Runoff

Like other infiltration BMPs, bioretention basins constructed prior to full site stabilization will become choked with sediment from upland construction operations, rendering them inoperable from the outset. Simply providing inlet protection or some other filtering mechanism during construction will not adequately control the sediment. One large storm may completely clog the bioretention basin, requiring complete reconstruction.

Experience with infiltration practices has also demonstrated that the bioretention basin site should NOT be used as the site of sedimentation basins during construction. Such use tends to clog the underlying strata and diminish their capacity to accept infiltration below that indicated in preconstruction soil studies.

Bioretention basins are landscape amenities and should be installed with other landscaping as the last stage of project construction. A detailed sediment control design to protect the bioretention basin during its construction should be included with the facility design.

The definition of the term "adequately stabilized" is critical to the success of the facility. At the conclusion of construction activity, the temporary erosion and sediment control measures are usually removed at the direction of the erosion and sediment control inspector when, at a minimum, stabilization measures such as seed and mulch are in place. This does not mean, however, that stabilization has actually occurred. Bioretention basins must be protected until stabilization of the upland site is functioning to control the sediment load from denuded areas. Provisions to bypass the stormwater away from the bioretention basin during the stabilization period should be implemented.

b. Urban Runoff

A fully stabilized site will generate particulate pollutant load resulting from natural erosion, lawn and garden debris such as leaves, grass clippings, mulch, roadway sand, etc. Pretreatment of runoff to remove sediments prior to entering the bioretention basin is usually provided by a grass filter strip or grass channel. When runoff from sheet flow from such areas as parking lots, residential yards, etc., is involved, a grass filter strip, often enhanced with a pea gravel diaphragm, is usually employed. Table 14 provides sizing guidelines as a function of inflow approach length, land use, and slope. Minimum filter strip length (flow path) should be 10 feet.

Table 14 Pretreatment Filter Strip Sizing Guidance
(Source: Claytor and Schueler, 1996)

Parameter	**Impervious Parking Lots**				**Residential Lawns**				**Notes**
Maximum Inflow Approach Length (feet)	**35**		**75**		**75**		**150**		
Filter Strip Slope	≤ 2%	≥2%	≤2%	≥2%	≤2%	≥2%	≤2%	≥2%	Maximum = 6%
Filter Strip Minimum Length	10'	15'	20'	25'	10'	12'	15'	18'	

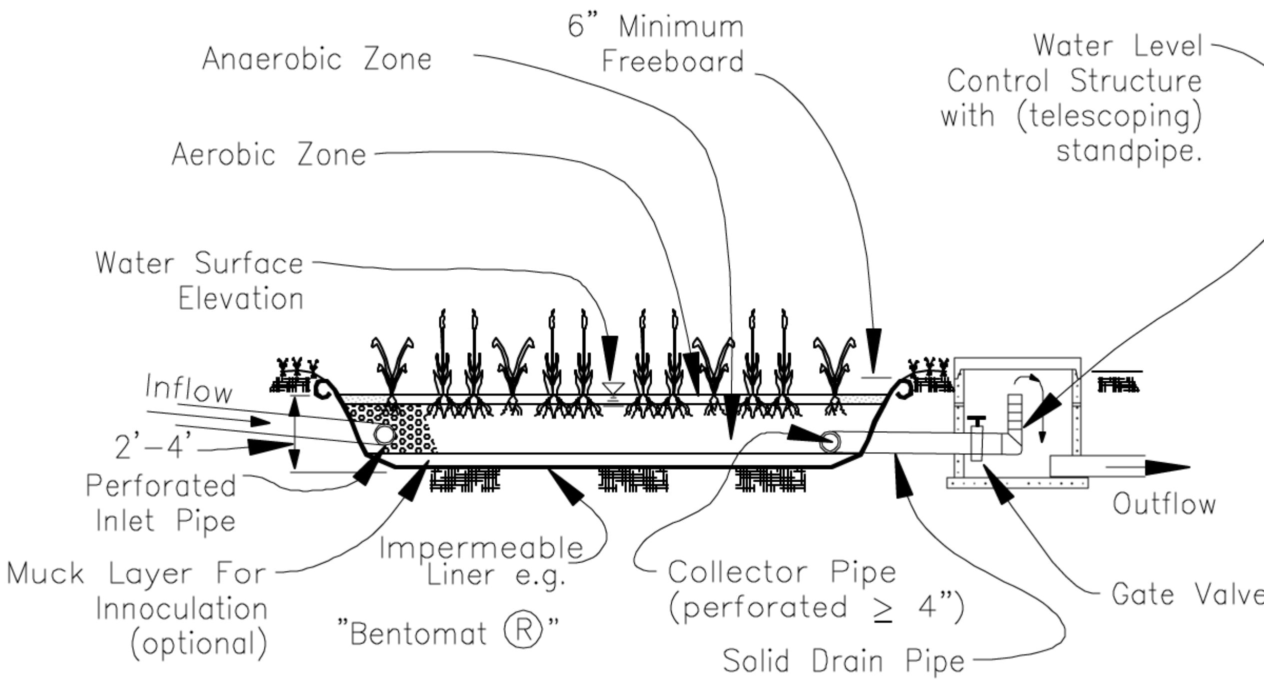
For applications where concentrated runoff enters the bioretention basin by surface flow, such as through a slotted curb opening, a grassed channel, often equipped with a pea gravel diaphragm to slow the velocity and spread out the flow entering the basin, is the usual pretreatment method. The length of the grassed channel depends on the drainage area, land use, and channel slope. Table 15 provides recommendations on sizing for grass channels leading into the bioretention basin for a one acre drainage area. The minimum grassed channel length should be 20 feet.

Table 15 Pretreatment Grass Channel Sizing Guidance for a 1.0-Acre Drainage Area
(Source: Claytor and Schueler, 1996)

Parameter	**≤ 33% Impervious**		**Between 34% and 66% Impervious**		**≥ 67% Impervious**		**Notes**
Slope	≤2%	≥2%	≤2%	≥2%	≤2%	≥2%	Maximum slope = 4%
Grassed channel minimum length (feet)	25	40	30	45	35	50	Assumes a 2' wide bottom width

When concentrated piped flow from impervious areas such as parking lots is routed to a bioretention basin, an energy absorbing and sedimentation structure in which the flow rises into the basin like a tide is usually advisable. Since sediments must usually be removed from such structures on a regular basis, they must be placed in locations where the extension booms on vacuum trucks may easily reach them. Figure 22, below, illustrates an upflow inlet structure for a bioretention basin. Maintenance requirements for pretreatment measures are discussed Section 7 Maintenance Inspection Guidelines.

Figure 22. Upflow Inlet for Bioretention Basin
(Source: City of Alexandria)



5. General Design Criteria

The purpose of this section is to provide minimum criteria for the design of bioretention basin BMPs intended to comply with the Winchester Stormwater program's runoff quality requirements and design requirements as well as the additional criteria set forth below. The designer is not only responsible for selecting the appropriate components for the particular design but also for ensuring long-term operation.

Soils Investigation

As with infiltration basins, a minimum of one soil boring log should be required for each 5,000 square feet of bioretention basin area (plan view area) and in no case less than three soil boring logs per basin.

Topographic Conditions

Like other infiltration facilities, bioretention basins should be a minimum of 50 feet from any slope greater than 15 percent. A geotechnical report should address the impact of the basin upon the steep slope (especially in marine clay areas). Also, bioretention basins should be a minimum of 100 feet up-slope and 20 feet downslope from any buildings.

Basin Sizing Methodology

Bioretention basins are designed to exfilter the treatment quantity into the underlying soil strata, or into an underlying perforated underdrain system connected to a storm drain system or other outfall when the underlying soils, proximity to building foundation, or other such restrictions preclude the use of infiltration. When such an underdrain system is used, the facility is referred to as a Bioretention Filter – Minimum Standard.

Recent research at the University of Maryland has supported a reduction in overall depth of the planting soil to 2.5 feet. Generally, the soil depth can be designed to a minimum depth equal to the diameter of the largest plant root ball plus 4 inches. The recommended soil composition was revised to reduce the clay and increase the sand content (Refer to Soil Texture and Structure later in this standard). This revised soil composition also eliminated the 12” sand layer at the bottom of the facility. The researchers concluded that significant pollutant reductions are achieved in the mulch layer and the first 2 to 2.5 feet of soil.

The elevation of the overflow structure should be 0.5 feet above the mulch layer of the bioretention bed. When underdrain system is used the overflow can be as much as 1.0 feet above the mulch layer.

The size of the bioretention facility is dictated by the amount of impervious surface in the contributing drainage area. For facilities capturing the first 0.5 inches of runoff from the impervious areas in the drainage shed, the surface area of the bioretention bed should be a minimum of 3% of the impervious area, or 1,300 square feet per impervious acre.

The minimum width and length is recommended at 10 feet and 15 feet respectively. (Widths as narrow as 4 feet may be used if the runoff arrives as dispersed sheet flow along the length of the facility from a properly sized vegetated strip).

The elevation of the overflow structure should be 0.5 feet above the mulch elevation of the bioretention bed.

Note that small projects such as single family residences may default to the minimum (10’ x 15’) 150 square foot area.

Runoff Pretreatment

Like other infiltration basins, bioretention basins must always be preceded by a pretreatment facility to remove grease, oil, floatable organic material, and settleable solids (see Urban Runoff section of Sediment Control under Planning Considerations above). Where space constraints allow, runoff should be filtered by a grass buffer strip and sand bed. The buffer strip and sand bed will reduce the amount of fine material entering the bioretention area and minimize the potential for clogging of the planting soil. The sand bed also increases the infiltration capacity and provides aeration for the plant roots in the bioretention area. For basins for which high sediment loadings are expected (treating largely pervious areas, etc.) the design can be modified to include a sediment forebay. Any pretreatment facility should be included in the design of the basin and should include maintenance and inspection requirements.

Drainage Considerations

The grading design must shape the site so that all runoff from impervious areas is routed through the bioretention basins. The basins must be sited so as to accept the design runoff quantity before bypassing any excess flow to the storm drainage system. Bioretention basin locations must therefore be integrated into the basic site design from its inception. Most of the Planning Considerations delineated above must come into play at this early stage in the design process. The overall site and impervious surfaces must be contoured to direct the runoff to the basins. Bioretention basins cannot usually be successfully integrated into a site design that does not take stormwater management into account from its inception. Elevations must be carefully worked out to assure that the desired amount runoff will flow into the basins and pool at no more than the maximum design depth. This requires a much higher degree of vertical control during construction that is normal with most landscaping work.

Preferably, bioretention basins should be placed “off-line”, i.e. the design should provide for runoff to be diverted into the basin until it fills with the treatment volume and then bypass the remaining flow around the BMP to the storm drainage system. The drainage systems shall be designed to handle the 10-year, 24 hour storm). To prevent flood damage, however, the bioretention basin design must take into account how the runoff will be processed when larger events occur. This may require, at a minimum, that a vegetated emergency spillway be provided, and that a path for overland flow to an acceptable channel be incorporated into the design. The designer should provide for relief from the 25-year storm event.

Figure 18 illustrates an “off-line” application at the edge of a parking lot with curb and gutter. The inlet deflectors divert runoff into the bioretention basin until the basin fills and backs up. Subsequent runoff then bypasses to the adjacent, down gradient storm inlet. Figure 19 illustrates an “off-line” application in a planting island in a parking lot, while Figure 20 illustrates an “off-line” application adjacent to a drainage swale (such highway drainage). Again, runoff flows into the bioretention basin until it fills, then bypasses down the swale. Placement of a flow diversion check dam in the swale will facilitate filling the basin. In some situations, an “off-line” configuration may not be practical or economical.

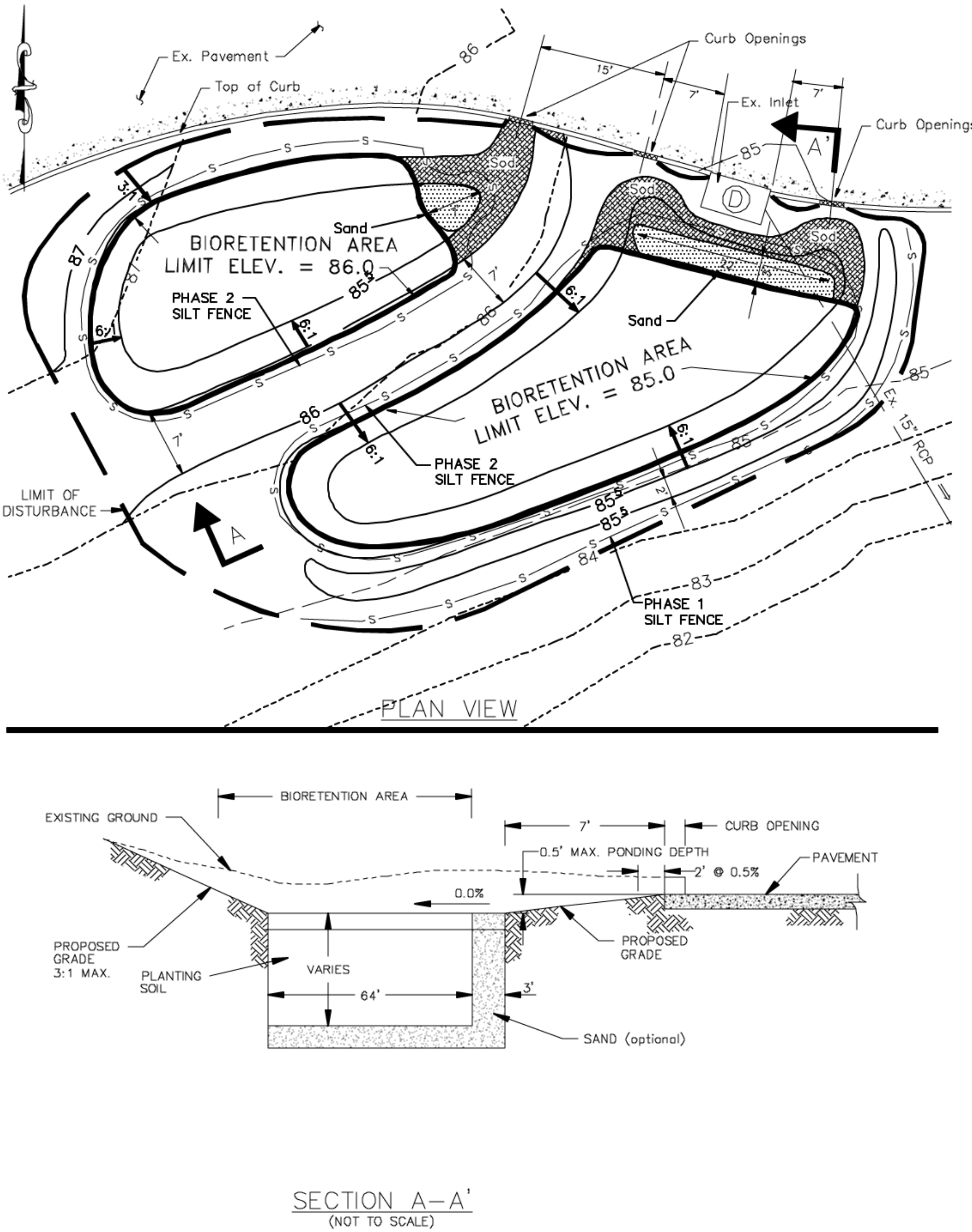
Figure 23, below, illustrates a grading plan for a bioretention basin. The grading plan was created for a double-cell bioretention area. There is a seven-foot buffer between cells which allow for the planting of upland trees. As indicated in the grading plan, sheet and gutter flow is diverted into the bioretention areas though openings in the curb. The elevation of the invert of the bioretention area, is set by the curb opening elevation. The curb opening elevation is 0.5 ft. higher than the invert of the bioretention area, so water is allowed to pond to a maximum depth of one-half foot before runoff bypasses the bioretention area and flows into the storm drain system.

Precise grading of the basin is critical to capturing the water quality volume and operation of the facility. The plan should have a contour interval of no more than one-foot, and spot elevations should be shown throughout the basin. The perimeter contour elevation should contain the design storm without over topping anywhere except at the overflow structure.

Planting Plan

Selection of plantings must include coordination with overall site planning and aesthetic considerations for designing the bioretention plant community. Tables listing suitable species of trees, shrubs, and ground cover are provided at the end of this section. This listing is not intended to be all-inclusive due to the continual introduction of new horticultural varieties and species in the nursery industry.

Figure 23. Grading Plan for Bioretention Basin



a. Planting Concept

The use of plantings in bioretention areas is modeled from the properties of a terrestrial forest community ecosystem. The terrestrial forest community ecosystem is an upland community dominated by trees, typically with a mature canopy, having a distinct sub-canopy of understory trees, a shrub layer and herbaceous layer. In addition, the terrestrial forest ecosystem typically has a well-developed soil horizon with an organic layer and a mesic moisture regime. A terrestrial forest community model for stormwater management was selected based upon a forest's documented ability to cycle and assimilate nutrients, pollutants, and metals through the interactions among plants, soil, and the organic layer. These three elements are the major elements of the bioretention concept.

Key elements of the terrestrial forest ecosystem that have been incorporated into bioretention design include species diversity, density, and morphology, and use of native plant species. Species diversity protects the system against collapse from insect and disease infestations and other urban stresses such as temperature and exposure. Typically, indigenous plant species demonstrate a greater ability of adapting and tolerating physical, climatic, and biological stresses.

b. Plant Species Selection

Plant species appropriate for use in bioretention areas are presented in Table 16 provided at the end of this section. These species have been selected based on the ability to tolerate urban stresses such as pollutants, variable soil moisture and ponding fluctuations. Important design considerations such as form, character, massing, texture, culture, growth habits/rates, maintenance requirements, hardiness, size, and type of root system are also included. A key factor in designating a species as suitable is its ability to tolerate the soil moisture regime and ponding fluctuations associated with bioretention. The plant indicator status (Reed, 1988) of listed species are predominantly facultative (i.e. they are adapted to stresses associated with both wet and dry conditions); however, facultative upland and wetland species have also been included. This is important because plants in bioretention areas will be exposed to varying levels of soil moisture and ponding throughout the year, ranging from high levels in the spring to potential drought conditions in the summer.

Recent research suggests an increase in the importance of the mulch layer and groundcover plant species in pollutant removal. The plant list in this standard will be expanded to include perennial flowering plants. A robust groundcover species with a thick mulch layer is recommended.

Table 16 Popular Native Plant Materials for Bioretention Basins

Perennials/Herbaceous	Shrubs	Trees
Virginia Wild Rye (*Elymus virginicus*)	Common Winterberry (*Ilex verticillatta*)	River Birch (*Betula nigra*)
Redtop Grass (*Agrostis alba*)	Inkberry (*Ilex glabra*)	Red Maple (*Acer rubrum*)
Swamp Milkweed (*Asclepias incarnate*)	Sweet Pepperbush (*Clethra ainifolia*)	Pin Oak (*Quercus palustris*)
Switchgrass (*Panicum virgatum*)	Wax Myrtle (*Myrica cerifera*)	Willow Oak (*Quercus phellos*)
Cardinal Flower (*Lobelia cardinalis*)	Virginia Sweetspire (*Itea virginica*)	Sweetgum (*Liquidambar styraciflua*)
Common Three Square (*Scirpus americanus)*	Swamp Azeala (*Azeala viscosum)*	Black Willos (*salix nigra)*
Sensitive Fern *(Onoclea sensibilis)*	Button Bush *(Cephalanthus occidentalis)*	Grey Birch *(Betula populifolia)*
Blue Flag *(Iris versicolor)*	Black Haw *(Virburnum prunifolium)*	Black Gum *(Nyassa sylvatica)*
Woolgrass *(Scirpus cyperninus)*	Indigo Bush *(Amorpha fruticosa)*	Sycamore *(Platanus occidentalis)*
Indian Grass *(Sorghastrum nutans)*	Arrowwood *(Virburum dentatum)*	Green Ash *(Fraxinu pennsylvanica)*
Marsh Marigold *(Caltha palustris)*		Sweetbay Magnolia* *(Magnolia virginiana)*
Joe Pye Weed *(Eupatorium purpureum)*		Atlantic White Cedar* *(Charnaecyparis thyoides)*
Turk's cap lily *(Lilium superbum)*		Bald Cypress* *(Taxodium distichum)*
Bee Balm *(Mornarda didyma)*		Grey Dogwood *(Cornus racernosa)*
Northern Sea Oats *(Chasmanthium latifolium)*		Smooth Alder *(Alnus serrulata)*
		Serviceberry *(Amelanchier canadensis)*
		Redbud *(Cercis candensis)*
		Box Elder *(Acer negundo)*
		Fringe Tree *(Chionanthus virginicus)*
Note: Prior to selection, please consult bioretention plant lists for more detailed information regarding inundation, drought and salt tolerance for each species.		

c. Site and Ecological Considerations

Selection of plant species should be based on site conditions and ecological factors. Site considerations include microclimate (light, temperature, wind), the importance of aesthetics, overall site development design and the extent of maintenance requirements, and proposed or existing buildings. Of particular concern is the increase in reflection of solar radiation from buildings upon bioretention areas. Aesthetics are critical in projects of high visibility. Species that require regular maintenance (shed fruit or are prone to storm damage) should be restricted to areas of limited visibility and pedestrian and vehicular traffic.

Intersections with adjacent plant communities are also critical. Nearby existing vegetated areas dominated by non-native invasive species pose a threat to adjacent bioretention areas. Proposed bioretention area species should be evaluated for compatibility with adjacent plant communities. Invasive species typically develop into monocultures by out competing other species. Mechanisms to avoid encroachment of undesirable species include increased maintenance, providing a soil breach between the invasive community for those species that spread through rhizomes, and providing annual removal of seedlings from wind borne seed dispersal. Existing disease or insect infestations associated with existing site conditions or in the general area that may effect the bioretention plantings.

d. Number of Species

A minimum of three species of trees and three species of shrubs should be selected to insure diversity. In addition to reducing the potential for monoculture mortality concerns, a diversity of trees and shrubs with differing rates of transpiration may ensure a more constant rate of evapotranspiration and nutrient and pollutant uptake throughout the growing season. Herbaceous ground covers are important to prevent erosion of the mulch and the soil layers.

e. Number and Size of Plants

The requisite number of plantings varies, and should be determined on an individual site basis. On average, 1000 trees and shrubs should be planted per acre. For example, a bioretention area measuring 15’ x 40’ would contain a combination of trees and shrubs totaling 14 individuals. The recommended minimum and maximum number of individual plants and spacing are given in Table 17. Two to three shrubs should be specified for each tree (2:1 to 3:1 ratio of shrubs to trees).

At installation, trees should be 1.0 inches minimum in caliper, and shrubs 3 to 4 feet in height or 18 to 24 inches in spread per ASNI Z60. Ground cover may be as seed or, preferably, plugs. The relatively mature size requirements for trees and shrubs are important to ensure that the installation of plants are readily contributing to the bioretention process (i.e. evapotranspiration, pollutant uptake).

Table 17 Recommended Tree and Shrub Spacing

	Tree Spacing (feet)	Shrub Spacing (feet)	Total Density (stems/acre)
Maximum	19	12	400
Average	12	8	1000
Minimum	11	7	1250

f. Plant Layout

The layout of plant material can be a flexible process; however, the designer should follow two basic guidelines. First, woody plant material should not be placed within the immediate areas of where flow will be entering the bioretention area. Besides possibly concentrating flows, trees and shrubs can be damaged as a result of the flow. Secondly, it is recommended that trees be planted primarily on the perimeter of bioretention areas, to maximize the shading and sheltering of bioretention areas to create a microclimate which will limit the extreme exposure from summer solar radiation and winter freezes and winds. An example planting plan is shown in Figure 24, page 109.

Mulch Layer Guidelines

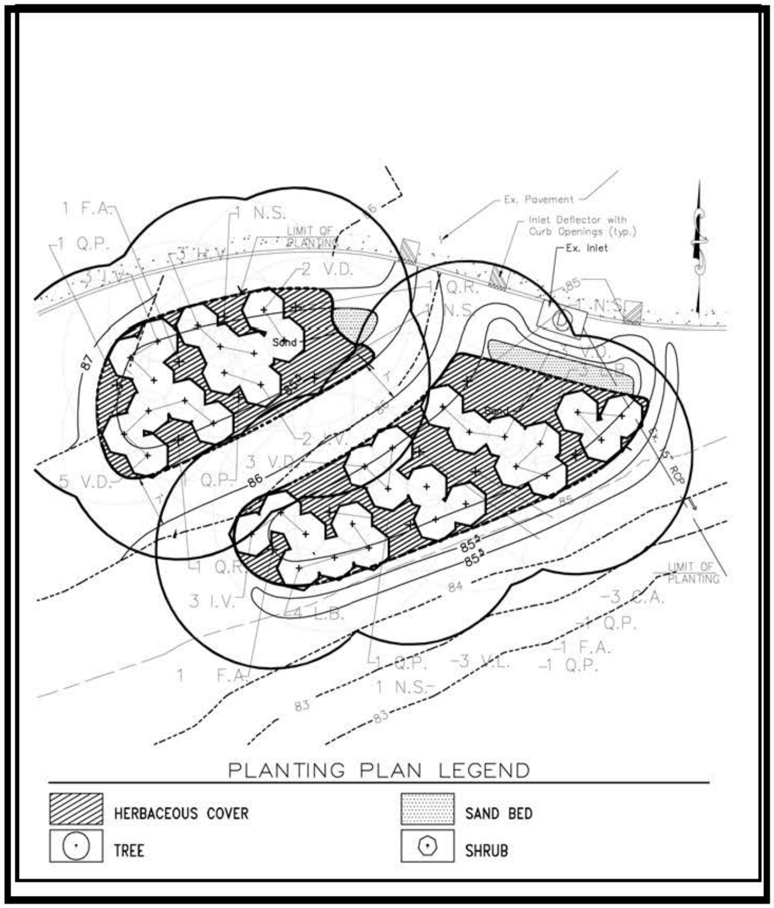
A mulch layer serves to prevent erosion and to protect the soil from excessive drying. Soil biota existing within the organic and soil layer are important in the filtering of nutrients and pollutants and assisting in maintaining soil fertility. Bioretention areas can be designed either with or without a mulch layer. If a herbaceous layer or ground cover (70 to 80% coverage) is provided, a mulch layer is not necessary. Areas should be mulched once trees and shrubs have been planted. Any ground cover specified as plugs may be installed once mulch has been applied.

The mulch layer recommended for bioretention may consist of either standard landscape fine shredded hardwood mulch or shredded hardwood chips. Both type of mulch are commercially available and provide excellent protection from erosion.

Mulch shall be free of weed seeds, soil, roots, or any other substance not consisting of either bole or branch wood and bark. The mulch shall be uniformly applied approximately 2 to 3 inches in depth. Mulch applied any deeper than three inches reduces proper oxygen and carbon dioxide cycling between the soil and the atmosphere.

Grass clippings are unsuitable for mulch, primarily due to the excessive quantities of nitrogen built up in the material. Adding large sources of nitrogen would limit the capability of bioretention areas to filter the nitrogen associated with runoff.

Figure 24 Sample Planting Plan



Plant Material Guidelines

a. Plant Material Source

The plant material should conform to the current issue of the American Standard for Nursery Stock published by the American Association of Nurserymen. Plant material should be selected from certified nurseries that have been inspected by state or federal agencies. The botanical (scientific) name of the plant species should be in accordance with a standard nomenclature source such as Birr, 1975.

Some of the plant species listed in Table 16 (page 105) may be unavailable from standard nursery sources. These are typically species native to Kentucky and may not be commonly used in standard practices. Designers may need to contact nurseries specializing in native plants propagation.

b. Installation

The success of bioretention areas is dependent on the proper installation specifications that are developed by the designer and subsequently followed by the contractor. The specifications include the procedures for installing the plants and the necessary steps taken before and after installation. Specifications designed for bioretention should include the following considerations:

- Sequence of Construction
- Contractors Responsibilities
- Planting Schedule and Specifications
- Maintenance
- Warranty

The sequence of construction describes site preparation activities such as grading, soil amendments, and any pre-planting structure installation. It also should address erosion and sediment control procedures. Erosion and sediment control practices should be in place until the entire bioretention area is completed. The contractor's responsibilities should include all the specifications that directly effect the contractor in the performance of his or her work. The responsibilities include any penalties for unnecessarily delayed work, requests for changes to the design or contract, and exclusions from the contract specifications such as vandalism to the site, etc.

The planting schedule and specifications include type of material to be installed (e.g. ball and burlap, bare root, or containerized material), timing of installation and post installation procedures. Balled and burlapped and containerized trees and shrubs should be planted during the following periods: March 15 through June 30 and September 15 through November 15. Ground cover excluding grasses and legumes can follow tree and shrub planting dates. Grasses and legumes typically should be performed by following the planting specifications set forth in the Winchester specifications that provide guidelines that ensure the proper placement and installation of plant material. Designers may choose to use other specifications or to modify the jurisdiction specifications. However, any deviations from the jurisdiction specifications needs to address the following:

- Transport of plant material
- Preparation of the planting pit
- Installation of plant material
- Stabilization seeding (if applicable)
- Maintenance

An example of general planting specification for trees and shrubs and ground cover is given under Construction Specifications below.

c. Warranties

Typically, a warranty is established as a part of any plant installation project. The warranty covers all components of the installation that the contractor is responsible for. The plant and mulch installation for bioretention should be performed by a professional landscape contractor. An example of standard guidelines for landscape contract work is provided below:

- The contractor shall maintain a one (1) calendar year 80% care and replacement warranty for all planting.

- The period of care and replacement shall begin after inspection and approval of the complete installation of all plants and continue for one calendar year.
- Plant replacements shall be in accordance with the maintenance schedule.

Plant Growth and Soil Fertility

A discussion of plant growth and soil fertility development over time is important to for estimating the success and lifespan of bioretention areas. The physical, chemical, and biological factors influencing plant growth and development will vary over time as well as for each bioretention area. However, there are certain plant and soil processes that will be the same for all bioretention areas.

a. Plant Growth

The role of plants in bioretention includes uptake of nutrients and pollutants and evapotranspiration of stormwater runoff. The plant material, especially ground covers, are expected to contribute to the evapotranspiration process within the first year of planting. However, trees and shrubs that have been recently planted demonstrate slower rates of growth for the first season due to the initial shock of transplanting. The relative rate of growth is expected to increase to normal rates after the second growth season.

The growth rate for plants in bioretention areas will follow a similar pattern to that of other tree and shrub plantings (reforestation projects, landscaping). For the first two years, the majority of tree and shrub growth occurs with the expansion of the plant root system. By the third or fourth year the growth of the stem and branch system dominates increasing the height and width of the plant. The comparative rate of growth between the root and stem and branch system remains relatively the same throughout the lifespan of the plant. The reproductive system (flowers, fruit) of the plants is initiated last.

The growth rates and time for ground covers to become acclimated to bioretention conditions is much faster than for trees and shrubs. The rate of growth of a typical ground cover can often exceed 100 percent in the first year. Ground covers are considered essentially mature after the first year of growth. The longevity of ground covers will be influenced by the soil fertility and chemistry as well as physical factors, such as shading and overcrowding from trees and shrubs and other ecological and physical factors.

Plants are expected to increase their contribution to the bioretention concept over time, assuming that growing conditions are suitable. The rate of plant growth is directly proportional to the environment in which the plant is established. Plants grown in optimal environments experience the greatest rates of growth. One of the primary factors determining this soil fertility.

b. Soil Fertility

Initially, soil in bioretention areas will lack a mature soil profile. It is expected that over time discrete soil zones referred to as horizons will develop. The development of a soil profile and the individual horizons is determined by the influence of the surrounding environment including physical, chemical, and biological processes. Two primary processes important to horizon development is microbial action and the percolation of runoff in the soil.

Horizons expected to develop in bioretention areas include an organic layer, followed by two horizons where active leaching (eluviation) and accumulation (illuviation) of minerals and other substances occur. The time frame for the development of soil horizons will vary greatly. As an average, soil horizons may develop within three to ten years. The exception to this is the formation of the organic layer often within the first or second year (Brady, 1984).

The evaluation of soil fertility in bioretention may be more dependent on the soil interactions relative to plant growth than horizon development the soil specified for bioretention is important in filtering pollutants and nutrients as well as supply plants with water, nutrients, and support. Unlike plants that will become increasingly beneficial over time, the soil will begin to filter pollutants and nutrients may decrease over time, reducing the soil fertility accordingly. Substances from runoff such as salt and heavy metals eventually disrupt normal soil functions by lowering the cation exchange capacity (CEC). The CEC, the ability to allow for binding of particles by ion attraction, decreases to the point that the transfer of nutrients for plant uptake cannot occur. However, the environmental factors influencing each bioretention area will vary enough that it is difficult to predict for the lifespan of soils. Findings from other stormwater management systems suggest an accumulation of substances eliminating soil fertility with five years. The monitoring of soil development in bioretention areas will help develop better predictions on soil fertility and development.

6. Construction Specifications

The construction of bioretention basins should be in accordance with the criteria set forth below.

Sequence of Construction

The sequence of various phases of basin construction must be coordinated with the overall project construction. As with other infiltration practices, rough excavation of the basin may be scheduled with the rough grading of the project o permit use of the excavated material as fill elsewhere on the site. However, the bioretention basin must not be constructed or placed in service until the entire contributing drainage area has been stabilized. Runoff from untreated, recently constructed areas within the drainage area may otherwise load the newly formed basin with a large load of fine sediment, seriously impairing the natural infiltration ability of the basin floor. For these reasons, the locations of infiltration bioretention basins must NOT be used for sediment basins for erosion and sediment protection during site construction. The sequence of construction shall be as follows:

a. Install Phase I erosion and sediment control measures for the site.

b. Grade each site to elevations shown on plan. Initially, the basinfloor may be excavated to within one foot of its final elevation. Excavation to finished grade shall be deferred until all disturbed areas within the watershed have been stabilized and protected. Construct curb openings, and/or remove and replace existing concrete as specified on the plan. Curb openings shall be blocked or other measures taken to prohibit drainage from entering construction area.

c. Complete construction on the watershed and stabilize all areas draining to the Bioretention basin.

d. Remove Phase I sediment control devices at direction of designated inspector.

e. Install Phase II erosion and sediment control measures for bioretention area.

f. Remove all accumulated sediment and excavate Bioretention Area to proposed depth. Use relatively light, tracked equipment to avoid compaction of the basin floor. After final grading is completed, deeply till the basin floor with rotary tillers or disc harrows that will provide a well-aerated, highly porous surface texture.

g. Install the infiltration chambers, piping, manifolds, drains, vents, and infiltration stone in accordance in with the specifications and directions of the chamber manufacturer. Install a six-inch layer of washed, 1/4-inch pea gravel above the stone. Install a 1-foot layer of ASTM C-33 concrete sand on top of the pea gravel. Lightly compact with a landscaping roller.

h. After confirmation that soil meets specs by performing the requisite gradation and chemical tests (see below), fill Bioretention Area with planting soil and sand, as shown in the plans and detailed in the specifications.

i. Install vegetation and ground cover specified in the planting plan for Bioretention Area.

j. Install mulch layer if called for in the design.

k. Place sod, EC fabric, or non-erosive lining (depending on inflow velocities) in the inlet channel and/or filter strips.

l. Upon authorization from designated inspector, remove all sediment controls and stabilize all disturbed areas. Unblock curb openings, and provide drainage to the Bioretention Areas.

Bioretention Area Soil Specifications

a. Planting Soil

The bioretention areas shall contain a planting soil mixture of 50% sand, 30% leaf compost (fully composted, NOT partially rotted leaves), and 20% topsoil. Topsoil shall be sandy loam or loamy sand of uniform composition, containing no more than 5% clay, free of stones, stumps, roots, or similar objects greater than one inch, brush, or any other material or substance which may be harmful to plant growth, or a hindrance to plant growth or maintenance.

The top soil shall be free of plants or plant parts of Bermuda grass, Quack grass, Johnson grass, Mugwort, Nutsedge, Poison Ivy, Canadian Thistle or others as specified. It shall not contain toxic substances harmful to plant growth.

One grain size analysis shall be performed per 90 cubic yards of planting soil, but no less than 1 test per Bioretention Area. Soil tests must be verified by a qualified professional.

b. Mulch

A mulch layer shall be provided on top of the planting soil. An acceptable mulch layer shall include shredded hardwood or shredded wood chips or other similar product.

Of the approved mulch products all must be well aged, uniform in color, and free of foreign material including plant material.

c. Sand

The sand for bioretention basins when utilized, shall be ASTM C-33 Concrete Sand and free of deleterious material.

d. Compaction

Soil shall be placed in lifts less than 18 inches and lightly compacted (minimal compactive effort) by tampering or rolled with a hand-operated landscape roller.

Bioretention Area Planting Specifications

a. Root stock of the plant material shall be kept moist during transport from the source to the job site and until planted.

b. Walls of planting pit shall be dug so that they are vertical.

c. The diameter of the planting pit must be a minimum of six inches (6”) larger than the diameter of the ball of the tree.

d. The planting pit shall be deep enough to allow 1/8 of the overall dimension of the root ball to be above grade. Loose soil at the bottom of the pit shall be tamped by hand.

e. The appropriate amount of fertilizer is to be placed at the bottom of the pit (see below for fertilization rates).

f. The plant shall be removed from the container and placed in the planting pit by lifting and carrying the plant by its’ ball (never lift by branches or trunk).

g. Set the plant straight and in the center of the pit so that approximately 1/8 of the diameter of the root ball is above the final grade.

h. Backfill planting pit with existing soil.

i. Make sure plant remains straight during backfilling procedure.

j. <u>Never cover the top of the ball with soil</u>. Mound soil around the exposed ball.

k. Trees shall be braced by using 2” by 2” white oak stakes. Stakes shall be placed parallel to walkways and buildings. Stake are to be equally spaced on the outside of the tree ball. Utilizing hose and wiring the tree is braced to the stakes.

l. Because of the high levels of nutrients in stormwater runoff to be treated, bioretention basin plants should not require chemical fertilization.

7. Maintenance/Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all inclusive. Specific facilities may require additional measures not discussed here.

A schedule of recommended maintenance for bioretention areas is given in Table 18, page 117. The table gives general guidance regarding methods, frequency, and time of year for maintenance.

Planting Soil

Urban plant communities tend to become very acidic due to precipitation as well as the influences of storm water runoff. For this reason, it is recommended that the application of alkaline, such as limestone, be considered once to twice a year. Testing of the pH of the organic layer and soil, should precede the limestone application to determine the amount of limestone required.

Soil testing should be conducted annually so that the accumulation of toxins and heavy metals can be detected or prevented. Over a period of time, heavy metals and other toxic substances will tend to accumulate in the soil and the plants. Data from other environs such as forest buffers and grass swales suggest accumulation of toxins and heavy metals within five years of installation. However, there is no methodology to estimate the level of toxic materials in the bioretention areas since runoff, soil, and plant characteristics will vary from site to site.

As the toxic substances accumulate, the plant biologic functions may become impaired, and the plant may experience dwarfed growth followed by mortality. The biota within the soil can also become void and the natural soil chemistry may be altered. The preventative measures would include the removal of the contaminated soil. In some cases, removal and disposal of the entire soil base as well as the plant material may be required.

Mulch

Bioretention areas should be mulched once the planting of trees and shrubs has occurred. Any ground cover specified as plugs may be installed once the area has been mulched. Ground cover established by seeding and/or consisting of grass should not be covered with mulch.

Plant Materials

An important aspect of landscape architecture is to design areas that require little maintenance. Certain plant species involve maintenance problems due to dropping of fruit or other portions of the plant. Another problem includes plants, primarily trees that are susceptible to windthrow, which creates a potential hazard to people and property (parked cars). As a result, some plant species will be limited to use in low-traffic areas.

Ongoing monitoring and maintenance is vital to the overall success of bioretention areas.

Annual maintenance will be required for plant material, mulch layer, and soil layer. A maintenance schedule should include all of the main considerations discussed below. The maintenance schedule usually includes maintenance as part of the construction phase of the project and for life of the design. An example maintenance schedule is shown in Table 18.

Table 18 Example Maintenance Schedule for Bioretention Basin

Description	Method	Frequency	Time of the Year
SOIL			
Inspect and Repair Erosion	Visual	Monthly	Monthly
ORGANIC LAYER			
Remulch any void areas	By hand	Whenever needed	Whenever needed
Remove previous mulch layer before applying new layer (optional)	By hand	Once every two to three years	Spring
Any additional mulch added (optional)	By hand	Once a year	Spring
Plants			
Removal and replacement of all dead and diseased vegetation considered beyond treatment	See planting specifications	N/A	3/15 to 4/30 and 10/1 to 11/30
Treat all diseased trees and shrubs	Mechanical or by hand	N/A	Varies, depends on insect or disease infestation
Watering of plant material shall take place at the end of each day for fourteen consecutive days after planting has been completed	By hand	Immediately after completion of project	N/A
Replace stakes after one year	By hand	Once a year	Only remove stakes in the Spring
Replace any deficient stakes or wires	By hand	N/A	Whenever needed
Check for accumulated sediments	Visual	Monthly	Monthly

Maintenance requirements will vary depending on the importance of aesthetics. Soil and mulch layer maintenance will be most likely limited to correcting areas of erosion. Replacement of mulch layers may be necessary every two to three years. Mulch should be replaced in the spring. When the mulch layer is replaced, the previous layer should be removed first. Plant material upkeep will include addressing problems associated with disease or insect infestations, replacing dead plant material, and any necessary pruning.

Control of Sediments on the Drainage Shed

Care must be taken to protect the bioretention basin from excessive sediments from the drainage shed. Whenever additional land disturbing activity takes place in the area draining to the basin, effective erosion and sediment control measures must first be put in place to exclude sediments from the basin. Performance based special measures over and above those specified in the Virginia Erosion and Sediment Control Handbook, latest edition, may be required to assure that the bioretention basin is not damaged by such land disturbance. When sand or other street abrasives are used during the snow or icing conditions to provide traction on roadways or parking lots draining to bioretention basins, the pavement should be power/vacuum swept as soon as freezing weather abates to prevent damage to the basins.

Bioretention Filter in multi-family residential setting

Bioretention Basins in office setting parking lot

K. INFILTRATION BASIN

1. Definition

   An infiltration basin is a vegetated, open impoundment where incoming stormwater runoff is stored until it gradually infiltrates into the soil strata.

2. Purpose

   Infiltration basins are used primarily for water quality enhancement. However, flooding and channel erosion control may also be achieved within an infiltration basin by utilizing a multi-stage riser and barrel spillway to provide controlled release of the required design storms above the water quality (infiltration) volume (refer to Figure 25).

3. Conditions Where Practice Applies

   Infiltration basins may be used where the subsoil is sufficiently permeable to provide a reasonable infiltration rate and where the water table is low enough to prevent pollution of groundwater.

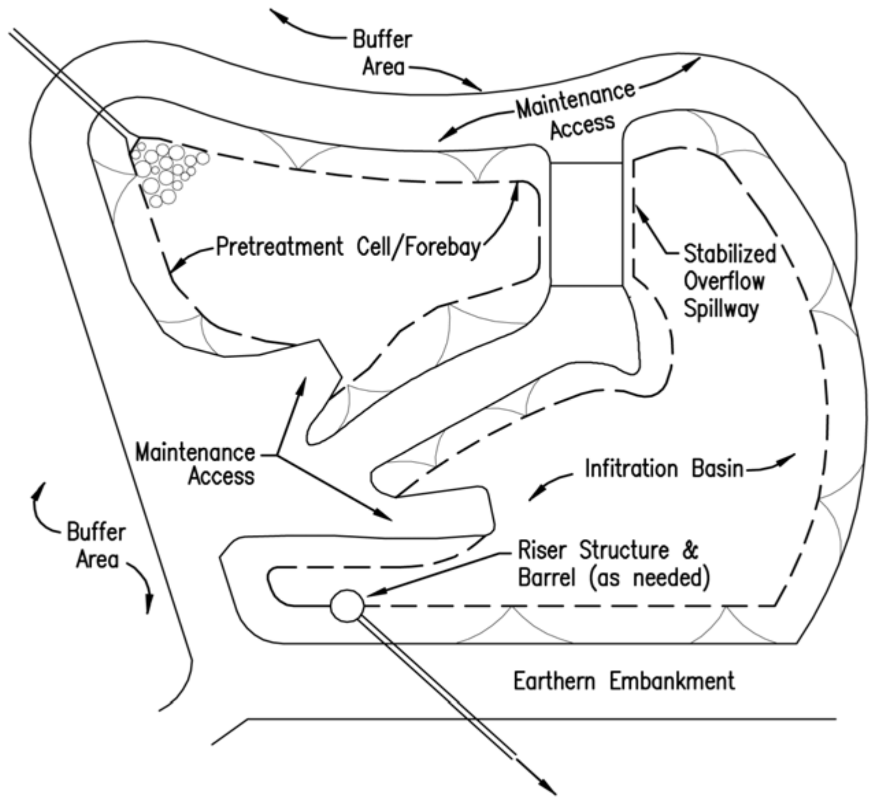
   Drainage Area

   Drainage areas served by infiltration basins should be limited to less than 50 acres. Drainage areas which are greater than 50 acres typically generate such large volumes of runoff that other detention or retention BMPs are more practical and cost-effective.

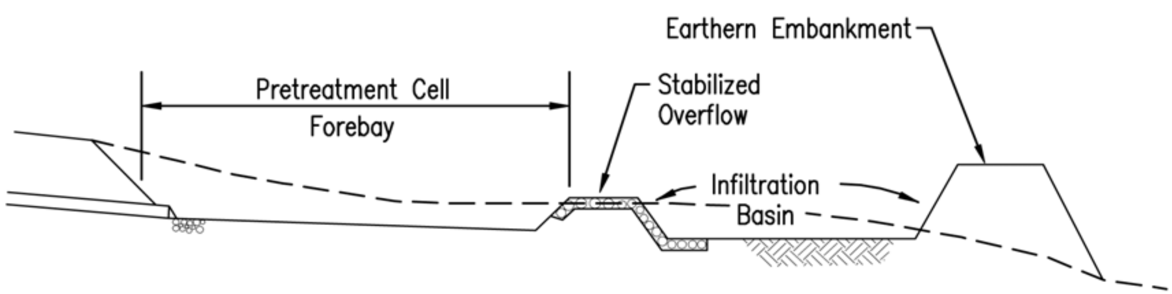
Development Conditions

Infiltration basins are generally suitable BMPs in low- to medium-density residential and commercial developments (38% to 66% impervious cover).

FIGURE 25
Infiltration Basin – Plan and Section



PLAN
No Scale



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4. Planning Considerations

Appropriate soil conditions and protection of the groundwater are among the important considerations when planning an infiltration basin.

An infiltration basin has relatively large surface area requirements, when compared with an infiltration trench or dry well, and ranges from 3 to 12 feet in depth. The seasonal high groundwater table or bedrock should be located at least 2 to 4 feet below the bottom of the basin.

Maintenance

Like all stormwater BMPs, access to infiltration basin should be considered in the planning stage. Access (as well as maneuvering room) should be provided to at least one side of the facility and the control structure or spillway. In addition, identifying a location and designing for on-site sediment disposal will greatly reduce long term maintenance costs.

5. Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of infiltration basins intended to comply with the runoff quality requirements of the Owensboro/Daviess County Stormwater Management program.

General

The design of infiltration basins should be according to the detention basin standard of OMPC and this chapter, along with additional criteria set forth below. The designer is not only responsible for selecting the appropriate components for his or her particular design but also for ensuring their long-term operation by specifying appropriate structural materials.

The design of the overflow vegetated spillway must consider the frequency of flow. The spillway may require an armored bottom if it is to function during every storm which exceeds the water quality volume.

Hydrology and Hydraulics

Follow procedures outlined in the Stormwater Manual.

Soils Investigation

A minimum of one soil boring log should be required for each 5,000 square feet of infiltration basin area (plan view area) and under no circumstances should there be less than three soil boring logs per basin.

Topographic Conditions

Infiltration basins should be a minimum of 50 feet from any slope greater than 15%. If unavoidable, a geotechnical report should address the potential impact of infiltration on or near the steep slope. Developments on sloping sites often require extensive cut and fill operations. The use of infiltration basins on fill sites is not permitted. Also, infiltration basins should be a minimum of 100 feet up-slope and 20 feet down-slope from any buildings.

Design Infiltration Rate

The design infiltration rate, f_d, should be set to equal one-half the infiltration rate, f, determined from the soil analysis. Therefore:

$$f_d = 0.5\ f$$

Maximum Ponding Time and Depth

All infiltration basins should be designed to completely drain stored runoff within 2 days following the occurrence of a storm event. Thus, an allowable maximum ponding time, T_{max}, of 48 hours should be used. The maximum ponding depth for an infiltration basin is:

$$d_{max} = f_d T_{max}$$

where:

d_{max} = maximum depth of the facility, in ft.
f_d = design infiltration rate of the basin area soils, in ft/hr (f_d = 1/2 f)
T_{max} = maximum allowable drain time = 48 hrs.

The ponding depth should not be so great as to contribute to the compaction of the soil surface. Depending on the specific soil characteristics, a maximum ponding depth of 2 feet is generally recommended (MWCOG, 1992).

The minimum surface area of the facility bottom is:

$$SA_{min} = \frac{Vol_{wq}}{f_d T_{max}}$$

where:

SA_{min} = minimum basin bottom surface area, in ft.^{2}
Vol_{wq} = water quality volume requirements, in ft.^{3}
F_d = design infiltration rate of the basin area soils, in ft/hr.
T_{max} = maximum allowable drain time, in hours

Runoff Pretreatment

Infiltration basins should always be preceded by a pretreatment facility. Grease, oil, floatable organic materials, and settleable solids should be removed from the runoff before it enters the infiltration basin. Vegetated filters, sediment traps and/or forebays, water quality inlets (refer to Section B.3, Manufactured BMP Systems) are just a few of the available pretreatment strategies.

At a minimum, the layout and design of the basin should include a sediment forebay or pretreatment cell, as shown in Figure 25, to enhance and prolong the infiltration capacity. Any pretreatment facility should be included in the design of the basin and should include maintenance and inspection requirements. It is recommended that a grass strip or other vegetated buffer at least 20 feet wide be maintained around the basin to filter surface runoff.

Principal and Emergency Spillways

A diversion structure upstream of an off-line basin will regulate the rate of flow into the basin, but not the volume. Therefore, infiltration basins should have a spillway to convey flows from storm events which are larger than the design capacity. The primary outlet should be located above the required infiltration volume. Additionally, a riser and barrel system is advantageous for future conversion to an extended-detention or retention facility if the infiltration capacity of the soil becomes impaired.

An emergency spillway is recommended for all impounding structures, including infiltration basins. If a vegetated spillway is to be used as the primary outlet above the water quality volume, care should be taken to design for the increased frequency of use. This is especially critical between maintenance operations when the infiltration capacity is decreased due to sediment loads. If a spillway is to be used for all storms which generate more runoff than the water quality volume, then a nonerodible surface should be provided.

Fencing

Fencing may be provided where deemed necessary by the developer, land owner, or locality for the purposes of public safety or protection of vegetation.

6. Construction Specifications

In general, widely accepted construction standards and specifications, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers, should be followed where applicable. Further guidance can be found in the Soil Conservation Service's Engineering Field Manual. Specifications for the work should conform to the methods and procedures indicated for installing earthwork, concrete, reinforcing steel, pipe, water gates, metal work, woodwork and masonry as they apply to the site and the purpose of the structure. The specifications should also satisfy all requirements of the local government.

Sequence of Construction

The sequence of various phases of basin construction should be coordinated with the overall project construction schedule. Rough excavation of the basin may be scheduled with the rough grading phase of the project to permit use of the material as fill in earthwork areas. Otherwise, infiltration measures should not be constructed or placed into service until the entire contributing drainage area has been stabilized. Runoff from untreated, recently constructed areas within the drainage area may load the newly formed basin with a large volume of fine sediment. This could seriously impair the natural infiltration ability of the basin floor.

The specifications for construction of a basin should state the following: 1) the earliest point at which storm drainage may be directed to the basin, and 2) the means by which this delay in basin use is to be accomplished. Due to the wide variety of conditions encountered among projects, each project should be evaluated separately to postpone basin use for as long as possible.

Excavation

Initially, the basin floor should be excavated to within one foot of its final elevation. Excavation to the finished grade should be delayed until all disturbed areas in the watershed had been stabilized or protected. The final phase of excavation should remove all accumulated sediment. Relatively light, tracked-equipment is recommended for this operation to avoid compaction of the basin floor.

After the final grading is completed, the basin floor should be deeply tilled by means of rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.

Lining Material

Establishing dense vegetation on the basin side slopes and floor is recommended. A dense vegetative cover will not only prevent erosion and sloughing, but will also provide a natural means to maintain relatively high infiltration rates. Inflow points to the basin should also be protected with erosion controls (e.g., riprap, flow spreaders, energy dissipaters, etc.), as well as a sediment forebay.

7. Maintenance / Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all-inclusive. Specific facilities may require other measures not discussed here.

Inspection Schedule

When infiltration basins are first made functional they should be inspected monthly and after any large storm event. Thereafter, once the basin is functioning satisfactorily and without potential sediment problems, inspections may be made semi-annually and after any large storm events. All inspections should include investigation for potential sources of contamination.

Sediment Control

The basin should be designed to allow for maintenance. Access should be provided for vehicles to easily maintain the forebay (pre-settling basin) without disturbing vegetation or sediment any more than what is absolutely necessary.

Grass bottoms in infiltration basins seldom need replacement since grass serves as a good filter material. If silty water is allowed to trickle through the turf, most of the suspended material is strained out within a few yards of surface travel. Well-established turf on a basin floor will grow up through sediment deposits forming a porous turf and preventing the formation of an impenetrable layer. Grass planted on basin side slopes should also prevent erosion.

Vegetation Maintenance

Maintenance of the vegetation on the basin floor and side slopes is necessary to promote a dense turf with extensive root growth, which subsequently enhances infiltration, prevents erosion and sedimentation, and deters invasive weed growth.

Bare spots should be immediately stabilized and revegetated.

The use of low-growing, stoloniferous grasses will permit long intervals between mowings. Mowing twice a year is generally satisfactory. Fertilizers should be applied only as necessary and in limited amounts to avoid contributing to pollution problems, including groundwater pollution, for which the infiltration basin helps mitigate.

8. Design Procedures

The following design procedure represents a generic list of the steps typically required for the design of an infiltration basin.

a. Determine if the anticipated development conditions and drainage area are appropriate for an infiltration basin application.

b. Determine if the soils (permeability, bedrock, water table, embankment foundation, etc.) and topographic conditions (slopes, building foundations, etc.) are appropriate for an infiltration basin application.

c. Locate the infiltration basin on the site within topographic constraints.

d. Determine the drainage area to the infiltration basin and calculate the required water quality volume.

e. Evaluate the hydrology of the contributing drainage area to determine peak rates of runoff.

f. Design the infiltration basin:

- Design infiltration rate, f_d = 0.5 f
- Max. storage time T_{max} = 48 hours
- Max. storage depth, d_{max}
- Runoff pretreatment – concentrated input, sheet flow input, sediment forebay
- Vegetated buffer around basin to filter surface runoff
- Vegetated emergency spillway and/or riser and barrel design
- Earthen embankment design

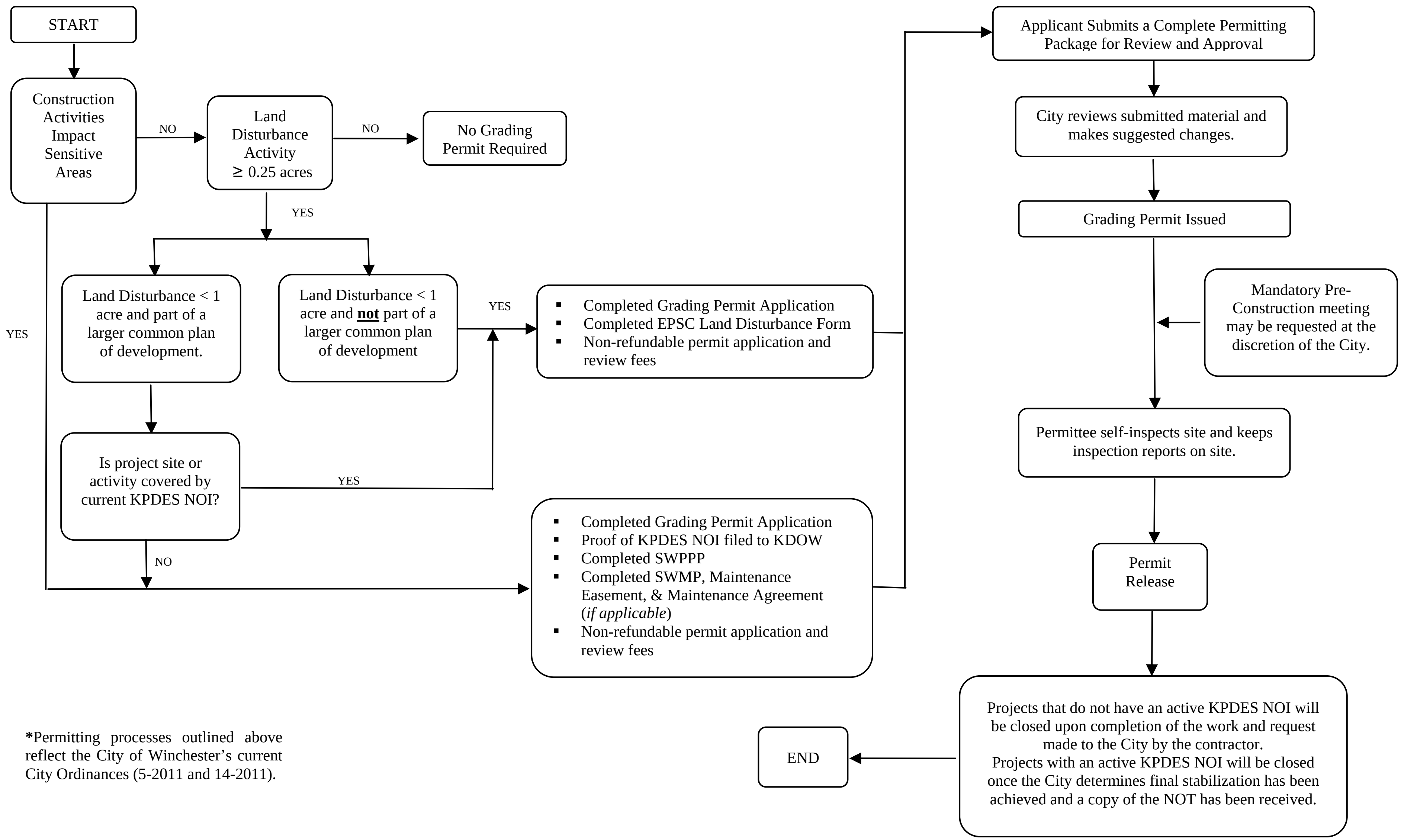
g. Provide material specifications.

h. Provide sequence of construction

i. Provide maintenance and inspection requirements.

APPENDIX A
Land Disturbance Permitting Process

LAND DISTURBANCE PERMITTING PROCESS*



***Permitting processes outlined above reflect the City of Winchester's current City Ordinances (5-2011 and 14-2011).

APPENDIX B
Post Construction Stormwater Management

POST CONSTRUCTION STORMWATER MANAGEMENT IN WINCHESTER

SWMP* for Plan Review

*SWMP – Stormwater Management Plan

Design

- √ Water Quality Volume shall be calculated using the approved Water Quality Treatment Standard
- √ If the project results in new or expanded discharge from the MS4 into a High Quality Water (HQW), BMPs shall be designated to protect existing in-stream uses and water quality.

BMP Selection

BMPs selected for the project shall have supporting documentation as to the applicability (quality and quantity) of the BMP for the project.

Maintenance Agreement & Easements

- √ Easements shall be provided and allow the City access to the BMP.
- √ A long-term maintenance agreement shall be submitted that is binding to subsequent owners, who are responsible for submitting an Annual Monitoring Report to the City.

BMP Alternatives

If on-site BMPs are not feasible, off-site mitigation and in-lieu fee payments may be pursued at the discretion of the City.

Installation of Post-Construction Stormwater Measures

Procedures

- √ The applicant must provide 24 hours notice to the MS4 prior to the installation of Post-Construction BMPs.
- √ Inspections of Post-Construction BMPs by qualified inspectors are the responsibility of the applicant.
- √ The MS4 will conduct periodic inspections to assure compliance with the SWMP.

Enforcement

Enforcement during installation of BMPs will follow procedures outlined below:

- Notice of Violation (NOV) is the first level of enforcement and does not include a fine.
- If the problem is not corrected, Citations will be issued with increasing monetary penalties.

The components of Post-Construction Stormwater Management are incorporated in the design, construction, and maintenance of a project. The state permit for Phase II MS4s mandates a local Water Quality Treatment Standard that requires all new development or redevelopments to treat the calculated water quality volume (WQ_V) with selection of appropriate BMPs.

BMPs selected for water quality management shall be inspected during construction and certified upon completion of construction activities that is was installed per approved plans.

After construction, the owner, as specified in the SWMP, shall perform the long-term maintenance activities necessary to keep the BMP functioning as designed. A Monitoring report shall be submitted each year to the City.

Stormwater BMP Maintenance

Monitoring

- √ Monitoring Reports of Post-Construction BMPs shall be submitted annually to the City to verify functionality of the BMP.
- √ The City shall inspect Post-Construction BMPs a minimum of once per current permit cycle.

Enforcement

Enforcement during maintenance of BMPs will follow procedures outlined below:

- Notice of Violation (NOV) is the first level of enforcement and does not include a fine.
- If the problem is not corrected, Citations will be issued with increasing monetary penalties.

The procedures summarized in this chart are from the City of Winchester's Ordinance 14-2011.

APPENDIX C

Annual Inspection Checklist

Permeable Pavement Inspection and Maintenance Checklist

Site Name:____

Location:____

Site Status:____

Date:________________________ Time:________________________

Inspector:____

Inspection Frequency Key: A=annual; M=monthly; S=after major storms

Inspection Item	Inspected (Yes or No)	Maintenance Needed (Yes or No)	Comments / Description
1. Pavement Area (Monthly)			
Pavement area free of debris			
Inlets and outlets unobstructed			
Is water standing after a storm event*			
Any evidence of clogged pores that require vacuum-sweeping			
Access to pervious pavement (egress and ingress routes) safe and efficient			
2. Vegetation			
Any evidence of eroding material coming into or from pervious pavement areas **			
Any noticeable irrigation needs			
Fallen leaves/plant debris collecting in paving area			
Grass height over 4 inches			
Vegetation health affected by oil/grease from vehicles **			

* After major storms
** Annually

Other **			
3. Hazards (Monthly)			
Obstructions or debris affecting overflows / emergency spillways			
Load-bearing capability of pavement intact			

Comments:

____

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____

Overall Condition of Facility ☐ **Acceptable** ☐ **Unacceptable**

Actions to be Taken:

____

____

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____

The next routine inspection is scheduled for approximately: ___________________
(date)

* After major storms
** Annually

Greenroof Inspections and Maintenance Checklist

Site Name:______________________________

Location:______________________________

Site Status:______________________________

Date:______________ Time:______________

Inspector:______________________________

Greenroof Type: Extensive Roof Cover ☐ Intensive Roof Garden ☐

Inspection Items	Inspected (Yes or No)	Maintenance Needed (Yes or No)	Comments / Description
1. Debris Removal (Monthly)			
Gutter inlets blocked by plant debris/trash or plant growth hindered by debris			
2. Vegetation (Monthly)			
Any evidence of additional irrigation needs? *			
Fallen leaves/debris interfering with plant health			
Any dead plants to be replaced			
Any need for weeding/ mowing/trimming *			
3. Soil Substrate/Growing Medium (Annual)			
Any evidence of wind or water erosion			
4. Structural Components (Annual)			
Any evidence of structural deterioration			
Load-bearing walls in good condition			
Spalling or cracking of structural parts			

* Monthly during growing season

Access/maintenance routes maintained and free of debris			
Other (After Major Storms)			
Any locations of standing water that may harbor insect infestations			

Comments:

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Overall Condition of Facility ☐ **Acceptable** ☐ **Unacceptable**

If any of the above Inspection Items are checked "Yes" for "Maintenance Needed," list Maintenance actions and their completion dates below:

Actions to be Taken: **Due Date:**

____

____

____

____

____

The next routine inspection is scheduled for approximately: ___________________
(date)

* Monthly during growing season

Operation and Maintenance Inspection Report for Enhanced Swales, Grass Channels, Open Channels and Filter Strips

Site Name:______________________________

Location:______________________________

Site Status:______________________________

Date:______________ Time:______________

Inspector:______________________________

Maintenance Item	Inspected (Yes or No)	Maintenance Needed (Yes or No)	Comments / Description
1. Debris Cleanout (Monthly)			
Facility and adjacent area clear of debris			
Inlets and outlets clear of debris			
Any dumping of yard wastes into facility			
Has litter (branches, etc) been removed			
2. Vegetation (Monthly)			
Adjacent areas stabilized			
Grass mowed			
Plant height not less than design water depth			
Any evidence of erosion			
Is plant composition according to approved plans			
Any unauthorized or inappropriate plantings			
Any dead or diseased plants			
Any evidence of plant stress from inadequate watering			
3. Oil and Grease (As applicable to BMP) (Monthly)			
Any evidence of filter clogging			

4. Dewatering (Monthly)			
Facility dewaters between storms			
5. Check Dams/Energy Dissipators (Annually, After major storms)			
Any evidence of sedimentation buildup			
Does sedimentation require removal (i.e. > 50% full)			
Any evidence of erosion at downstream toe of drop structures			
6. Sediment Deposition (Annually)			
Swale clean of sediments			
Sediments should not be > than 20% of swale design depth			
7. Outlets/overflow spillway (Annually, After major storms)			
General condition			
Any evidence of erosion			
Any evidence of blockages			
8. Integrity of Facility			
Has facility been blocked or filled inappropriately			

Comments:

____

____

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Overall Condition of Facility ☐ **Acceptable** ☐ **Unacceptable**

If any of the above Inspection Items are checked “yes” for “Maintenance Needed”, list maintenance actions below:

Maintenance Actions to be Taken:

____

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The next routine inspection is scheduled for approximately ____________________
(date)

Infiltration Trench Operation, Maintenance, and Management Inspection Checklist

Site Name:______________________________

Location:______________________________

Site Status:______________________________

Date:______________ Time:______________

Inspector:______________________________

Maintenance Item	Inspected (Yes or No)	Maintenance Needed (Yes or No)	Comments / Description
1. Debris Cleanout (Monthly)			
Trench surface clear of debris			
Inflow pipes clear of debris			
Inlet area clear of debris			
Overflow spillway clear of debris			
2. Sediment Traps or Forebays (Annual)			
Obviously trapping sediment			
Greater than 50% of storage volume remaining			
3. Dewatering (Monthly)			
Trench dewaters between storms			
4. Sediment Cleanout of Trench (Annual)			
Evidence of sedimentation in trench			
Does sedimentation currently require removal			
5. Inlets (Annual)			
Good condition			
Any evidence of erosion			

6. Outlet/Overflow Spillway (Annual)			
Good Condition, no need for repair			
Any evidence of erosion			
7. Aggregate Repairs (Annual)			
Surface of aggregate clean			
Top layer of stone in need of replacement			
Trench in need of rehabilitation			

Comments:

____

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Overall Condition of Facility ☐ **Acceptable** ☐ **Unacceptable**

If any of the above Inspection Items are checked "yes" for "Maintenance Needed", list maintenance actions below:

Maintenance Actions to be Taken:

____

____

____

The next routine inspection is scheduled for approximately ____________________
(date)

Sand/Organic Filter Operation, Maintenance, and Management Inspection Checklist

Site Name:____

Location:____

Site Status:____

Date:____________________ Time:____________________

Inspector:____

Inspection Frequency Key: A=annual; M=monthly; S=after major storms.

Maintenance Item	Inspected (Yes or No)	Maintenance Needed (Yes or No	Comments / Description
1. Debris Cleanout (Monthly)			
Contributing areas cleanout of debris			
Filtration facility clean of debris			
Inlet and outlets clear debris			
2. Oil and Grease (Monthly)			
No evidence of filter surface clogging			
Activities in drainage area minimize oil and grease entry			
3. Vegetation (Monthly)			
Contributing drainage area stabilized			
No evidence of erosion			
Area mowed and clipping removed			
4. Water Retention Where Required (Monthly)			
Water holding chambers at normal pool			
No evidence of leakage			
5. Sediment Deposition (Annual)			

Filter chamber free of sediments			
Sedimentation chamber not more than half full of sediments			
6. Structural Components (Annual)			
No evidence of structural deterioration			
Any grates are in good condition			
No evidence of spalling or cracking of structural parts			
7. Outlets/Overflow Spillway (Annual)			
Good condition (no need for repair)			
No evidence of erosion (if draining into a natural channel)			
8. Overall Function of Facility (Annual)			
Evidence of flow bypassing facility			
No noticeable odors outside of facility			

Comments:

____

____

____

Overall Condition of Facility ☐ **Acceptable** ☐ **Unacceptable**

If any of the above Inspection Items are checked "yes" for "Maintenance Needed", list maintenance actions below:

Maintenance Actions to be Taken:

____

____

____

The next routine inspection is scheduled for approximately ____________________
(date)

Stormwater Pond Operation, Maintenance, and Management Inspection Checklist

Site Name:______________________________

Location:______________________________

Site Status:______________________________

Date:______________ Time:______________

Inspector:______________________________

.

Maintenance Item	Inspected (Yes or No)	Maintenance Needed (Yes or No	Comments / Description
Embankment and emergency spillway (Annual, After Major Storms)			
1. Vegetation and ground cover adequate			
2. Embankment erosion			
3. Animal burrows			
4. Unauthorized planting			
5. Cracking, bulging or sliding of dam			
a. Upstream & downstream face			
b. At or beyond toe (downstream/upstream)			
c. Emergency spillway			
6. Pond, toe & chimney drains clear and functioning			
7. Seeps/leaks on downstream face			
8. Slope protection or riprap failure			
9. Vertical/horizontal Alignment of top of Dam “As-Built”			

10. Emergency spillway clear of obstructions and debris			
11. Other (specify)			
Riser and principal spillway (Annual)			
1. Flow office obstructed			
2. Low flow trash rack			
3. Weir trash rack maintenance			
4. Excessive sediment accumulation insider riser			
5. Condition of riser and barrels a. cracks or displacement			
b. Minor spalling (<1")			
c. Major spalling (rebars exposed)			
d. Joint failures			
e. Water tightness			
6. Metal pipe condition			
7. Control valve a. Operational/exercised			
b. Chained and locked			
8. Pond drain valve a. Operational/exercised			
b. Chained and locked			
9. Outfall channels functioning			
10. Other (specify)			
Permanent Pool (Wet Ponds)	**(Monthly)**		
1. Undesirable vegetative growth			
2. Floating or floatable debris removal required			
3. Visible pollution			

4. Shoreline problem			
5. Other (specify)			
Sediment Forebays			
1. Sedimentation noted			
2. Sediment cleanout when depth <50% design depth			
Dry Pond Areas			
1. Vegetation adequate			
2. Undesirable vegetative growth			
3. Undesirable woody vegetation			
4. Low flow channels clear of obstructions			
5. Standing water or wet spots			
6. Sediment and/or trash accumulation			
7. Other (specify)			
Condition of Outfall into Ponds (Annual, After Major Storms)			
1. Riprap failures			
2. Slope erosion			
3. Storm drain pipes			
4. Endwalls / Headwalls			
5. Other (Specify)			
Other (Monthly)			
1. Encroachment on pond or easement area			
2. Complaints from residents			
3. Aesthetics a. Grass growing required			
b. Graffiti removal needed			

c. Other (specify)			
4. Any public hazards (specify)			
Constructed Wetland Area (Annual)			
1. Vegetation healthy and growing			
2. Evidence of invasive species			
3. Excessive sedimentation in Wetland Area			

Comments:

____

____

____

Overall Condition of Facility ☐ **Acceptable** ☐ **Unacceptable**

If any of the above Inspection Items are checked "yes" for "Maintenance Needed", list maintenance actions below:

Maintenance Actions to be Taken:

____

____

____

The next routine inspection is scheduled for approximately ____________________
(date)

Constructed Wetlands Inspections and Maintenance Checklist

Site Name:____

Location:____

Site Status:____

Date:____________________ Time:____________________

Inspector:____

Inspection Item	Inspected (Yes or No)	Maintenance Needed (Yes or No	Comments / Description
Embankment and emergency spillway (Monthly, After major storm)			
Vegetation healthy			
Erosion on embankment			
Animal burrows in embankment			
Cracking, sliding, bulging of dam			
Drains blocked or not functioning			
Leaks or seeps on embankment			
Emergency spillway obstructed			
Erosion in/around emergency spillway			
Other			
Riser and principal spillway (Annually)			
Low-flow orifice functional*			
Trash rack (Debris removal needed? Corrosion?)*			
Sediment buildup in riser			
Concrete/Masonry condition (Cracks,displacement, spalling?)			
Metal pipe in good condition			
Control valve operation			
Pond drain valve operation			

*After major storm

Outfall channels function, not eroding			
Other (describe)			
Sediment Forebays (Annually)			
Sedimentation description			
Sediment cleanout needed (over 50 percent full)*			
Constructed Wetland Ponding Areas (Monthly)			
Wetland vegetation present and healthy			
Vegetation removal needed			
Floatable debris			
Shoreline problem			
Erosion at outfalls into pond			
Headwalls in good condition			
Hazards (Monthly)			
Have there been complaints from residents			
Public hazards noted			

Comments:

____

____

____

Overall Condition of Facility ☐ **Acceptable** ☐ **Unacceptable**

If any of the above Inspection Items are checked "Yes" for "Maintenance Needed," list Maintenance actions and their completion dates below:

Maintenance Action Needed: **Due Date**

____

____

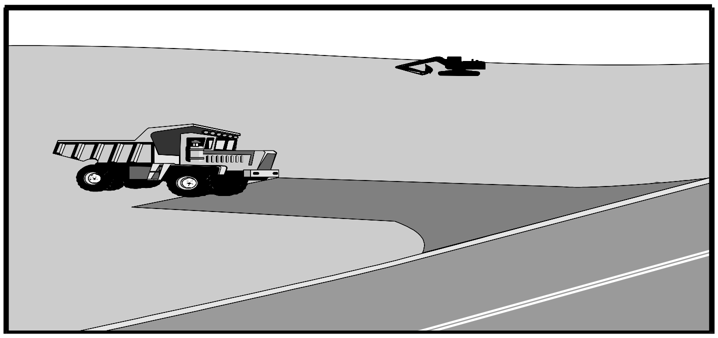
____

The next routine inspection is scheduled for approximately: ____________________
(date)

*After major storm

APPENDIX D
Erosion Protection and Sediment Control BMPs

ACTIVITY: Stabilized Construction Entrance	ES – 01



Targeted Constituents

● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit		
● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances	
○ Nutrients	○ Toxic Materials	◗ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

A stabilized construction entrance involves a pad of aggregate underlain with filter cloth located at any point where traffic will be entering or leaving a construction site. Stabilizing the construction entrance significantly reduces the amount of sediment (dust, mud) tracked offsite, especially if a washrack is incorporated for removing caked sediment. See ES-02, Tire Washrack, if soil and storm water runoff conditions warrant additional removal of mud from construction vehicles. This management practice is likely to create a significant reduction in sediment and a partial reduction in oil and grease.

Suitable Applications

- All points of construction ingress and egress, especially from dirt or soil conditions to a paved public roadway.

Approach

Stabilized construction entrances shall be constructed early in the process of setting up erosion and sediment controls, prior to the movement onsite of large vehicles and equipment.

Stabilized construction entrances are moderately effective in removing sediment from equipment leaving a construction site. Efficiency is greatly increased when a tire washrack is included as part of a stabilized construction entrance (see ES-02).

The entrance must be properly graded to prevent runoff from leaving the construction site. When washracks are provided, washing is done on a reinforced concrete pad that drains to a properly constructed sediment trap or sediment basin. Other erosion and sediment controls should be in place to prevent sediments from entering into the storm water drainage system, ditch, or waterway.

- Construct on level ground where possible, at a location suitable for traffic safety and sight distance.

- Length is typically 50 feet and width is typically 20 feet. Busy entrances will need the capability of handling a lane of traffic each way, typically 30 feet wide. It is more important for trucks exiting the site to be cleaned on the way out.

- Aggregate should generally be crushed, washed, and well-graded rock, with 2” to 3” median size (D_{50}), for a depth of at least 6 inches. Smaller size aggregate, such as washed #57 stone, do not remove mud and clay soils. Smaller size aggregate is easily pushed into the street by trucks, or can be washed away by heavy rains.

- Place aggregate on top of a medium to heavy geotextile (typically 12 ounces per square yard) suitable for material separation applications. Do not drop aggregate from a large height.

- Inspect and clean construction entrance and adjacent pavement at the end of each shift or workday, do not wash sediment and mud into the storm water system or into natural creeks or streams. Street sweeping or street vacuuming may be needed depending on the level of mud deposited on the roadway. Mud on public streets and roads is a traffic hazard and is a violation of the City of Winchester’s good house keeping practices for prevention of pollutants entering the city’s MS4 system.

- Provide ample turning radius as part of stabilized construction entrance, taking into account the speed of traffic on the intersecting roads.

- It is strongly suggested that perimeter fencing be installed adjacent to the stabilized construction entrance in order to limit egress. Use chain-link fencing or silt fence in accordance with the level of security needed.

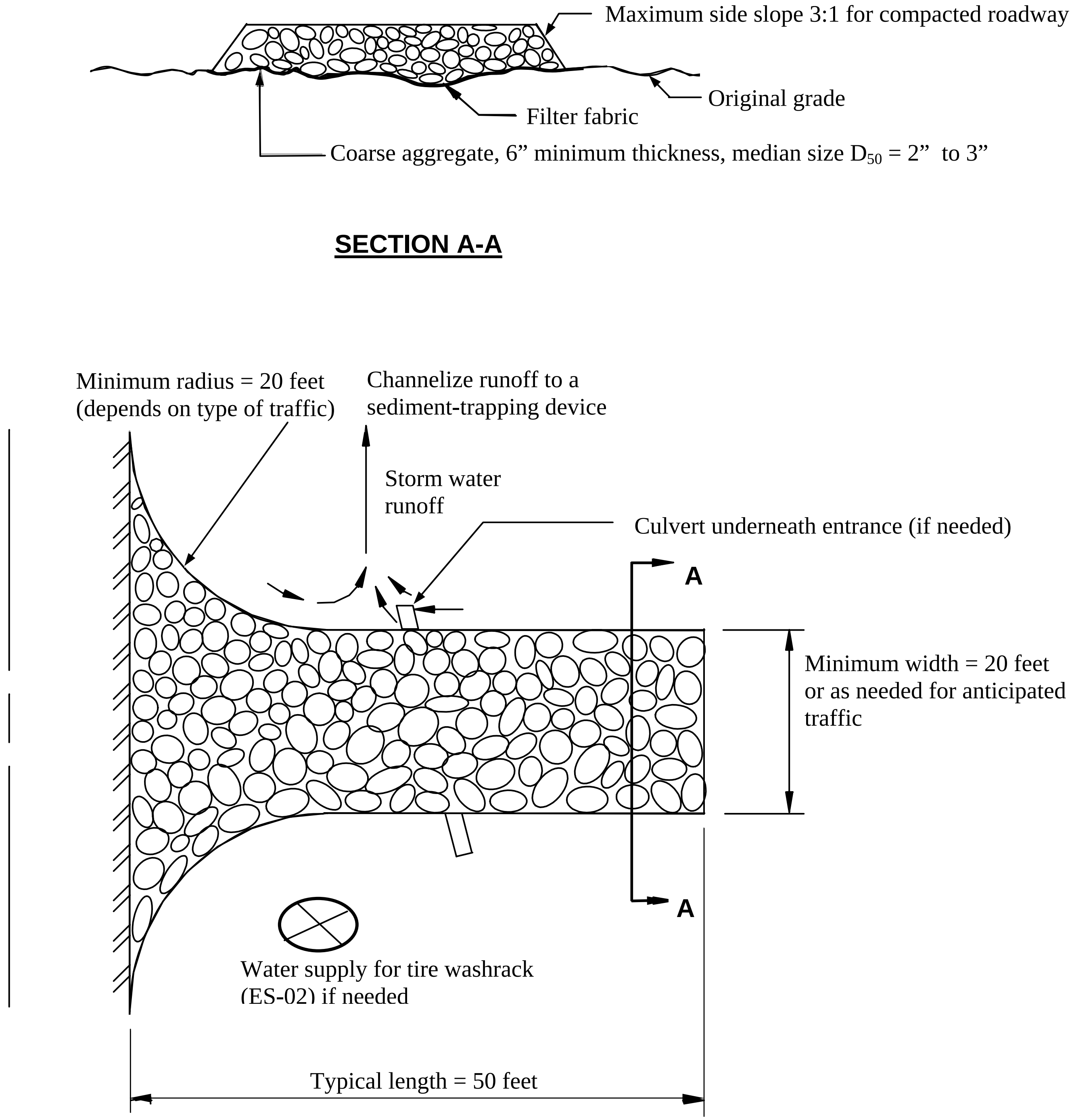
Maintenance

- Inspect daily to ensure that mud and dirt are not tracked onto roadways. Remove all sediment deposited on paved roadways at the end of each workday, do not wash the sediment and mud into the storm water system or into natural creeks or streams.

- Requires periodic top dressing with additional gravel material, especially if the subgrade is soft or becomes saturated.

- Remove gravel material and filter fabric at completion of construction, or as paved surfaces are finished.

- Restrict employees and subcontractors from using unauthorized construction ingress and egress points.

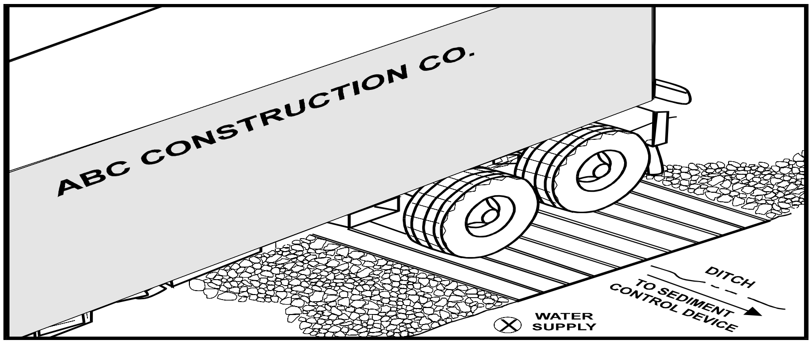


NOT TO SCALE

Figure ES-01-1
Stabilized Construction Entrance

ACTIVITY: Tire Washrack

ES – 02



Targeted Constituents			
● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit	
● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances

○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

An application that supports a stabilized construction entrance. It is intended to prevent or reduce the discharge of pollutants as a result of vehicular ingress and egress to the construction site by providing facilities that remove mud and dirt from vehicle tires and undercarriages prior to entering public roads. See ES-01, Stabilized Construction Entrance, for basic application and installation guidelines. This management practice is likely to create a significant reduction in sediment.

Approach

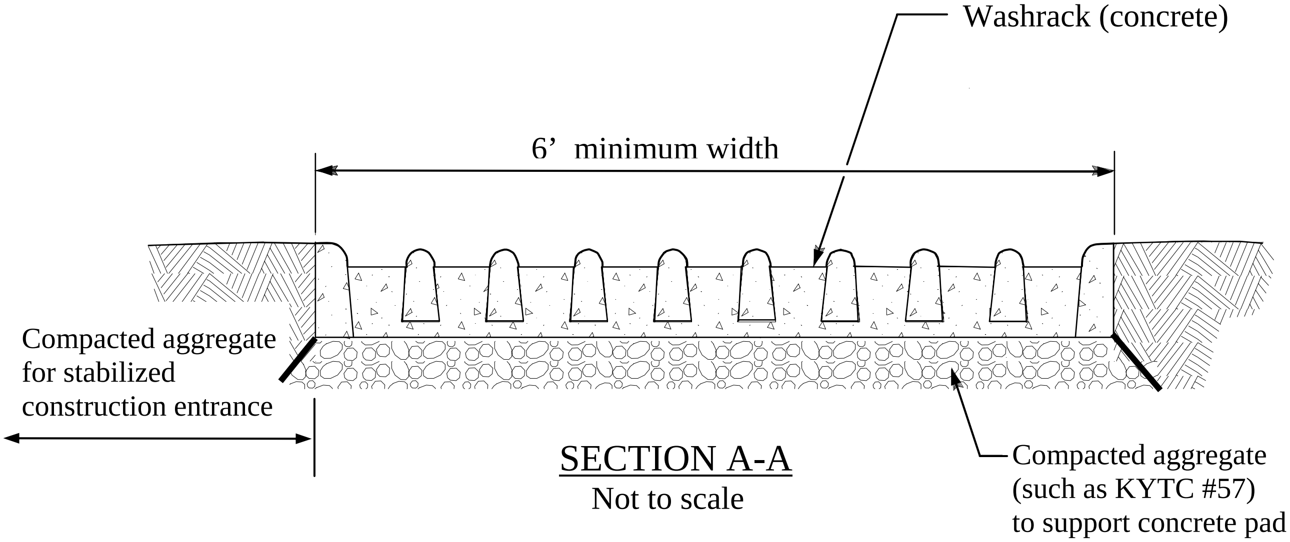
- If a tire washrack is necessary, it shall be designed for anticipated traffic loads and placed on compacted level ground, on a pad of coarse aggregate. The washrack will freely drain to a swale leading to a sediment-trapping facility.
- Require that all employees, subcontractors, and visitors with mud-caked tires or undercarriages use the washrack prior to exiting the construction site. It is strongly encouraged that perimeter fencing be installed adjacent to the construction entrance in order to limit egress to the designated construction exits.
- A typical washrack is shown in Figure ES-02-1. Other materials may be used, provided that the construction is durable and effective in removing dirt and mud. Increase the width of the tire washrack, or modify the washrack design, if the intention is to routinely wash vehicle undercarriages.

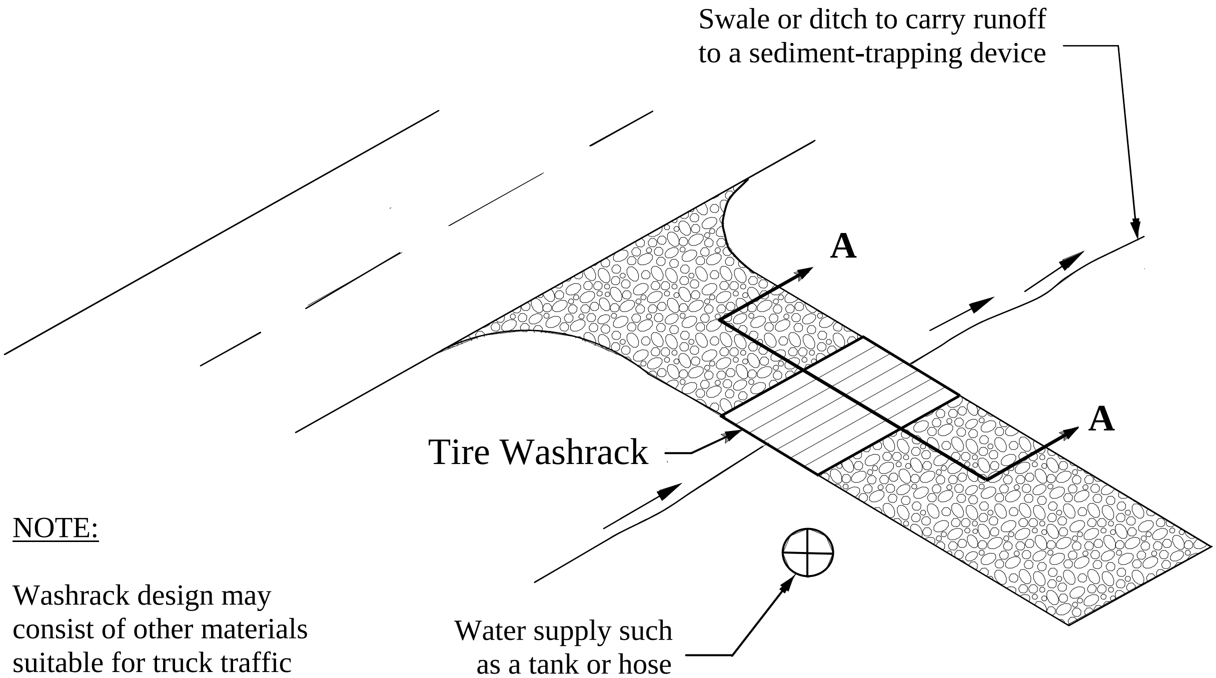
Maintenance

Remove accumulated sediment in tire washrack and sediment traps as necessary to maintain system performance. Inspect routinely for damage and repair as needed.

Limitations

- Requires a supply of water, either by overhead tank, pressurized tank or by water pipeline. All washwater shall drain into a sediment-trapping device such as a sediment basin or sediment trap.
- If chlorinated water (such as ordinary tap water or hydrant water) is used, allow the water to sit for 24 hours, to allow chlorine to dissipate into the air, prior to discharging effluent to the storm water system or to a natural stream. Effluent may be checked by a standard pool test kit to verify that it is chlorine-free.
- May require a turnout or an extra-wide exit to avoid entering vehicles from having to drive through the tire washrack area (which is intended for exiting vehicles).



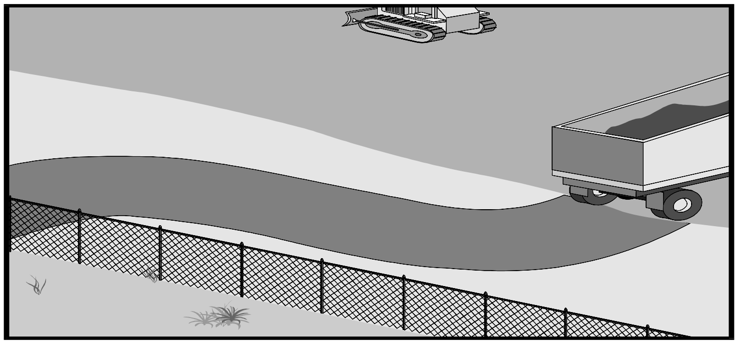


NOTE:

Washrack design may consist of other materials suitable for truck traffic that remove mud and dirt.

Figure ES-02-1
Typical Washrack for Construction Entrance

ACTIVITY: Construction Road Stabilization | **ES – 03**



Targeted Constituents

● Significant Benefit ◗ Partial Benefit ○ Low or Unknown Benefit

● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances	
○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

Access roads, subdivision roads, parking areas, and other onsite vehicle transportation routes should be stabilized immediately after grading and frequently maintained to prevent and control erosion and dust. This management practice is likely to create a significant reduction in sediment.

Suitable Applications

- Temporary construction traffic.
- Phased construction projects with offsite road access.
- Detour roads for local or temporary construction traffic.
- Construction during wet weather.
- Any construction road with a temporary stream crossing must be permitted and approved prior to construction. Consult Figures ES-03-1 and ES-03-2 for typical illustrations of temporary stream crossings, using a temporary bridge and culverts respectively.

Considerations

Areas which are graded for construction vehicle transport and parking purposes are especially susceptible to erosion and dust. The exposed soil surfaces are continually disturbed, leaving no opportunity for vegetative stabilization. During wet weather, these areas become muddy and generate significant quantities of sediment that pollute storm drainage systems and nearby streams. Dirt roads become unstable during wet weather, rendering them unusable and delaying construction.

Efficient construction road stabilization not only reduces onsite erosion but can significantly speed transit, avoid instances of immobilized machinery, and generally improve site efficiency and working conditions during adverse weather conditions.

Permanent roads and parking areas should be paved as soon as possible after grading. Where feasible, alternative routes may be used for construction traffic in wet conditions. Wet conditions will generally require that the contractor should reduce expected construction goals and adjust accordingly. Temporary gravel roads should be heavily considered on any slopes which are greater than 5 percent.

Approach

- Temporary construction roads should follow topographic contours to reduce erosion. Roadway slope should preferably be less than 10 percent and must not exceed 15 percent.

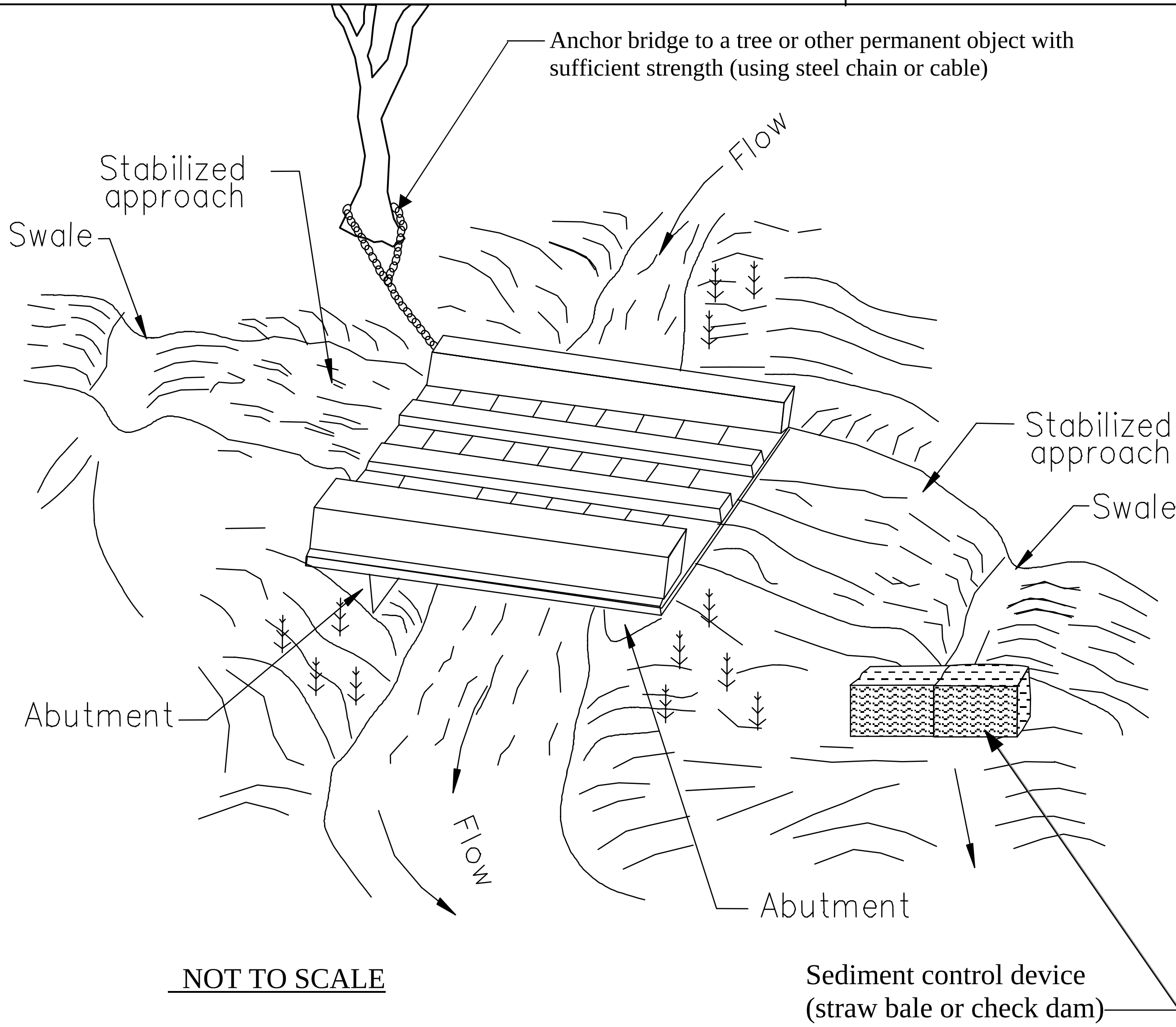
- Compact subgrade surface and provide drainage culverts as necessary. The use of engineered geotextile fabric is recommended to improve subgrade support and strength. Install according to manufacturer's recommendations for overlap and anchoring. Place initial lift of aggregate carefully on geotextile.
- Gravel roads should be a minimum of 6 inches thick with 2-inch approximate size coarse aggregate base applied immediately after grading or as recommended by design engineer or soils engineer.
- Roadways should be carefully graded to drain transversely. Provide drainage swales on each side of the roadway. Simple gravel berms without a trench can also be used. Installed inlets should be protected to prevent sediment from entering the storm sewer system.
- Temporary stream crossings may only be constructed in accordance with KDOW and/or Corps of Engineers permits. Temporary stream crossings should be installed for the shortest possible time period so that the possibility of stream flooding is minimized. Generally corrugated metal pipe is used for temporary pipes, due to inexpensive cost and light weight.
- Chemical stabilizers or water are usually required on gravel or dirt roads to prevent dust; apply as needed to meet dust control requirements. Chemical stabilization may also be used upon compacted native subgrade. These chemical controls should be applied in accordance with the manufacturer's directions.

Maintenance

- Maintain gravel roads so that mud and dirt are not tracked offsite from the project. Periodically apply additional aggregate on gravel roads. Use shovels to remove excess dirt from gravel roads. Do not wash gravel roads with water, which allows the sediment and mud to enter the storm water system, natural creeks or streams.
- Active dirt construction roads are commonly watered three or more times per day during the hot and dry weather.
- Inspect weekly and after each rain event. Look particularly for rill and gully erosion. Repair any eroded areas immediately.

Limitations

- The roadway must be removed or paved when construction is complete.
- Certain chemical stabilization methods may cause storm water pollution and are not generally allowed.
- Gravel construction roads are moderately expensive, but cost is usually balanced by reductions in construction delays, travel times, street sweeping, etc.



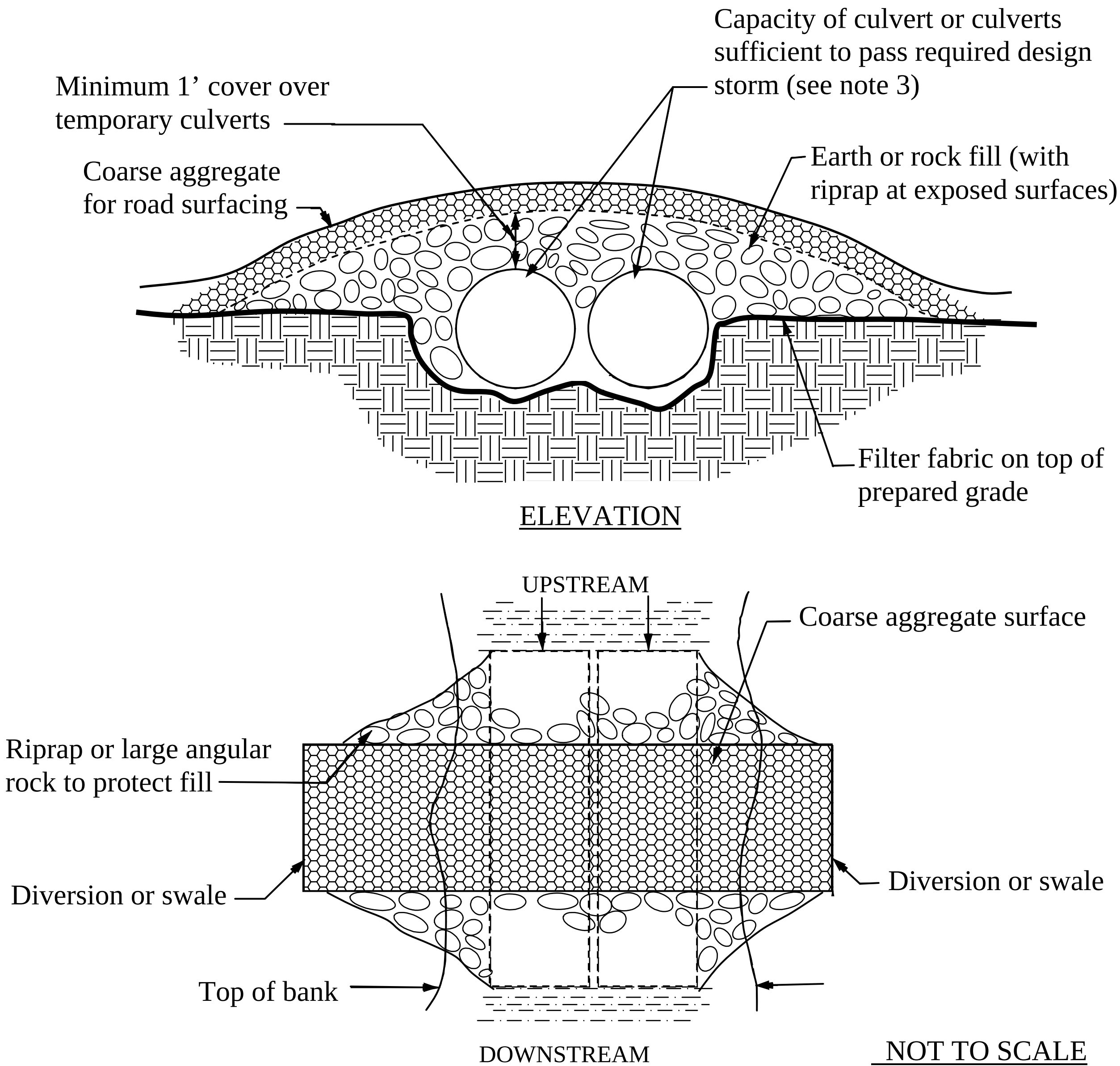
NOTES:

1. Temporary bridge structure must be designed and inspected by a licensed structural engineer in order to protect the safety of all workers. Temporary bridge structure must be capable of passing the required design storm at a minimum. A larger design storm must be used if there is potential for flooding buildings, structures, or adjacent property owners.

2. All temporary stream crossings must be approved and permitted prior to beginning construction.

3. Securely anchor temporary bridge to an existing structure or tree.

Figure ES-03-1
Temporary Stream Crossing - Bridge



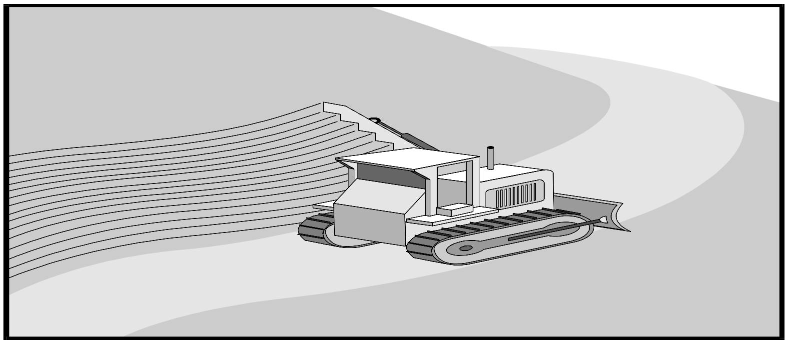
NOTES:

1. Temporary culvert structure must be designed and inspected by a licensed engineer in order to protect the safety of all workers.

2. All temporary stream crossings must be approved and permitted prior to beginning construction.

3. Use a larger design storm for culvert capacity if there is potential for flooding to buildings, structures or adjacent property.

Figure ES-03-2
Temporary Stream Crossing - Culverts



Targeted Constituents				
● Significant Benefit		◗ Partial Benefit		○ Low or Unknown Benefit
● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances	
○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

Terraces prevent or reduce the discharge of pollutants to the storm drain system or to watercourses as a result of construction activity by decreasing runoff velocities, trapping sediment, increasing infiltration, and supporting the establishment of vegetative cover. This management practice is likely to create a significant reduction in sediment.

Suitable Applications

- Slopes steeper than 3:1 (H:V) and greater than 5 feet in height, which are not part of a trench or excavation.
- Graded areas with smooth hard surfaces or any cleared area prior to permanent seeding and planting.
- Where length of slopes need to be shortened by terracing. Note: terracing is usually permanent and should be designed under the direction of and approved by a licensed professional civil engineer based on site conditions. Terraces must be designed with adequate drainage and stabilized outlets.

Approach

- Terraced slopes, as well as any slopes which are steeper than 3:1, should be designed by a licensed professional civil engineer based upon actual site conditions. Adequate drainage channels and diversions must be provided.
- Terraces and benches are commonly used in trenches or excavations as a means of providing slope stability. It is extremely important that trenches and excavations meet all of the Occupational Safety and Health Administration (OSHA) regulations in 29 CFR 1926, Subpart P – Excavations, latest edition. The gradient terraces in this BMP are intended for slopes and hillsides, not for use in trenches and other excavations.
- Graded areas with smooth, hard surfaces give a false impression of “finished grading” and a job well done. It is difficult to establish vegetation on such surfaces due to reduced water infiltration and root penetration. Rough surfaces with uneven soil and rocks left in place may appear unattractive or unfinished at first, but they encourage water infiltration, speed the establishment of vegetation, and decrease runoff velocity. Rough, loose soil surfaces give lime, fertilizer, and seed some natural coverage and favorable moisture levels that aid seed germination.

- If terraced slopes become unstable due to diverted runoff patterns, then alternative measures should be considered. Alternative measures can include flow diversion, drains, swales, level spreaders, geotextiles, and bank stabilization practices.

Application

There are several ways to create a gradient terrace that will meet slope stability requirements. Factors to be considered are the steepness of slope, mowing requirements, and whether the slope is formed by fill or by excavation. Generally, a slope cannot be mowed if it is steeper than 3:1 (H:V).

The following methods are shown in the attached figures:

Figure ES-04-1	Contour furrow
Figure ES-04-2	Serrated slope
Figure ES-04-3	Stepped slope, terraced slope

There are also different methods for achieving a roughened soil surface on a slope, and the selection of an appropriate method depends upon the type of slope. Roughening methods include grooving and tracking. The use of different equipment in various areas may be used to accomplish different levels of compaction or roughening.

Contour Furrows

Contour furrows may be used for slopes which are 3:1 (H:V) or flatter. Diversion berms or channels may be necessary at the top of slope and along the edges of the slope in order to prevent concentrated storm water runoff from eroding the slope. The maximum distance between furrows shall be 40 feet, and the maximum slope length shall be 200 feet.

Serrated Slopes

A serrated slope may be used for slopes which are 2:1 (H:V) or flatter. This type of gradient terrace is labor-intensive in that bladed equipment will be needed to make numerous passes along a slope, beginning at the top and working downward. The maximum slope length shall be 100 feet.

Stepped Slopes

Graded areas steeper than 3:1 (H:V), which will not be mowed, should preferably have a stepped slope as in Figure ES-04-3. The stair-stepping effect will help vegetation become attached and also trap soil eroded from the slopes above. Stepped slopes are particularly appropriate in soils containing rock. Each step catches rocky material, which sloughs from above, and provides a level site where vegetation can become established.

Steps should be wide enough to work with standard earth moving equipment. Preferably the horizontal distance should be at least 1.5 times the vertical cut distance. Slightly grade the horizontal bench inwards (e.g. back towards the top of slope). Do not make individual vertical cuts more than 24 inches high in soft materials or more than 3 feet high in rocky materials. Groove the slope using machinery to create a series of ridges and depressions that run across the slope and on the contour.

Terraced Slopes

Terraced slopes are preferable for longer slopes that will be regularly mowed. A designed drainage channel is located within the terraces at regularly spaced intervals. The designed drainage channel shall have a regular cross section that includes slope and depth requirements. It may be necessary to locate intersecting channels to safely convey storm water to the bottom of the slope. The intersecting channels typically incorporate downdrains, riprap, energy dissipators, stilling basins, concrete aprons and other measures to safely control velocities and erosive forces.

Fill Slope Roughening

- Place fill slopes with a gradient steeper than 3:1 (H:V) in lifts not to exceed 8 inches and make sure each lift is properly compacted. Fill slopes are not as stable as cut slopes, no matter how much compaction is applied.

- Ensure that the face of the slope consists of loose, uncompacted fill 4 inches to 6 inches in depth. This is not to be confused with proper compaction necessary for slope stabilization. Use grooving or tracking to roughen the face of the slopes, if necessary.

- Apply fertilizer, mulch, or other soil amendments as necessary and as specified. Do not over fertilize. Then track or crimp. Do not blade or scrape the final slope face.

Cut Slope Roughening

- Create shallow grooves by normal tilling, disking, harrowing, or use a mechanical seeder. Make the final pass of any such tillage along the contour.

- Make grooves formed by such implements close together, less than 10 inches apart, and not less than 1 inch deep. Excessive roughness is undesirable where mowing is planned.

Maintenance

Periodically check the seeded or planted slopes for rills and washes, particularly after significant storm events greater than 0.5 inch. Fill rills and washes slightly above the original grade, then reseed and mulch as soon as possible.

Inspect monthly for the first year after construction. The slope should be inspected in early fall thereafter.

Limitations

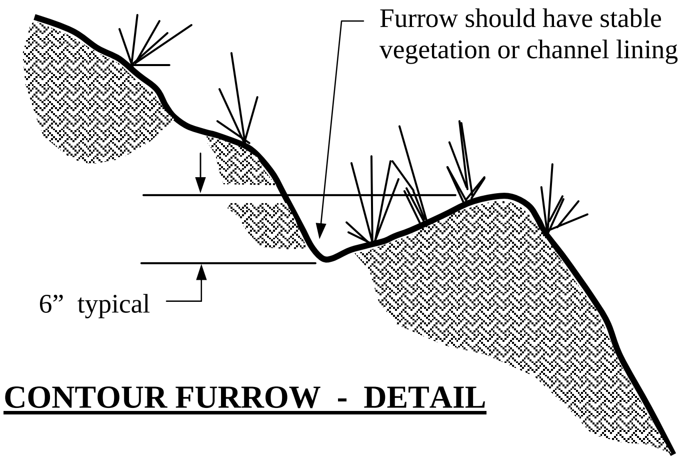
- A stepped slope (or stair-step grading) is not practical for sandy soils or other soils with low cohesiveness.

- Terraced slopes and stepped slopes, as well as any slopes which are steeper than 3:1, should be designed by a licensed professional civil engineer based upon actual site conditions. Adequate drainage channels and diversions must be provided.

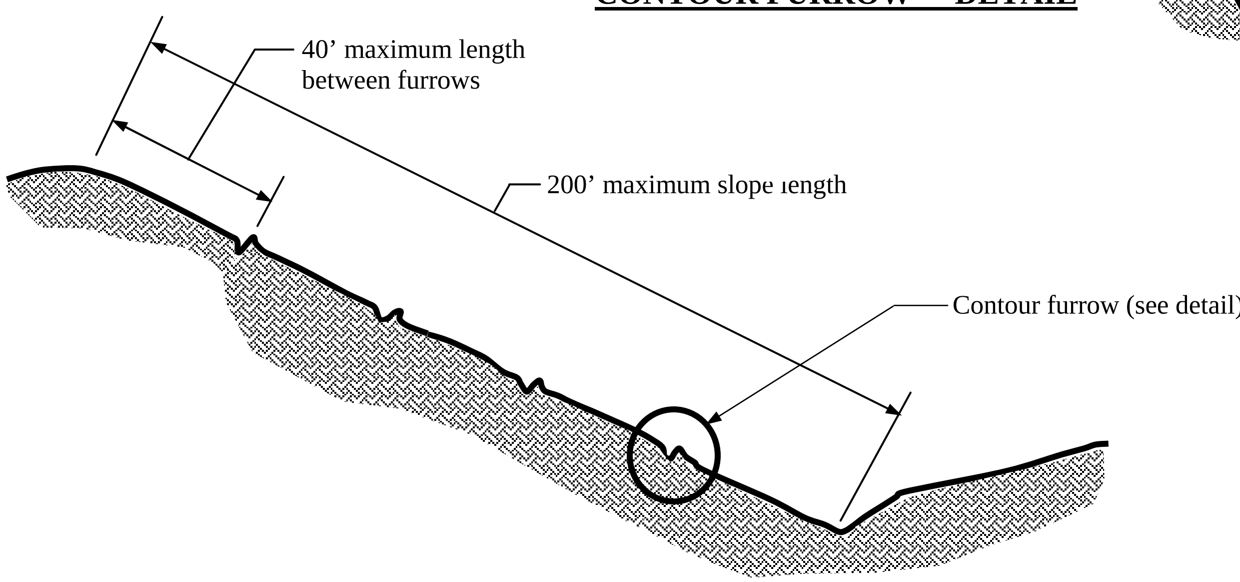
Notes:

1. Contour furrows will catch fertilizer, seed, mulch and rainfall to reduce storm water runoff.

2. Contour furrows should be designed with appropriate channel slope to safely convey storm water without excessive velocity.



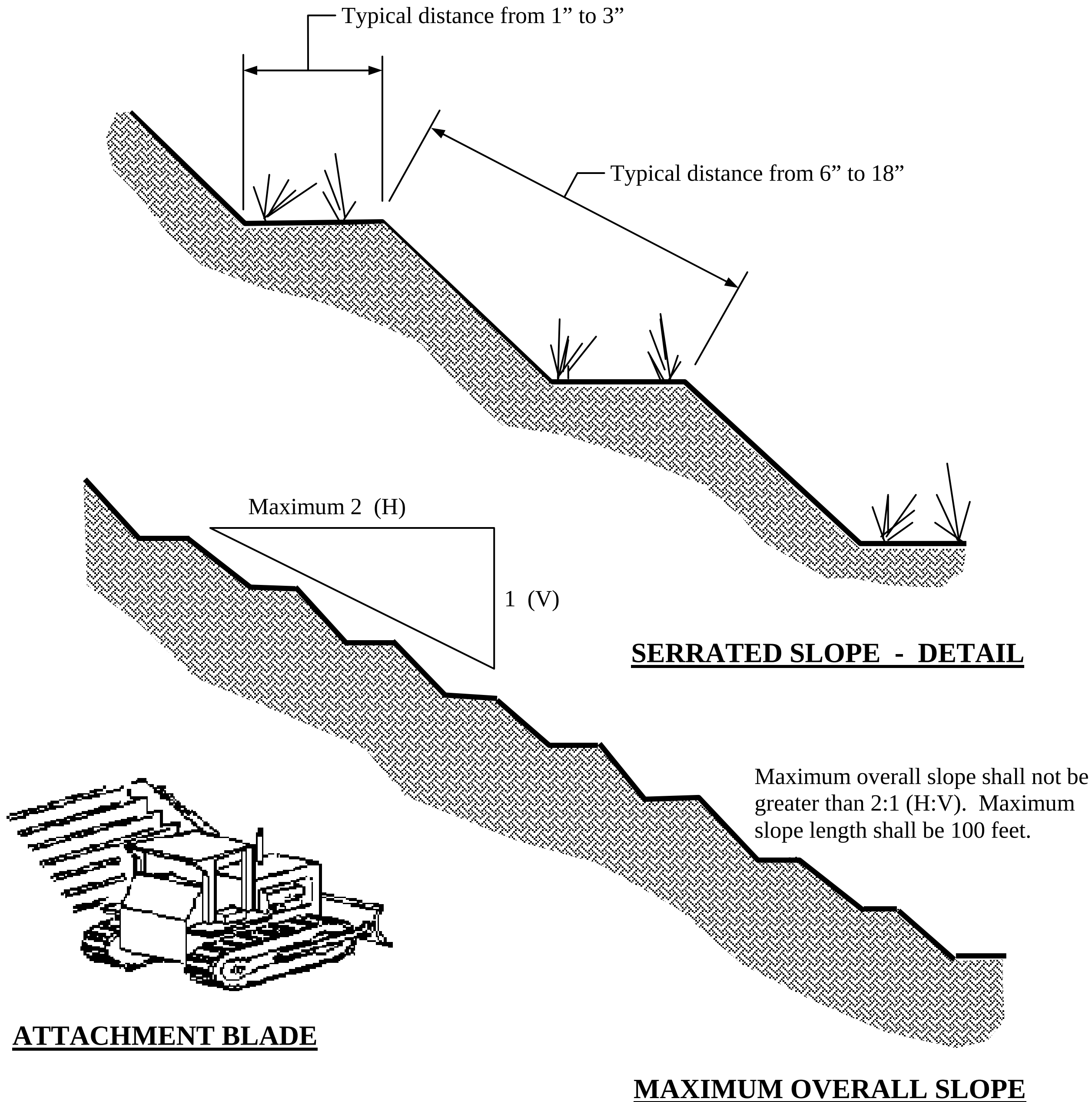
CONTOUR FURROW - DETAIL



CONTOUR FURROW - SPACING

NOT TO SCALE

Figure ES-04-1
Furrow Layout

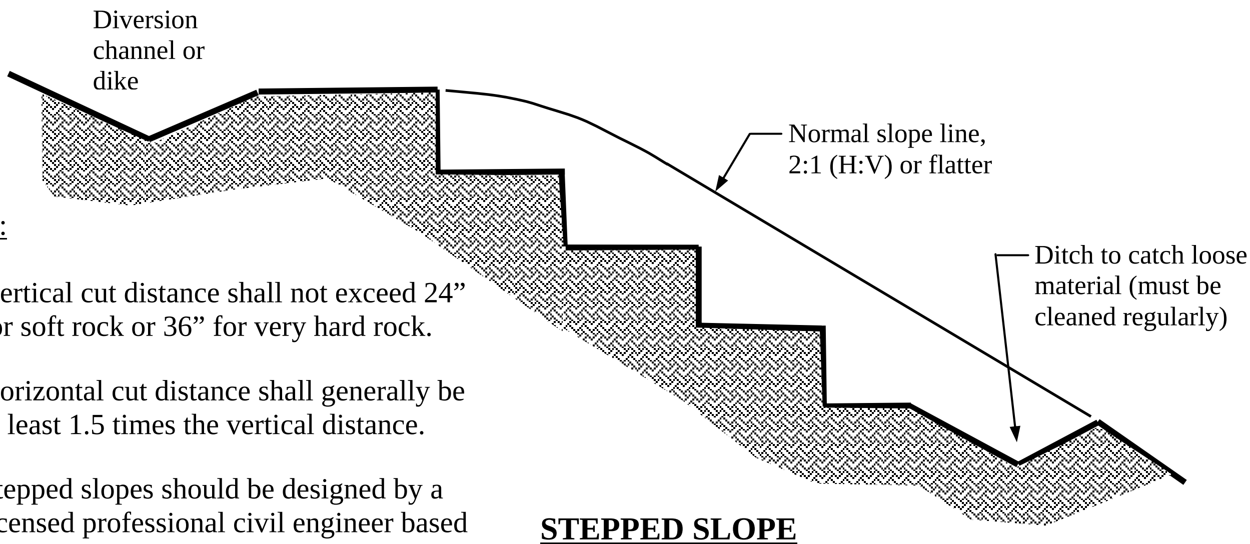


Note:

Serrated slopes will catch fertilizer, seed, mulch and rainfall to reduce storm water runoff.

NOT TO SCALE

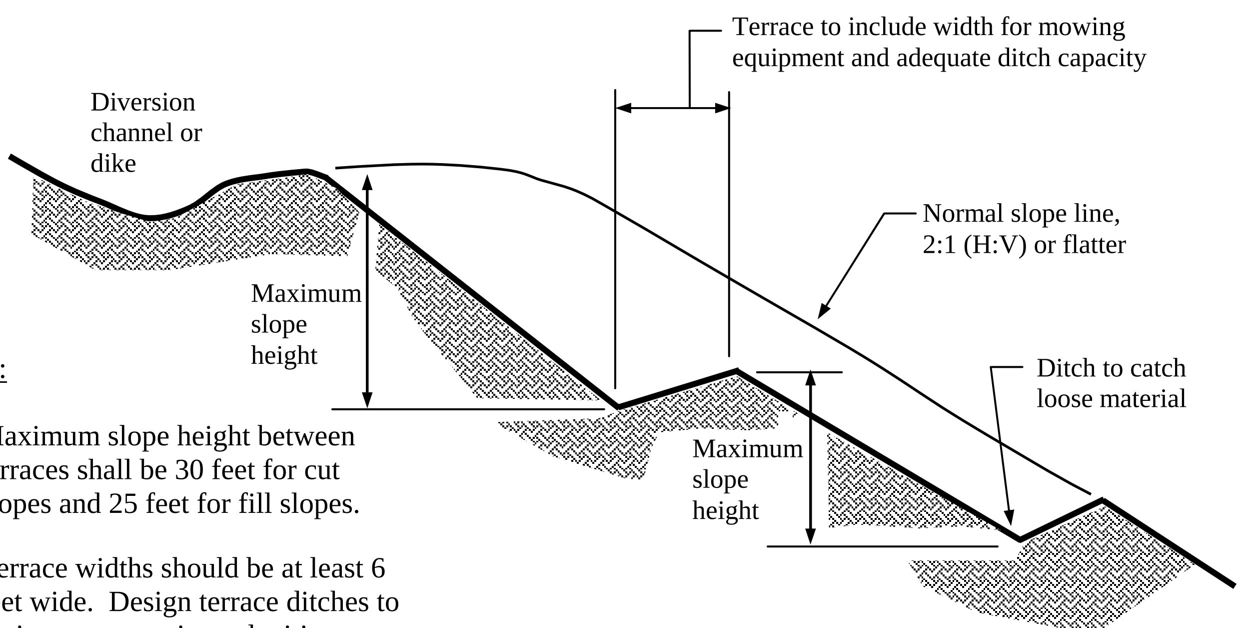
Figure ES-04-2
Serrated Slope Layout



Notes:

1. Vertical cut distance shall not exceed 24” for soft rock or 36” for very hard rock.
2. Horizontal cut distance shall generally be at least 1.5 times the vertical distance.
3. Stepped slopes should be designed by a licensed professional civil engineer based upon actual site conditions.

STEPPED SLOPE



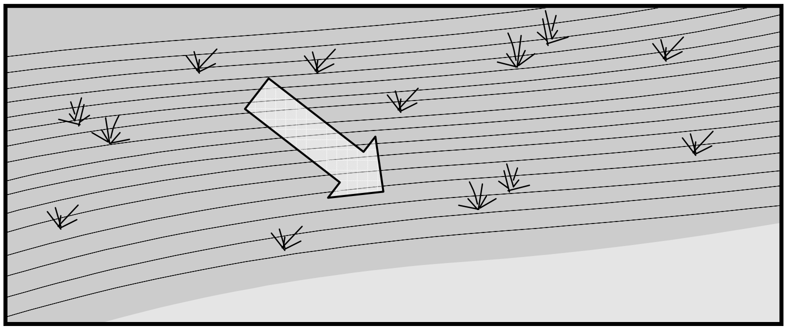
Notes:

1. Maximum slope height between terraces shall be 30 feet for cut slopes and 25 feet for fill slopes.
2. Terrace widths should be at least 6 feet wide. Design terrace ditches to drain at non-erosive velocities.
3. Terraced slopes should be designed by a licensed professional civil engineer based upon actual site conditions.

TERRACED SLOPE

NOT TO SCALE

Figure ES-04-3
Stepped Slopes and Terraced Slopes



Targeted Constituents

● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit

● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances	
○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

Soil roughening is a technique used for creating unevenness on bare soil. The primary function of surface roughening is to reduce erosion potential by decreasing runoff velocities, trapping sediment, and increasing infiltration of water into the soil. It should be used as a permanent measure to prepare slopes for permanent vegetation.

Suitable Applications

- On all construction slopes where seeding, planting, and mulching to stabilize exposed soils will benefit from surface roughening.
- Graded areas with smooth, hard surfaces, and the potential for erosion of clay, silt or sand sized particles.

Approach

Roughening methods may include tilling, disking or harrowing, which must be done across the slope along the contour. Tracking, by contrast, must be done up and down the slope. Factors to be considered in choosing a method are slope steepness, mowing requirements, type of soil, and whether the slope is formed by cutting or filling. Generally, a slope cannot be mowed if it is steeper than 3:1 (H:V). Roughening is performed after the slopes have been graded and dressed. Steep slopes may require the techniques discussed in ES-04, Gradient Terraces.

Cut Slope Roughening

- Consider the use of stepped slopes or terraced slopes. Tilling, disking, and harrowing are acceptable methods of roughening a cut slope. Groove the slope using machinery to create a series of ridges and depressions that run across the slope and on the contour. Make grooves less than 10 inches apart and not less than 1 inch deep. Excessive roughness is undesirable where mowing is planned.
- There are special attachments to equipment specifically for aerating soils, particularly for prepared lawns for houses, parks, golf courses, etc. These attachments should be used as directed by the manufacturer's directions.
- Roughening with tracked machinery should preferably be limited to soils with a sandy textural component to avoid undue compaction of the soil surface. Operate tracked machinery up and down the slope to leave horizontal depressions in the soil. Each pass should move across the slope gradually. Do not backblade during

the final grading operation. Seed and mulch roughened areas to obtain optimum seed germination and growth.

Fill Slope Roughening

- Place fill slopes in lifts not to exceed 8 inches and make sure each lift is properly compacted. Fill slopes are not as stable as cut slopes, no matter how much compaction is applied. Therefore, slopes which are steeper than 3:1 (H:V) should be avoided. The face of the slope should consist of loose uncompacted fill 4 to 6 inches deep.

- Use grooving or tracking to roughen the face of the slopes as necessary. Operate tracked machinery up and down the slope to leave horizontal depressions in the soil. Each pass should move across the slope gradually. Apply fertilizer, mulch, or other soil amendments as necessary prior to grooving or tracking. Do not blade or scrape the final slope face. Seed and mulch roughened areas to obtain optimum seed germination and growth.

Maintenance

Periodically check the seeded or planted slopes for rills and washes, particularly after significant storm events greater than 0.5 inches. Fill rills and washes slightly above the original grade, then reseed and mulch as soon as possible.

Limitations

- Surface roughening may increase grading costs and result in sloughing in certain soil types. Surface roughening and/or stepped slopes may not be practical for sandy, steep, or shallow soils.

- Use equipment that will not rollover on steep slopes. Keep blades and other attachments in the lowered position. Rollover bars must be installed.

- Roughening alone as an erosion control measure is of limited effectiveness in intense rainfall events. If roughening effects are washed away in a heavy storm, the surface will have to be roughened again and new seed and mulch applied.

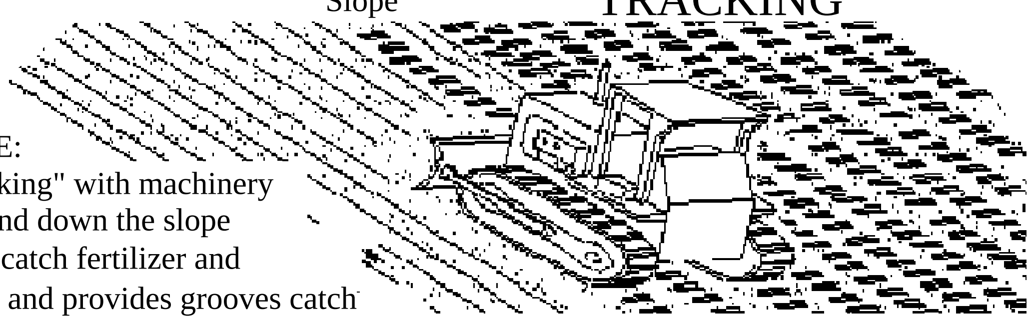
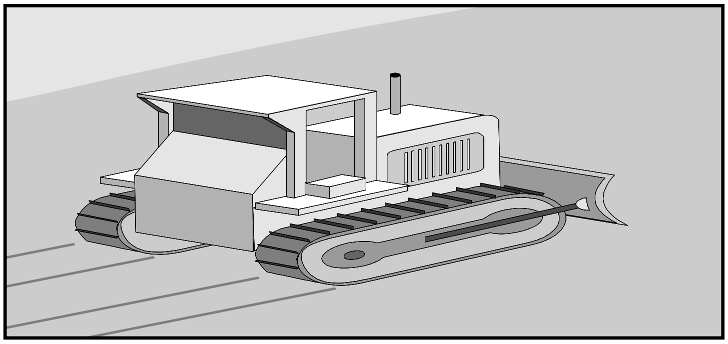


Figure ES-05-1
Surface Roughening – Equipment Tracking



Targeted Constituents

● Significant Benefit ◗ Partial Benefit ○ Low or Unknown Benefit

● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances	
○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	◗ Construction Wastes

Description

Topsoil from the construction site should be preserved and used to enhance the final site stabilization with vegetative cover. This management practice is to be done in support of temporary or permanent seeding, in conjunction with erosion source control practices such as silt fences and mulching.

Suitable Applications

This technique is applicable to all types of areas where earth-disturbing activities expose subsoil layers that are poorly suited to supporting vegetation growth. Topsoil is generally not placed on areas that are steeper than 3:1 or which are not adequately graded and compacted.

Approach

Preservation and reuse of native topsoil helps to improve the success rate of new vegetation. Importing topsoil may be necessary for some areas which do not have fertile soil layers.

Typically, a minimum of 4 inches of stabilized topsoil is needed to support grass vegetation. Trees, shrubs and vines will require a good layer of topsoil in addition to the proper subsurface soils. If the site is excavated down to rock such as sandstone or shale, then 6 to 12 inches of topsoil is recommended for good plant growth.

Stripping Topsoil

- Vegetative material that is cleared and grubbed during construction can be economically reused as compost or mulch onsite if handled correctly. Inspect to be sure that nuisance vegetation and weeds are not composted. Stockpile and water as necessary.

- Prior to stripping away topsoil, make certain that all downslope sediment control practices are in place and operational.

- Strip topsoil (typically 4 to 6 inches) only from those areas that will be disturbed by excavation, filling, road building, or compaction from equipment. Locate topsoil stockpiles where they will not erode, block drainage structures, or interfere with work on the site. Contain sediment using measures such as silt fences, straw bales, temporary seeding, erosion control mats, etc.

Placing Topsoil

- Prior to placing topsoil, verify that the subgrade has been graded and compacted. Scarify subgrade to a depth of 3 inches or disk the subgrade to ensure that topsoil bonds with underlying earth.

- Imported topsoil, if needed, shall be from a reliable non-contaminated source. Perform pH tests prior to placement in order to determine soil amendments and treatments necessary to support vegetation growth. Perform pH tests whenever a change in topsoil is noted or a different source is selected.

- Apply a minimum of 4 inches topsoil evenly. Compact soil with one or two passes of a tracked piece of equipment up and down the slope (see ES-05, Surface Roughening) to reduce erosion potential.

- Apply fertilizer at rates suitable for the particular type of vegetation and soil conditions. Consult an agricultural extension agent or a horticulturist for specific instructions and recommendations.

- Table ES-06-1 shows the typical amount of lime needed for topsoil which does not meet normal pH requirements. The amount of lime will also depend on the particular type of vegetation selected.

Maintenance

Inspect areas of newly-applied topsoil frequently until vegetation is fully established. Maintain newly-graded topsoil areas and inspect regularly. Restore areas showing wash and settlement to the specified grades with a tolerance of 1 inch above or below. Finish grading is ordinarily done by hand shovel operations.

Limitations

- Topsoil can wash away if erosion control practices are not provided. Place stockpiles in protected areas with silt fences and other controls.

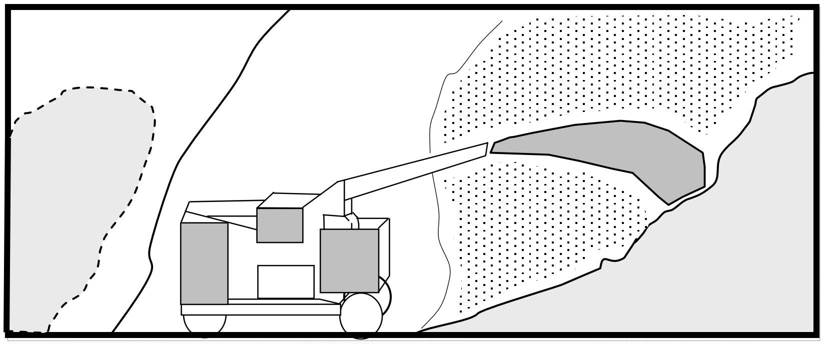
- Topsoil should not be applied to slopes steeper than 3:1 (H:V) without the use of suitable erosion control matting or geotextile (see ES-11 and ES-12).

Table ES-06-1
Typical Amount of Lime Required for Grass Seeding

Topsoil pH	Lime required per 1000 square feet
Less than 4.0	(soil not suitable for use)
4.0 to 4.5	160 pounds
4.5 to 5.0	120 pounds
5.0 to 5.5	80 pounds
5.5 to 6.0	40 pounds
6.0 to 8.0	0 pounds
Over 8.0	(soil not suitable for use)

ACTIVITY: Mulch

ES – 07



Targeted Constituents

● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit		
● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances	
◗ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

Mulch is the application of shredded or processed material to the ground surface for the purpose of protecting vegetation. Mulch is used to temporarily or permanently stabilize cleared or freshly-seeded areas. Common types of mulches include organic materials, straw, wood chips, and bark or other wood fibers. Mulch is likely to create a significant reduction in sediment and a partial reduction in nutrients.

Uses

- Temporary stabilization of freshly seeded and planted areas, or during periods unsuitable for growing permanent vegetation.

- Permanent stabilization around established plants, such as trees or shrubs, in order to prevent the growth of weeds and to maintain soil moisture conditions.

- On poor or marginal soils, to add organic matter and retain moisture and fertilizer, as a strategy to speed establishment of permanent vegetative cover.

- As a short-term ground cover on steepened slopes to reduce rainfall impact, decrease the velocity of sheet flow, and settle out sediment.

Approach

The term “mulch” is commonly used to describe a variety of materials, such as:

- Grass clippings from lawnmowers
- Shredded tree bark and other woody materials, to protect trees and shrubs
- Straw or hay, scattered across a slope or disturbed area
- Peat mulch, used in planting trees and shrubs (see ES-10)

Grass Clippings

Since grass clippings and other vegetative matter decompose quickly, these materials should not be disposed as municipal waste to be carried to a landfill. Mulching mowers are specifically designed to make short grass clippings that will remain on the ground surface and decompose quickly. The essential practice for protecting storm water is to remove grass clippings from streets, driveways, ditches, storm water channels, detention basins, slopes and any other areas subject to storm water flow.
Grass clippings may also be composted, along with most types of non-acidic tree leaves.

- Grass clippings can be left on lawns if the volume is small and the clippings have been chopped into small pieces. Remove grass clippings from paved surfaces and drainage channels.

- Remove only one-third of the total height of the grass blades at each mowing, these clippings can be left on the lawn and are unlikely to wash away.

- Mulching mowers work best when about one inch of grass is removed at each mowing. For actively-growing lawns, this equates to once a week (depending on the type of grass, amount of fertilizers, sun/shade, etc.).

- If two inches or more is cut at each mowing, mow more frequently or use a bagging-type mower to prevent accumulation of excess clippings on the lawn surface. Rainfall, temperature, and soil fertility may cause variations in the normal mowing interval for many homeowners.

General Description

Mulch is basically defined as a layer of material spread uniformly over a ground surface to prevent weeds and/or retain soil moisture. Mulch is usually an organic material such as shredded tree bark, hay, straw, sawdust or leaves. Mulch prevents erosion by protecting the soil surface from rain and runoff impact and fostering growth of new seeds or seedlings. The choice of mulch should be based on the size of the area, site slopes, amount of sunlight or shade, proximity to drainage features and natural streams, soil hardness and moisture, weed potential, and availability of mulch materials. Organic materials may also decompose and aid the soil in providing nutrients for vegetation.

Inorganic materials such as inert black plastic or manufactured landscaping fabric can also be used to prevent weeds and retain moisture, but are not considered as mulch. Newspaper is also commonly used to control weeds, but is subject to leaching of ink and chemicals. The use of newspaper within soil for weed control is discouraged.

Grass Vegetation

Mulch helps to establish temporary or permanent grass vegetation for disturbed soils after a construction project or land-use reclamation project. Straw and hay mulch are often selected due to the ease of application and good results. Alternatively, hydroseeding (including hydraulic application of mulch) is often performed, especially on steep slopes and locations which require quick establishment of grass.

Applying straw or hay mulch to a slope or hillside will require either physical measures (crimping, erosion control mats) or chemical binders (special asphalt emulsions) to keep the mulch from washing away or blowing away. The binder is also called a tacking agent or tackifier. A typical application rate might be 100 pounds of straw or hay mulch per 1000 square feet.

Application

Vegetative Fibers

Loose hay or straw are the most common mulch materials used in conjunction with direct seeding of soil. Straw mulch is preferable over hay mulch, which may contain weeds and other objectionable material. Straw mulch is the short-term protection most commonly used with seeding. Wheat or oat straw is recommended from the current season's crop (less than 12 months old). Average fiber length should exceed 6 inches.

Straw mulch is applied immediately after seeding, either by machine or by hand distribution. Anchor the mulch in place using a tacking agent, plastic netting, or punching into the soil mechanically. Plastic netting (see ES-11, Erosion Control Matting) requires wire staples, wooden stakes, or plastic stakes. If the slopes are too steep for netting, then tacking agents should be selected on the basis of longevity and ability to hold the fibers in place.

Shredded Vegetation

"Green" mulch is produced by recycling of vegetation trimmings such as grass, shrubs, and trees. Methods of application are generally by hand, although pneumatic methods are currently being developed. It can be used as a temporary ground cover with or without seeding. The green material should be evenly distributed at a depth necessary to prevent erosion. Anchor green mulch in place with a tacking agent on steep slopes and in areas where overland sheet flow is anticipated. The quality of green mulch may vary, and there is a strong potential for establishing unwanted weeds and plants.

Wood and Bark Chips

Wood and bark chips are suitable for landscaped areas that will not be closely mowed. Wood and bark chips should not be used on steep slopes and therefore do not require tacking agents. Wood chips may require nitrogen treatment (12 pounds/ton typical rate) to prevent nutrient deficiency. Bark chips do not require additional nitrogen fertilizer.

If there is a wood source near the project site, wood and bark chips can be very inexpensive. Caution must be used in areas of steep slopes, since both wood and bark chips tend to wash down slopes exceeding 6 percent. Wood and bark chips are also used around trees and shrubs, or in ornamental or landscape gardens. A typical depth is 2 to 3 inches.

Hydraulic Mulch

Hydraulic mulch can be made from virgin wood fibers or from recycled waste paper sources (newsprint, magazine). There are also mulches available which are a combination. In general, virgin wood fibers contain a longer fiber length than recycled paper mulch.

Hydraulic mulch is mixed in a hydraulic application machine (such as a hydro-seeder or a mulch blower) and then applied as a liquid slurry. The hydro-seeder slurry contains recommended rates of seed and fertilizer for the site, usually specified with a tacking agent. Slurry must be constantly agitated to keep the proper application rate and achieve uniform effective coverage.

Hydraulic application of seeding and other materials (hydro-seeding) can be done quickly and efficiently with the correct equipment and ingredients. Also, hydraulic application must be done when no rainfall is expected, preferably within a 24-hour time period.

Virgin wood fiber mulch consists of specially-prepared wood fiber that does not contain any growth-inhibiting factors. The mulch is manufactured and processed so the fibers will remain in uniform suspension in water under agitation to form a homogenous slurry. The fiber lengths should be as long as possible to increase the effectiveness for erosion control. Wood fiber mulching should not be used in areas of extremely hot summer and late fall seasons because of fire danger. When used as a tacking agent with straw mulch, wood fiber mulches are good for steep slopes and severe climates.

A wood fiber mulch can be manufactured containing a tacking agent in each bag or specified without a tacking agent. A typical construction specification for wood fiber mulch is as follows:

- Composed of 100 % wood fiber.
- Moisture content (total weight basis) not to exceed 12%.
- Organic matter content (dry weight) = 99.3% minimum.
- Inorganic matter (ash) content (dry weight) = 0.7% maximum.
- Controlled pH values
- Water-holding capacity (dry weight) = minimum 1.2 gallons per pound.

A high-quality type of hydraulic matrix known as a Bonded Fiber Matrix (BFM) is generally manufactured for easy application by the appropriate equipment. It generally contains a tacking agent mixed with the wood fibers.

Combination mulch may include wood fiber and paper fiber, with a tacking agent. A hydraulic matrix can be formulated using varying quantities of these components. A typical mixture is as follows:

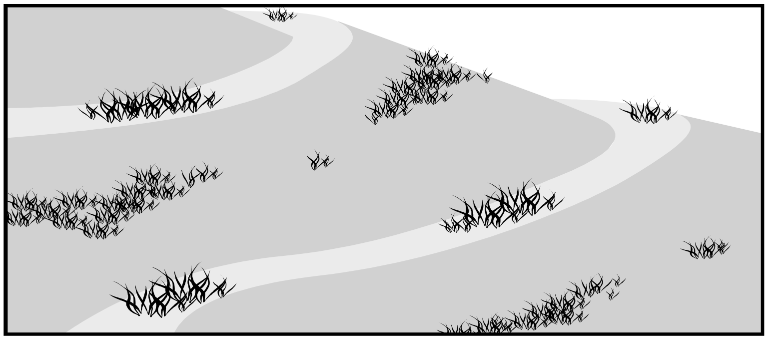
- 12 pounds per 1000 square feet wood fiber mulch.
- 24 pounds per 1000 square feet recycled paper mulch.
- 2 gallons per 1000 square feet acrylic copolymer (55% solids content).

Maintenance

- Avoid traveling on mulched and seeded areas. Maintain traffic barriers and fencing as necessary.
- Inspect mulched areas weekly and after rainfall for damage or deterioration. Replace as necessary. Continue inspections until vegetation is firmly established.

Limitations

- Organic mulches tend to lower the soil surface temperature, and may delay germination of some seeds. Organic mulches may also affect the pH of soil.
- The tackifier may lose adhesiveness during very cool weather or due to extreme temperature variations.



Targeted Constituents

● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit

● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances

◗ Nutrients	◗ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

Temporary or permanent stabilization of soil, with rapidly growing annual or perennial grasses, is used to prevent erosion on disturbed areas. Temporary seeding is performed for graded areas that are not ready to receive permanent vegetation. Permanent seeding is performed for finished construction areas and for eroded areas that need a permanent vegetation cover.

Suitable Applications

- Apply temporary seeding whenever grading operations are temporarily halted for over 14 days and final grading of exposed surfaces is to be completed within one year. Apply temporary seeding to soil stockpiles.

- Apply permanent seeding whenever grading operations are completed and all construction operations will not impact the disturbed area. Apply permanent seeding to all non-construction areas which show signs of excessive erosion.

Approach

Sheet erosion, caused by the impact of rain on bare soil, is the source of most fine particles in sediment. To reduce this sediment load in runoff, the soil surface itself should be protected. The most efficient and economical means of controlling sheet and rill erosion is to establish vegetative cover.

Proper seedbed preparation and the use of quality seed are important in this practice. Failure to carefully follow sound agronomic recommendations will often result in an inadequate stand of vegetation that provides little or no erosion control.

Temporary seeding is essential to preserve the integrity of earthen structures used to control sediment, such as dikes, diversions, and the banks and dams of sediment basins. Temporary seeding may prevent costly maintenance operations on other erosion control systems. Annual plants which sprout rapidly and survive for only one growing season are suitable for establishing temporary vegetative cover.

Permanent seeding is necessary to prevent long-term erosion of topsoil from the land surface. If performed correctly, permanent seeding will provide many benefits such as increased land value, aesthetics and animal habitats, in addition to reduced erosion and sedimentation.

General Seeding Guidelines

- Verify that erosion control devices are functioning. Prepare ground surface using methods in ES-04, Gradient Terraces, and ES-05, Surface Roughening.
- Select desired type of grasses.
- Analyze topsoil for fertilizer and lime requirements. Fertilizer and lime shall be uniformly incorporated into soil at a minimum depth of 1 inch, typically by rakes.
- A typical fertilizer application rate is anywhere from 5 to 20 pounds per 1000 square feet with commercial grades 6-12-12 and 10-10-10 being commonly used. Fertilizer should be free-flowing and uniform in composition. Fertilizer packaging should indicate weight, chemical analysis and date of production.
- Lime requirements are listed in Table ES-06-1 for soils with a pH less than 5.5. Requirements for crushed agricultural limestone are generally a minimum of 85% by weight calcium carbonate and magnesium carbonate.
- Purchase seed from a reputable dealer in original packaging that indicates percentage of seed mix, date of production, net weight, seed purity and germination rates.
- Apply selected seed at rate recommended for temporary or permanent seeding, using seeding package instructions or as directed by local experts (such as a horticulturist or agricultural extension agent). Seed should be sown uniformly by means of a rotary seed spreader, hydraulic equipment, or hand broadcasting.
- Apply straw mulch with tackifier, especially to seedlings in the fall for winter cover or on slopes that exceed 3:1 (H:V). See ES-07, Mulch, for additional description and methods.
- A tackifier should generally be used in conjunction with mulch for steep slopes. A tackifier is an inflammable, non-toxic, non-asphaltic, organically-formulated product which is capable of holding mulch and soil in place. Tackifier compound may contain a color additive to assist in the uniform application of product after mixing with water.
- Tackifier and water shall be blended and applied at a rate that is in accordance with the manufacturer's written instructions. Written instructions may give different application rates for revegetation (mulch tackifying) and for erosion control (soil stabilization). Application shall be performed with a fine spray immediately after each area is mulched.
- Do not seed during rainfall events or when heavy rain is predicted. No seeding shall be done during windy weather or when the ground surface is frozen, wet or otherwise unsuitable. Permanent seeding shall not be performed during December and January. Temporary seeding may be performed during the winter months with expectations that additional seeding is required in the spring.
- For slopes steeper than 3:1 or where surface water cannot be diverted from flowing over the face of slopes, install erosion control matting such as jute nets or excelsior mats (see ES-11, Erosion Control Matting). Mulch and tackifier are not required

for areas that receive erosion control matting.

- Do not allow any equipment or material placed on any seeded areas. Erect suitable barricades and guards to prevent equipment, vehicles or labor from traveling onto or over any seeded areas.

- Maintain newly seeded areas until final acceptance of the construction project or until erosion problems have stopped. Restore areas which are washed out or which have settled. Reseed as necessary until an acceptable grass stand has been achieved.

Temporary Seeding

- All areas receiving temporary grass mixture shall receive an application of fertilizer and be protected with mulch or erosion control matting. Apply fertilizer at a minimum rate of 5 pounds per 1000 square feet. Uniformly incorporate into soil for a depth of 1 inch. Lightly water to aid dissipation of fertilizer.

- Apply seed mixture at recommended application rate evenly in two intersecting directions by the use of a mechanical spreader. Do not seed an area in excess of that which can be mulched on the same day. Do not sow immediately following rain, when ground is too dry, or during windy periods.

- Straw mulch shall be applied at a minimum rate of 100 pounds per 1000 ft^2 and traversed with mechanical roller or other device specially manufactured for crimping. Mulch shall be applied immediately after seeding. All mulched areas shall receive an application of tackifier.

- Lawns and parks: Apply the desired permanent grass mixture at reduced rates. Use straw mulch liberally, and use additional slope stabilization methods for steep grades. Typical seeding rate is 2 to 3 pounds per 1000 square feet.

- Fields and open spaces: Consult local agricultural extension office for recommended types of crops or grasses, and follow suggested seeding dates.

Permanent Seeding

- All areas receiving permanent grass mixture shall receive an application of fertilizer and be protected with mulch or erosion control matting. Apply fertilizer at a rate of not less than 10 pounds per 1000 square feet. Apply lime at rate based on pH of soil. For dry seeding, uniformly incorporate into soil for a depth of 1 inch and lightly water to aid the dissipation of fertilizer.

- Apply seed mixture at recommended rates evenly in two intersecting directions by the use of a mechanical spreader or hydro-seeder. Do not seed area in excess of that which can be mulched on same day. Do not sow immediately following rain, when ground is too dry, or during windy periods.

- Combined hydraulic application of seed, fertilizer, and mulch may be performed. Tackifier application may be within the combined mixture if allowed by manufacturer's recommendations. Hydraulic spraying equipment and mixture shall be designed so that when the grass mixture is sprayed over the area, the mixture components shall be equal in quantity to the specified rates.

- Wood fiber mulch shall be applied at a minimum rate of 35 pounds per 1000 square feet. As an option, straw mulch can be utilized at a rate of 100 pounds per 1000 square feet. Mulch shall be applied immediately after seeding or during seeding. All mulched areas shall receive an application of tackifier.

- Lawns and parks: Tall fescue grasses have good resistance to high temperatures, drought, and soil acidity. Bermuda grass is commonly used for lawns and for athletic fields; it does not fare well in shady areas. Shady lawns and parks may require a more specialized seed mixture. Plant in the late summer or early spring to take advantage of mild climate conditions in spring and autumn. Typical seeding rate is 5 to 8 pounds per 1000 square feet.

Hydroseeding

Hydroseeding is the wet hydraulic spraying of seed, fertilizer, tackifier and usually mulch in a one-step process. Materials are mixed with water in a slurry tank to form a homogeneous slurry, which is then sprayed on the soil surface at a uniform rate in two intersecting directions by a hydraulic seeder.

Ordinary mulch is not suitable for hydroseeding. Mulch for hydroseeding is generally virgin wood fiber mulch at a rate of 35 pounds per 1000 square feet, manufactured to be uniformly suspended as a slurry. Alternatively, straw mulch can be applied after hydroseeding at a rate of 100 pounds per 1000 square feet.

Maintenance

- Inspect frequently within the first six weeks of planting to see if grass stands are uniform and dense and to assure that appropriate moisture levels are maintained. Make provisions to water as needed to penetrate to a depth of 6 inches.

- Check for damage caused by equipment or heavy rains. Damaged areas should be repaired, fertilized, seeded, and mulched. Tack or tie down mulch as necessary.

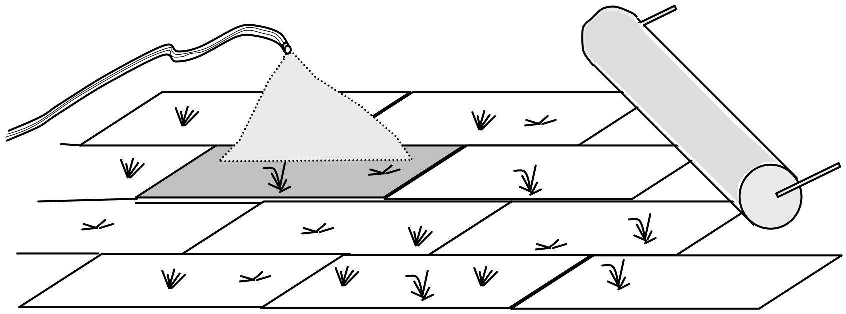
Limitations

- Annual rye grass and a few other types of annual grass may reseed the following year without assistance. This may make it difficult to establish a different type of grass as permanent vegetation.

- Uneven application of fertilizer, lime, seed or other materials may cause patchy growth and erosion. Over application of fertilizer or lime causes storm water runoff pollution.

ACTIVITY: Sodding

ES – 09



Targeted Constituents				
● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit		
● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances	
○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

The placement of sod allows the rapid establishment of grass vegetation, along with a layer of good topsoil. This can be beneficial in critical erosion areas, adjacent to natural streams and ditches, and as a filter strip to slow storm water runoff and trap sediment.

Suitable Applications

- Critical erosion areas such as slopes, drainage channels, detention basins and streambanks.
- Adjacent to paved areas such as streets, sidewalks and parking lots to slow storm water runoff and to filter pollutants.
- Adjacent to catch basins and yard inlets to filter pollutants.
- Areas without enough topsoil to establish seeded vegetation and grass.

Approach

Sodding is usually specified for aesthetic reasons on projects which have a substantial landscaping budget. However, sodding can also be useful for projects which have almost no landscaping budget and a limited erosion control budget. The use of sod adjacent to paved areas can greatly reduce the amount of sediment entering streets and parking lots. The use of sod in detention basins and adjacent to catch basins will greatly reduce the maintenance effort to clean storm water structures.

The type of grass should be selected on the basis of use, site conditions and slope, amount of sunlight, intended grass height, etc. Popular types of grass that can be placed by sodding include:

- Kentucky bluegrass (all-purpose, residential and commercial lawns)
- Bermuda grass (athletic fields)

Soil preparation is just as necessary for sod placement as it is for seeding operations. Do not place sod on compacted and hard soils. Disking and harrowing will usually be necessary to prepare the subgrade soil for receiving sod. See Table ES-09-1 for a comparison of advantages for seeding versus sodding.

The use of certified sod will ensure that a high-quality, dense stand of grass is established on fertile soil that is generally free from weeds, insects and plant disease.

Production

Sod is grown in controlled environments using certified seeds and carefully controlled soil. Obtain sod from a reputable dealer with appropriate certifications to ensure best quality. It may be beneficial to visit the facility in order to verify that adequate watering and fertilization equipment is used.

Sod should be at least 3/4 inch thick, consisting of a thatch and root zone that is capable of supporting the sod during transportation and placement. Biodegradable polypropylene netting is often placed on the sod early in the growing cycle as an erosion control measure to protect seedling. Sod shall consist of live, well-rooted growth of the specified permanent grasses. Often a blend of two or more tolerant grasses is specified, in order to increase survival rates. Sod shall be free from insects and disease. Sod shall be free from weeds such as Johnson grass, dandelion, nutgrass, poison oak or ivy, crabgrass, thistles, rush grass, morning glory, etc.

Sod is generally harvested and transported the same day, in order to limit stress on the grass. Transportation distances are usually less than 100 miles, which also ensures that the sod is grown in climate conditions similar to the installation location. Harvesting may be done by slabs or rolls using mechanical cutters. Typical slab dimensions are 18” wide and 24” long. Transportation methods must minimize hot and cold temperatures and also desiccation by air during highway speeds.

Placement

Carefully prepare the subgrade soils prior to placing sod. Remove rocks, large clods and roots as a first step. The subgrade soils must be loosened to a depth of at least 3 inches prior to placing sod. Apply fertilizer and lime to the subgrade immediately prior to placing sod. Soil testing is recommended to determine fertilizer and lime application rates. Typical application rates are 10 pounds fertilizer and 50 pounds agricultural lime per 1000 square feet.

Inspect sod upon delivery; reject damaged sod or desiccated sod. Install sod soon after delivery to the project site. Keep sod in the shade prior to placement. Liberally water subgrade soils prior to placement to establish moisture beneath the sod layer. Place sod in a brick pattern so that there are no seams in the longer direction. Seams in the shorter lawn direction are permissible but should be limited in length. Align direction of sod so that cutting and trimming of slabs will be minimized. Do not use pieces of sod that are damaged.

Carefully handle sod during unloading and placement, to retain as much topsoil as possible for the grass root systems. Each strip of sod should be closely fitted to the existing edges. A machine cut may be angled in such a way that butt ends will fit. A mason’s trowel is often used to correctly fit and tuck ends of sod together. Do not stretch a piece of sod to cover a few more inches; trim sod and place an additional piece of the correct size. Roll the sod into place using a lightweight hand-operated roller in order to create solid contact with the subgrade soil.

Sod should be immediately watered after installation, at a rate of up to 1 inch the first day during the heat of summer. Apply water gently and evenly so that the soil is moist throughout. Water at least daily for a period of three weeks.

Sod placed in drainage channels or slopes steeper than 4:1 will usually require pegs or staples. A typical pattern is four pegs/staples per block of sod, with an additional secure point in the middle for large pieces of sod. Additional jute netting or other erosion control may be required for drainage channels with substantial flows.

Maintenance

- Sod maintenance is important to preserve the cost and effort investment. Sod should be kept moist for at least 3 weeks until it is properly rooted. Do not mow sod for three weeks; set the mowing height to only trim the grass blades by 1/3 or less when cutting the sodded grass for the first time.

- Inspect sod daily, especially after heavy storms or severe winds. Repair damage promptly using stakes or pegs. High-quality topsoil may be used to repair chinks or gaps from storm damage.

Limitations

- Placement of sod can be expensive and time consuming. Sod must be handled carefully. Appropriate moisture conditions can be difficult to maintain during transportation and placement, especially in hot weather.

- Do not place sod during the winter or when frozen conditions may occur. Ideal conditions generally occur in the middle of spring or autumn.

- Protect newly-placed sod from heavy use and vehicle traffic for at least one month. Protect sod from burrowing animals and from foot traffic (children playing) when possible.

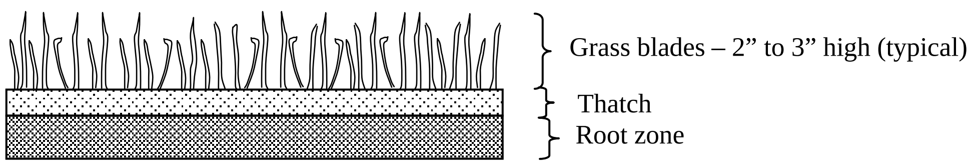
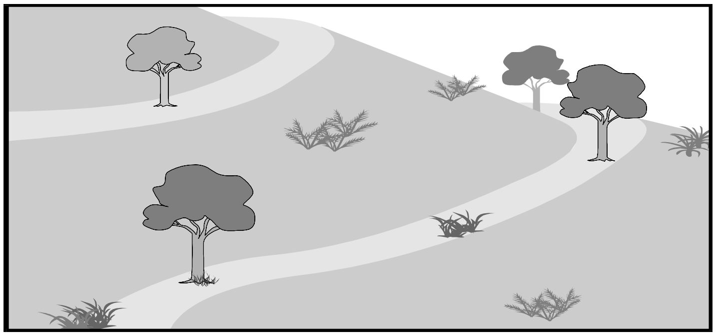


Table ES-09-1 **Comparison of Seeding and Sodding**	
Advantages of seeding:	Advantages of sodding:
Less expensive materials Less labor and effort required No transplanting Grass develops in final location	Establish high-quality grass surface Less chance of failure Immediate aesthetics Immediate erosion control No weeds

ACTIVITY: Trees, Shrubs and Vines	ES – 10



Targeted Constituents			
● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit	
● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances
◗ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses
○ Construction Wastes			

Description

Planting trees, shrubs, vines and other ground covers will provide long-term stabilization of soil. The primary functions of permanent vegetation is to improve aesthetics, reduce erosion by slowing runoff velocities, enhance infiltration and transpiration, trap sediment and other particulates, protect soil from raindrop impact, and provide habitat for wildlife. This management practice is likely to create a significant reduction in sediment.

Suitable Applications

- Appropriate for site stabilization both during construction and after construction
- Open areas and slopes, such as parks or playgrounds
- Landscaping corridors and buffer areas
- Near buildings and structures, to provide shade and aesthetics

Approach

Existing vegetation should be preserved whenever possible, particularly native species which are aesthetically pleasing and provide wildlife habitats.

Selecting the right type of vegetation to be planted depends on many factors such as sunlight or shade, water requirements, allowable room, soil pH, amount of soil available, tolerance to automobile emissions or street deicing salts, fertilizer and other maintenance requirements, preference for deciduous or evergreen trees, and aesthetic considerations. For instance, some trees may grow considerably and create problems for overhead utilities or underground pipes.

Trees in particular are essential for improving the urban environment. They provide shade and protection from the elements for humans and for wildlife. Trees greatly improve ground temperatures, air temperatures, the movement of air, humidity, and the transmission of urban noise.

There are also many different species of vines and ground covers from which to choose, but care must be taken in their selection. It is essential to select planting materials suited to both the intended use and specific site characteristics.

For construction projects, planting should be performed as soon as final grading is completed, unless there is a specific planting time recommended for a particular plant.

In areas where no activity is performed, vegetation may be maintained or established along landscaped corridors and buffer zones to act as filter strips.

Permanent planting during the construction stage of projects will require careful coordination between the local agency inspectors, project managers, construction managers, and landscape contractor. Protocols for site access and construction staging are the responsibility of the site owner or his designated site manager.

Trees and Shrubs

Selection: Trees and shrubs, when properly selected, are low-maintenance plantings that stabilize adjacent soils, moderate the adjacent air and ground temperatures, filter air pollutants, and serve as a barrier to wind. Some desirable characteristics to consider in selecting species for trees and shrubs include vigor, potential size and shape, tolerance to man-made environment, adaptability, climate, wildlife habitat, etc.

Sites for new plantings should be evaluated for prior land use, potential for soil contamination, adverse soil conditions such as poor drainage or acidity, exposure to wind, temperature extremes, location of utilities or pavement, and proximity to traffic,

Transplanting: In general, autumn is the preferred time for transplanting small trees. Evergreen trees can also be transplanted in spring. Seedlings (although not usually specified for an urban setting) can generally be planted in the early spring or early autumn to take advantage of moderate temperatures. Proper transplanting for a tree or shrub includes the conservation of as much of the root system as possible. Soil adhering to the roots should be damp when the tree is dug, and kept moist until replanting. The soil ball should be 12 inches in diameter for each inch of diameter of the trunk. Most transplanted trees and shrubs will need artificial support to prevent excessive swaying. Soil around the tree should be thoroughly watered after the tree is set in place, and then watered deeply once a week during summer and dry periods. Mulching at the base of a tree or shrub is helpful in preventing roots from drying out.

Vines and Ground Covers

Selection: Vines and ground covers can quickly spread and stabilize a slope, preventing erosion from occurring. Vine and ground covers come in many types, colors, and growth habits. Some vines and ground covers are suitable only as part of a small well-maintained landscape area, while others can stabilize large areas with little maintenance. Flowers do not provide erosion control but may be planted to add color and beauty. Vines and ground covers provide food and habitat for many types of wildlife.

Site Preparation: Ground covers are plants that naturally grow very close together, which may create competition for space, nutrients and water. Soil for ground covers should be well prepared. The entire area should be spaded, disked, or rototilled to a depth of 6 inches. Approximately 2 to 3 inches of organic material, such as good topsoil or peat, should be spread over the entire area.

General Planting Guidelines

The following general steps will help ensure good plant growth:

1. Position the plantings to follow the contours of the land, taking into account drainage patterns and the potential for heavy winds.
2. Dig the holes approximately 1/3 larger than the plant root ball.
3. Use good topsoil or soil mixture with a lot of organic matter. Fill hole approximately ¼ full and gently shake plants to settle soil among roots.
4. Leave a saucer-shaped depression around the plant to hold water. Use mulch to protect the soil from erosion and to retain soil moisture.
5. Water thoroughly and regularly. Stake and support trees or other vegetation as necessary until root systems are capable of firmly infiltrating the subgrade.

Figures ES-10-1 and ES-10-2 show typical details for planting a shrub or vine and also for planting a tree (balled-and-burlapped). Plants grown in containers are handled in a similar manner. Acclimate plants to outdoor conditions prior to transplanting.

The importance of properly supporting and staking a tree or shrub cannot be overemphasized. Although some trees may take root after a few months, other trees may need to be supported for a couple years. Therefore use proper materials and methods that will both remain functional and look attractive.

Maintenance

- Water trees regularly once a week, particularly during summer months or dry periods. Young trees should receive an inch of water each week for the first two years after planting. Fertilizing may be required for some types of trees and shrubs, in late autumn or early spring. Mulch applied to the base of a tree will help to reduce weeds and retain soil moisture.
- Proper pruning, watering, and application of fertilizer is necessary to maintain healthy and vigorous shrubs. A heavy layer of mulch applied around the shrubs reduces weeds and increases the retention of soil moisture.
- Vines and ground covers will require pruning and watering during the summer months. Vines and ground covers may not provide sufficient erosion control during winter months.
- Trees and shrubs with thin bark may require additional protection from insects and small animals. Spraying may be necessary for some types of trees and shrubs. Repair wounds and abrasions by either tree paint or by removing limbs. Consult an arborist or horticulturist as necessary for the care of trees or shrubs.

Limitations

- If the site is susceptible to erosion, additional control measures may be necessary during the establishment of vegetation. Caution should be exercised in selecting non-native vegetation because of potential impacts to native vegetation on adjacent lands. Non-native species may quickly spread and compete with originally undisturbed vegetation.
- Over application of fertilizers, herbicides and pesticides may create storm water pollution. Follow the guidelines in AM-13 (Pesticides, Herbicides, and Fertilizer Use) to prevent misuse of these materials. Follow package instructions carefully.

- Construction activities are likely to injure or kill trees unless adequate protective measures are taken. Direct contact by equipment is the most obvious problem, but damage is also caused by root stress from filling, excavation, or compacting soil near trees. Follow guidelines in AM-03, Preservation of Existing Vegetation.

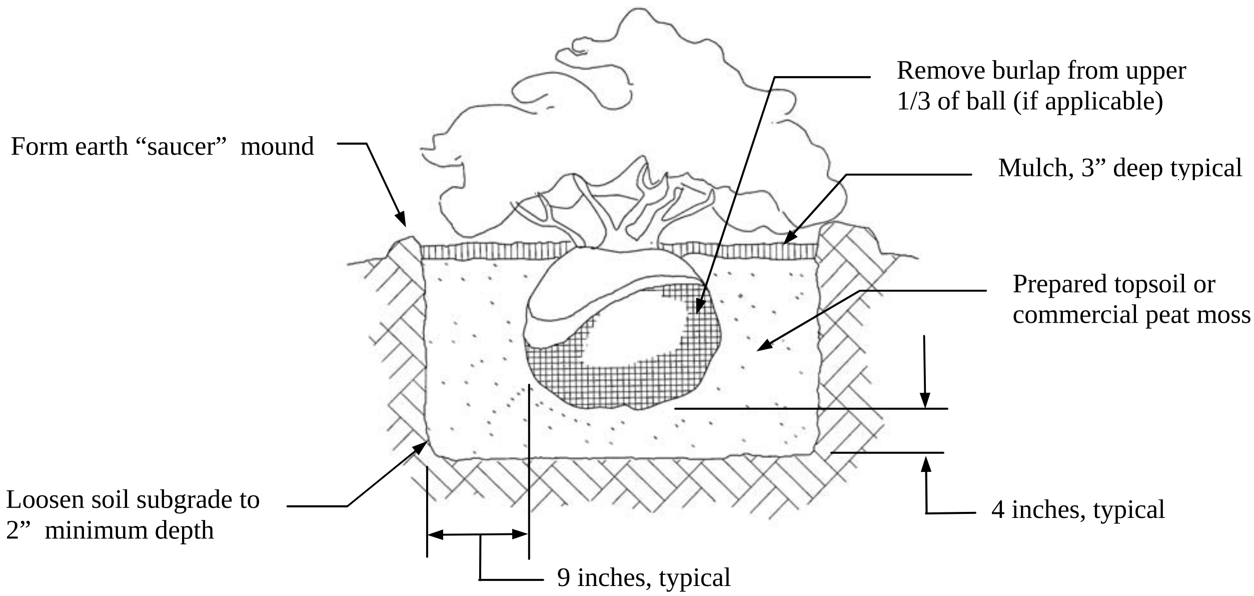


Figure ES-10-1
Typical Planting Detail – Shrub or Vine

Notes:

1. Balled-and-burlapped (B&B) stock from nurseries shall meet the standards of ANSI Z60.1, American Standard for Nursery Stock.
2. Young deciduous trees may be wrapped from the base of the tree to the height of the lowest branches. Wrap shall consist of 4-inch wide rolls of bituminous impregnated tape which is specially manufactured to resist insects.
3. Alternative materials for staking trees include common garden hose, sliced open and fitted around trunk, and galvanized wire, 12-gauge or thicker.

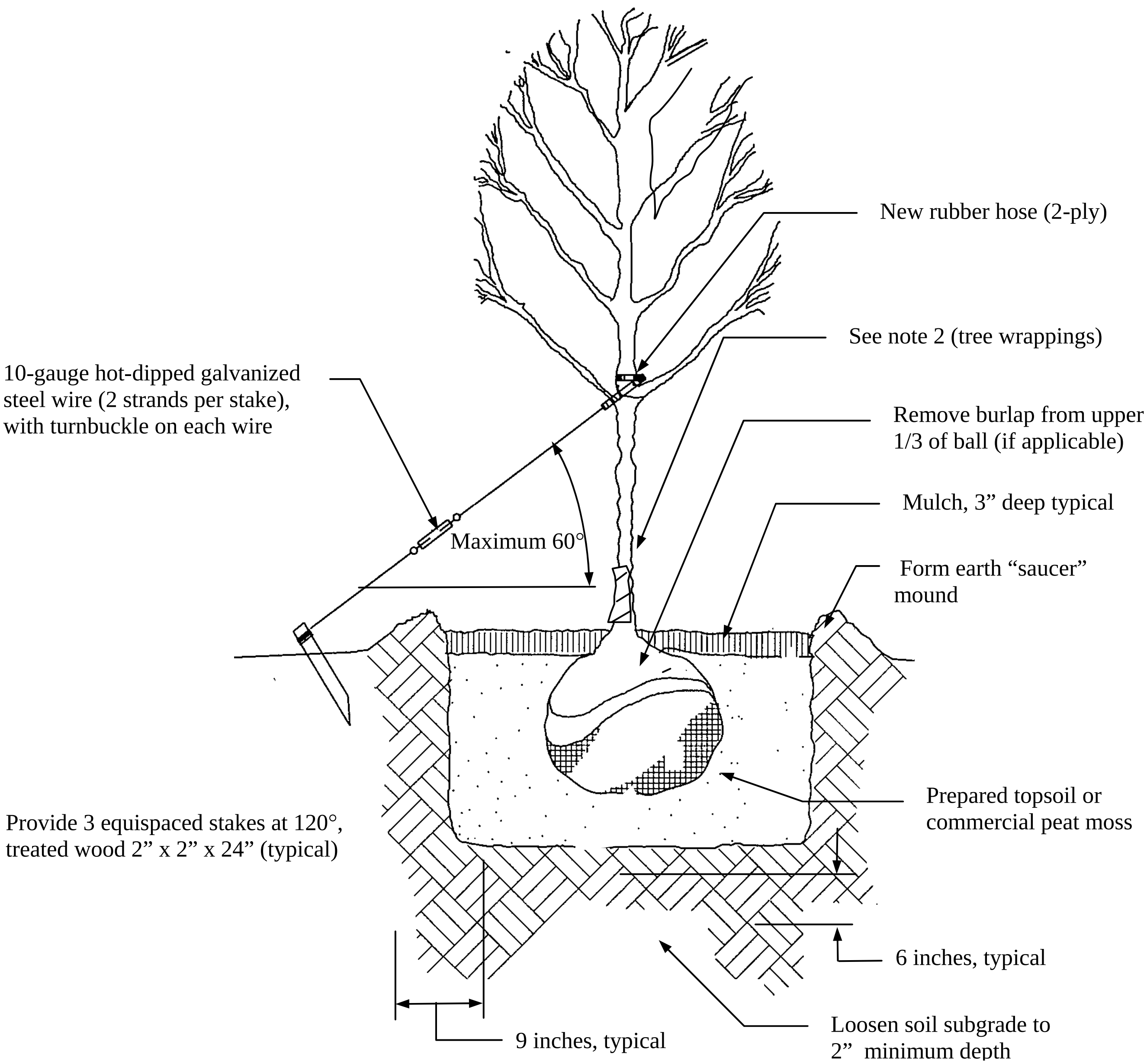
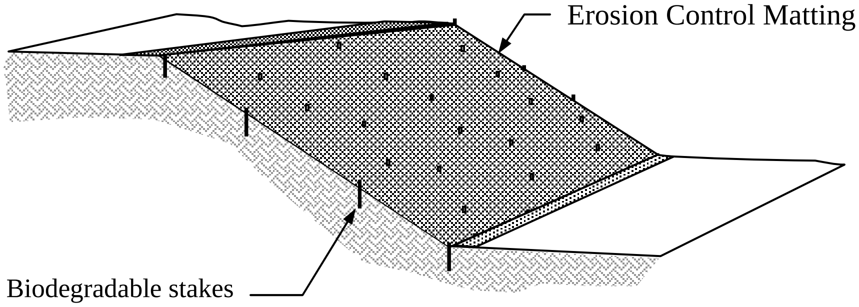


Figure ES-10-2
Typical Planting Detail – Tree

ACTIVITY: Erosion Control Matting

ES – 11



Targeted Constituents

● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit		
● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances	
○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

Placing jute mesh, excelsior matting, or other lightweight erosion control mat will reduce erosion on previously graded and seeded swales, channels, slopes, or critical areas. Firmly anchor erosion control matting by means of trenching, anchor slots, stakes or staples. This practice will create a significant reduction in sediment.

Applications

Erosion control matting can be used in any area subjected to erosive action for which permanent grass vegetation has been planted. Typical applications include: graded slopes, storm water channels, detention structures, stream banks or swales.

Approach

Erosion control matting is a temporary slope stabilization measure that allows seeded vegetation to grow through the mat. Erosion control matting can also be used to stabilize storm water channels or other areas which are subject to occasional flowing water. See ES-12, Geotextiles, for areas which are normally underwater or which require permanent slope stabilization measures. Hydraulically applied mulch with a tackifier (as specified in ES-07) also functions similar to an erosion control matting for shorter time periods, and could be specified as an alternative. If the slope is subject to slumping, groundwater or structural failure, then consult ES-04, Gradient Terraces.

Erosion control matting generally consists of a biodegradable plastic net with some form of organic material such as straw, wood shavings, or coconut fiber. The overall purpose of the matting is to protect the soil and seeds from raindrop impact or from surface water runoff, while allowing air and sunlight to pass through the matting to the underlying vegetation.

The biodegradable net is manufactured as a very thin plastic mesh (polypropylene) which does not contain any chemicals to resist deterioration from the natural ultraviolet sunlight. The net biodegrades naturally within a year or two, by which time a thick healthy stand of vegetation should be established. Principal functions of the biodegradable net are to:

- Contain the organic matting from blowing or washing away.
- Allow easy transportation and installation of the product.

The areas to receive the erosion control matting should be previously shaped, fertilized, and seeded. A smooth surface, free of depressions and eroded areas, is necessary to prevent water from flowing underneath the matting edges, especially on the uphill side.

Materials

Numerous types of erosion control matting currently exist on the marketplace. Erosion control products should always be installed in accordance with the manufacturer's instructions; typical generic installation procedures are given in Figure ES-11-1. The basic types of lightweight erosion control mats for gentle slope applications are:

> Straw Blanket: Straw shall consist of clean, weed-free harvested straw with an average length of at least 6 inches. The typical roll will be 4 to 12 feet wide, and has a minimum dry weight of approximately 0.5 pounds per square yard.
>
> Excelsior Blanket: Excelsior (shaved wood fibers) shall generally be curled with at least 80% of fibers having a minimum length of 6 inches. A typical roll will be 4 to 12 feet wide, and has a minimum dry weight of 0.8 pounds per square yard.
>
> Jute Mesh: Jute mesh consists of woven root fiber or yarn, with regularly spaced openings between strands. A typical jute mesh will weigh approximately 1.0 pounds per square yard for basic slope applications.

Coconut fiber can also be specified as part of an erosion control mat. Other types of biodegradable products can also be used. Most erosion control mats also contain thin thread to keep the materials within the plastic netting. An approximate rule of thumb is that a one-sided blanket lasts for 1 year and a two-sided blanket lasts for 2 years.

Several common manufacturers have different gradations of product in order to meet different needs, including blankets with various amounts of seeding, fertilizer, etc., already within the blanket itself. Erosion control blankets also come in different colors, with a green blanket being very popular for aesthetic reasons.

There are a wide variety of ways to fasten an erosion control mat. Trenching and cutoff slots are used to anchor the mat, but additional fasteners are usually needed.
It is highly recommended that biodegradable materials and methods should be used to install a temporary product such as erosion control matting.

Basic materials for anchoring erosion control mats are:

> Metal Staples: Metal U-shaped wire staples are commonly used in conjunction with a staple gun as a quick way to install anchoring. Typical staples are 6" to 10" deep, with a 1" width to hold down the erosion control mat. Staples are generally 10-gauge or 11-gauge.
>
> Wooden Stakes: Stakes should be made from sound pieces of wood, at least 1" wide, and typically sawn into a triangular shape. Wooden stakes are usually 12" to 18" in length, depending on the type of soil.
>
> Biodegradable Stakes: Biodegradable stakes are made of plastic or other materials which will degrade naturally in a few years. Choose biodegradable stakes with projected life as recommended by the manufacturer. Plastic stakes are specifically made to hold erosion control matting and are generally more effective than wood stakes.

Installation

Erosion control fabrics may generally be applied perpendicular or horizontal to the contour lines depending upon slope characteristics and the roll width. Place erosion control mats in direction of water flow for ditch installation, working upstream. Trim matting as necessary to fit the area to be covered. Use large pieces whenever possible and discard small pieces. The following guidelines are suggested for orientation:

- Erosion control matting should be placed horizontal (with contours):
  - On slopes that are less than 2:1 (H:V) and less than 20 feet long.
  - In situations where one width of the fabric roll will cover entire length.
- Erosion control matting should be placed perpendicular (downhill):
  - On slopes steeper than 2:1 (H:V) or on slopes longer than 20 feet.
  - If the downhill length of the slope exceeds the width.
  - On slopes with runoff from adjacent areas regardless of length or steepness.

Site Preparation

Proper site preparation is essential to ensure complete contact with subgrade. Grade and shape the installation area, removing all rocks, clods, vegetation or other obstructions. Prepare subgrade by loosening at least 2 inches of topsoil beneath erosion control matting installation. Incorporate topsoil amendments as necessary, such as lime and fertilizer, according to soil tests and manufacturer recommendations.

Delivery and Storage

Deliver erosion control matting to the application site in rolls that are wrapped with protective coverings to prevent damage from mud, dirt, dust and debris. Inspect materials to ensure that they are free of defects or flaws. Store materials above the ground surface and away from potential storm water contact. Protect materials from direct sunlight and from extreme hot or cold temperatures.

Slopes

- Excavate anchor trench at the top and bottom of each slope. The anchor trench should be at least 6 inches deep and 6 inches wide, or as recommended by the manufacturer for the specific application. The top anchor trench should be placed at least 1 foot past the top of slope.
- The erosion control mat should be tucked into the top trench, stapled or staked, and then covered with topsoil. The mat is then unrolled downhill and stapled as the work proceeds. The mat should be allowed to lay smoothly and loosely on the surface. Do not stretch or twist the erosion control matting.
- For horizontal applications (involving short or gentle slopes), work must proceed from the bottom toward the top of the slope with a minimum 4-inch overlap. After cutting or trimming each end, the material should be folded under by 3 to 4 inches, stapled or staked, and then covered with topsoil.
- Staples or stakes should generally be placed 12 inches apart within anchor trenches and along horizontal overlapping joints. Interior staples or stakes should be placed in the pattern recommended by the mat manufacturer. Extra staples or stakes should be used for drainage channels, particularly near culverts and flumes.
- Slopes flatter than 4:1 (H:V) may have a typical staple or stake spacing of 5 feet

apart on all edges and 1 foot apart at all joints and ends. On all slopes steeper than 4:1 (H:V) and in all ditches, a typical installation pattern is three staggered rows spaced 3 feet apart. Follow manufacturer's recommendations for spacing and materials.

- Check slots should be spaced at not more than 50 feet from an end slot or another check slot. Check slots should be placed with a tight fold of matting anchored 6 inches vertically into the ground and 6 inches across, then tamped firmly.

Ditches and Channels

- Matting should be unrolled from the downstream end headed toward the upstream direction of flow. The mat should generally be installed to minimize the number of seams and joints in the channel, with edges and ends above the bottom invert of the ditch. This may require a wider roll of erosion control mat to be purchased especially for ditches.
- Anchor ditches are required on all four sides of the erosion control mat, in addition to staples or stakes. Anchor ditches within the channel or adjacent to culverts should have a transverse fold (as shown in Figure ES-11-1, third picture).
- When unrolled, fibers should be in contact with the soil and the netting should be on top (to prevent fibers from floating or washing away). Stakes or staples should be driven vertically into the ground, anchoring the mat firmly to the soil, and driven flush with the surface of the mat.
- Check slots should be spaced at not more than 50 feet from an end slot or another check slot. Check slots should be placed with a tight fold of matting anchored at least 6 inches vertically into the ground and 6 inches across, then tamped firmly.

The following items should be checked when inspecting the installation of erosion control mats:

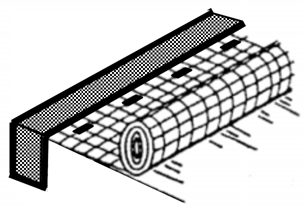
- Uphill and downhill anchor slots should be installed at least 6 inches deep.
- Overlap by at least 3 inches or as recommended by manufacturer.
- Fasteners should be spaced and distributed evenly at correct density.

Maintenance

- Inspect erosion control mats weekly and after rainstorms to check for movement of topsoil, movement of the mulch, or erosion.
- Promptly repair or replace erosion control matting in the event of washout, breakage, or erosion damage. Repair ground surface with topsoil, replace mulch and fertilizer in addition to seed, and then install new netting.

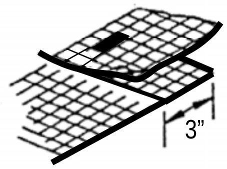
Limitations

- Inadequate coverage or anchoring results in erosion, washout, and poor plant establishment. If appropriate anchor spacing is not applied, then seed, topsoil, and mulch may be lost to wind and storm water runoff.
- Do not install within a stream or drainage channel that carries water continuously. If the channel grade and liner are not appropriate for the runoff velocity, channel bottom erosion will result and vegetation will grow poorly.



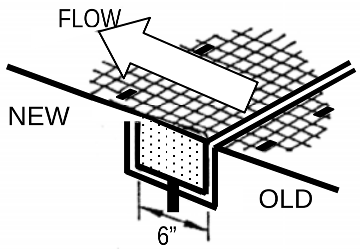
UPHILL ANCHOR SLOT:

Bury the uphill end of the mat within a trench at least 6” deep (12” deep for longer slopes). Tamp the soil firmly. Staple or stake at 12” intervals across the mat.



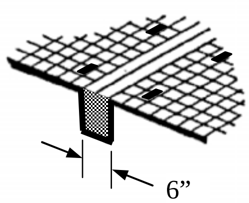
OVERLAP:

Overlap edges of the strips at least 3” (and preferably more for channels). Staple or stake every 12” down the center of the overlap.



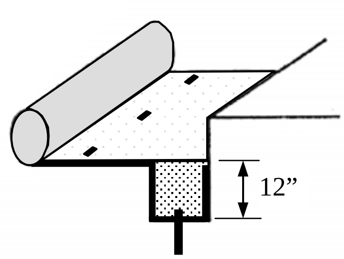
ANCHOR SLOT (WITHIN A CHANNEL):

Dig a slot 6” deep and 6” wide at end of the previous roll, and insert old roll on bottom and sides of anchor slot. Insert the new roll on bottom and sides of anchor slot, then install stakes or staples through both rolls at the bottom of the anchor slot. Fill anchor slot with soil, tamp firmly, and then install new roll in the upstream direction.



CHECK SLOTS:

Check slots should be made every 50 feet on slopes and intermittent drainage channels. Insert a fold of the mat into a 6” deep trench and tamp firmly. Staple or stake at 12” intervals across the mat. Lay mat smoothly on the surface of the soil. Do not stretch the mat and do not allow wrinkles.

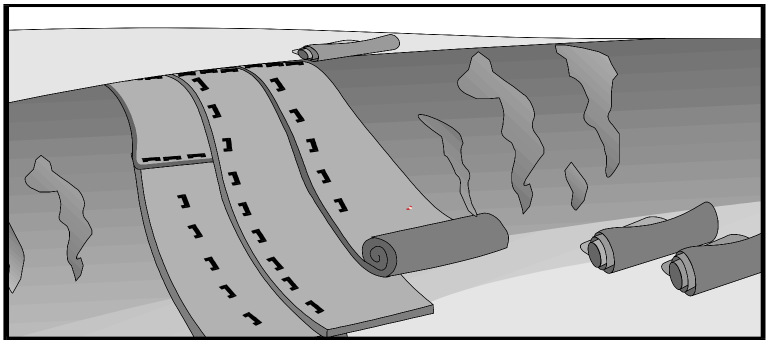


ANCHORING ENDS AT STRUCTURES:

Place end of mat in a 12” deep slot at the side of structure. Place stakes or staples at 12” intervals within slot. Fill trench and tamp firmly. Roll mat up the channel or downhill as necessary.

Figure ES-11-1
Typical Anchoring Details for Erosion Control Matting

ACTIVITY: Geotextiles	ES – 12



Targeted Constituents

● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit		
● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances	
○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

Prevent or reduce the discharge of sediment as a result of construction activity by stabilizing soil, using a wide variety of geotextile materials and applications. Areas with current and potential erosion problems may also benefit from the installation of geotextiles. Geotextiles may also be used in conjunction with other construction methods or as part of a landscaped terrain to prevent potential erosion problems. This practice will create a significant reduction in sediment.

Suitable Applications

- Areas where disturbed soils must be stabilized on a construction project, for which erosion control matting, hydraulic mulch and other methods are not appropriate.
- Slopes steeper than 2:1 (H:V), or where the erosion hazard is high.
- Critical areas, such as streams, wetlands or other highly-valued resources needing protection.
- Channels intended to be vegetated or otherwise lined where the design flow exceeds the permissible velocity.

Overview

This BMP will include a discussion of various geotextiles used for typical construction projects and for erosion control applications. A related application is ES-11, Erosion Control Matting, for temporary uses involving a thin plastic mesh to contain organic materials in establishing permanent vegetation growth.

Geotextiles have filtration and separation properties that directly contribute to erosion and sediment control. Other geotextile products, by virtue of streamlining or shortening the construction process, contribute to erosion and sediment control in terms of reduced schedules or reduced excavations.

As a word of explanation, geotextiles are a particular type of geosynthetic material. Geosynthetic materials are made from long polymers of plastic substances such as polypropylene, polyethylene, polyvinyl chloride and other types, usually created from petrochemical raw materials. Geosynthetics have unique properties that are used to replace traditional materials in the construction process. Geosynthetic liners are waterproof, chemically-resistant plastic sheets that are commonly used for landfills, stream channels, holding ponds, vapor barriers, etc.

Approach

A geotextile is not waterproof and generally has the appearance of cloth or fabric. There are two types, woven and non-woven, indicating how the geotextile was made. Most applications can use either woven or non-woven geotextiles; each type has its advantages and disadvantages. Some geotextile applications may affect slope stability, bearing strength and settlement; these applications should be designed by a registered engineer in conjunction with product information from the geotextile manufacturer. Common applications are listed below; this BMP only discusses the first two items.

- Erosion Control: A geotextile can be installed on steep slopes or drainage channels as part of a permanent solution to sloughing soils or high flow velocities. Other types of geosynthetic materials, such as turf reinforcement mats or geocells, are briefly mentioned in this BMP as alternatives for controlling erosion.
- Sediment Control: A geotextile can be used as part of a silt fence, excavation dewatering system, sand filter, outlet control structure to prevent sediment from leaving a construction site. The principal geotextile property would be the size of openings in the fabric.
- Subgrade Stabilization: A geotextile can be placed on subgrade to help bridge loads for traffic, buildings or permanent structures. Can often be installed on muddy or soft soils as a first step in constructing a temporary access road.
- Protection or Cushion: A geotextile can act as a cushion during the construction process, to prevent impact damage, or as a barrier.
- Filtration or Drainage: A geotextile can separate two materials while still allowing water to drain in either direction. This property makes geotextiles highly desirable in the construction of subsurface drains, french drains, sand filters, retaining walls, streets and roadways, and buildings.

Definition of Terms

Geotextile Filtration: The property of a geotextile barrier that allows the passage of water while retaining the solid material on the uphill or upstream side of the barrier.

Geotextile Separation: The property of a geotextile barrier placed between dissimilar materials so that the integrity of both materials can remain intact or be improved.

Nonwoven Geotextile: Geotextiles made by extruding and spraying fibers onto a moving conveyor belt to form a continuous web which is then joined by melt-bonding, resin-bonding, or needle punching.

Woven Geotextile: Geotextiles made by weaving polymeric threads on a loom.

Minimum Average Roll Value (MARV): The minimum average value of a representative number of tests made on selected rolls of a production lot, with a minimum of a 95% confidence level as determined statistically.

Geogrid or Geocell: A geosynthetic material to be placed at a stream or channel location where it can be filled with soil or rock, or where it can fill with sediment, so that the geosynthetic material can reinforce the soil against movement.

Fiber Roll: A roll of organic material, reinforced by plastic mesh or netting, installed to capture sediment on a slope or to prevent storm water from eroding a stream bank.

Factors for Material Selection

There are many types of geotextiles; selection of the appropriate type should be based on the desired need and site conditions. The following criteria should be considered in selecting a geotextile:

- Effectiveness (reducing erosion, slowing flow velocity, retaining soils)
- Engineering properties (strength, texture, weight, opening size)
- Acceptability (no environmental impacts, regulatory approval, aesthetics)
- Function (vegetation enhancement, safety, affect on wildlife)
- Maintenance (longevity, repair or replacement methods, inspection schedule)
- Costs (materials, transportation, preparation, installation, maintenance)

Geotextiles are commonly specified and categorized by weight, which allows a quick comparison on prices and performance. A lightweight geotextile typically weighs in the neighborhood of 4 to 6 ounces per square yard. A heavyweight geotextile may weigh as much as 16 ounces per square yard. However, always check properties and test values as reported on the vendor catalog or on the delivery sheet.

Geotextile properties are referenced to standards procedures or specifications by the American Society for Testing and Materials (ASTM). The chart below has commonly referenced properties to include a few methods of measuring strength. Geotextile producers monitor quality with onsite laboratories and independent third-party checks. Geotextiles are usually inert to common chemicals and hydrocarbons; they are also resistant to mildew, rot, insects and rodents.

The following list contains a typical geotextile specification for use as a separator beneath riprap or aggregate linings in drainage channels. Assumptions include that riprap will be dumped carefully onto the fabric from a height of less than 5 feet, and for non-muddy areas where the geotextile will not be driven on directly.

Typical Properties for Geotextile Underneath Riprap or Aggregate	
Property	**Typical values (MARV)**
Tensile strength (grab)	200 pounds
UV degradation at 500 hours	70%
Puncture strength	80 pounds
Burst strength	180 psi
Trapezoidal tear strength	60 pounds
Weight	6 ounces per square yard
Apparent opening size	40 to 70 (US sieve sizes)

Field joining should be accomplished by sewing for critical applications, such as flowing streams or steep slopes. A typical stitch density for nylon thread is 5 stitches per inch with either single-thread or double-thread stitching patterns.

Field joining for less critical applications may also be accomplished by overlapping and then using stakes or staples in the overlapped portions. The amount of overlap depends on the size and positioning of the stakes or staples.

Site Preparation

- Proper site preparation is essential to ensure complete contact of a geotextile with the subgrade. Grade and shape the installation area. Remove all rocks, clods, vegetation or other obstructions.

- Prepare subgrade by loosening at least 2 inches of topsoil. Incorporate topsoil amendments as necessary, such as lime and fertilizer, according to soil tests, vegetation plan, and manufacturer's recommendations.

Delivery and Storage

- Deliver geotextiles to the application site in rolls that are wrapped with protective coverings to prevent damage from mud, dirt, dust and debris. Inspect geotextiles to ensure that the materials are free of defects or flaws.

- Store geotextiles above the ground surface and away from potential storm water contact. Protect materials from direct sunlight and from extreme hot or cold temperatures. Limit exposure to sunlight to a few days; ultraviolet light degrades any geosynthetic material that does not contain carbon black additives. Do not allow mud and dirt to clog geotextile fabric, thus preventing filtration or drainage.

Installation of Geotextiles on Slopes or Drainage Channels

Consult manufacturer's written guidelines for installation. Typical methods and anchor guidelines are shown in Figures ES-12-1 and ES-12-2. Geotextiles are usually not difficult to handle, except that strong winds can create an uplift. Use temporary weights during placement of geotextile to prevent movement or damage. Field joining by sewing requires special equipment and expertise, so this method is not described.

Geotextiles which are to be placed permanently on long slopes or steep grades must be selected and designed by a registered engineer with appropriate experience and knowledge. Slope stability and slope failure analyses may be necessary to ensure that a geotextile will not be a potential problem, particularly in areas that could endanger people or property. Placing geotextile under a layer of soil generally creates a potential slope failure plane, which could be mitigated by terraces or structural measures.

- Install the geotextile in anchor trench at least 6 inches deep and 6 inches wide at the uphill location, or at the downstream location if in a channel. Backfill anchor trench and tamp earth firmly.

- Unroll blanket down the slope or in the upstream direction of water flow. Lay blankets loosely and maintain direct contact with the subgrade soil. Do not stretch or twist geotextile fabric. Overlap edges of adjacent parallel rolls by at least 3 inches and then stake or staple within the overlap.

- When blankets must be spliced, place blankets end over end (shingle style) with a minimum overlap of 6 inches. Install stakes or staples through overlapped area approximately 12 inches apart.

- Stake or staple geotextiles as recommended by the manufacturer for the specific application. Stagger stakes or staples rather than installing in a straight line. Use biodegradable materials whenever possible. Place initial lift of material carefully onto geotextile; avoid damage from heavy equipment blades, buckets or tracks.

Fiber Rolls

Fiber rolls (or fiber logs) are very similar to erosion control matting, except that they come in a different shape. Fiber rolls are installed horizontally (along a level contour) to prevent sediment from moving downhill. Fiber rolls are also useful along a stream bank or channel, to prevent damage from rising/falling water levels or from wave action. See Figure ES-12-3 for typical installation of fiber rolls or fiber logs.

Maximum spacing between rows of fiber rolls is usually 30 feet or less, depending on the slope. Typical fiber roll diameters range from 8 to 20 inches. Wood or metal stakes with a minimum length of 3 feet are needed at a typical spacing of 4 feet. The fiber roll should be entrenched into the slope or streambank a minimum of 4 inches deep, so that it will act in the same manner as a straw bale.

Geocells and Turf Reinforcement Mats

A geocell or geogrid, while not considered to be a geotextile, is a type of geosynthetic product that is commonly used to stabilize channel crossings or stream banks. The geocell is usually a mat consisting of hexagonal cells, possibly 4 to 6 inches across and also 4 to 6 inches deep, from a relatively thick piece of geosynthetic material. The honeycombed cells are filled with either aggregate or soil; a filled geocell typically has enough strength to support vehicle traffic.

Consult the manufacturer's recommendations for installation of geocells or geogrids. The manufacturer will have design charts and anchor patterns based upon the application. These structures require careful installation prior to backfilling with soil and other materials.

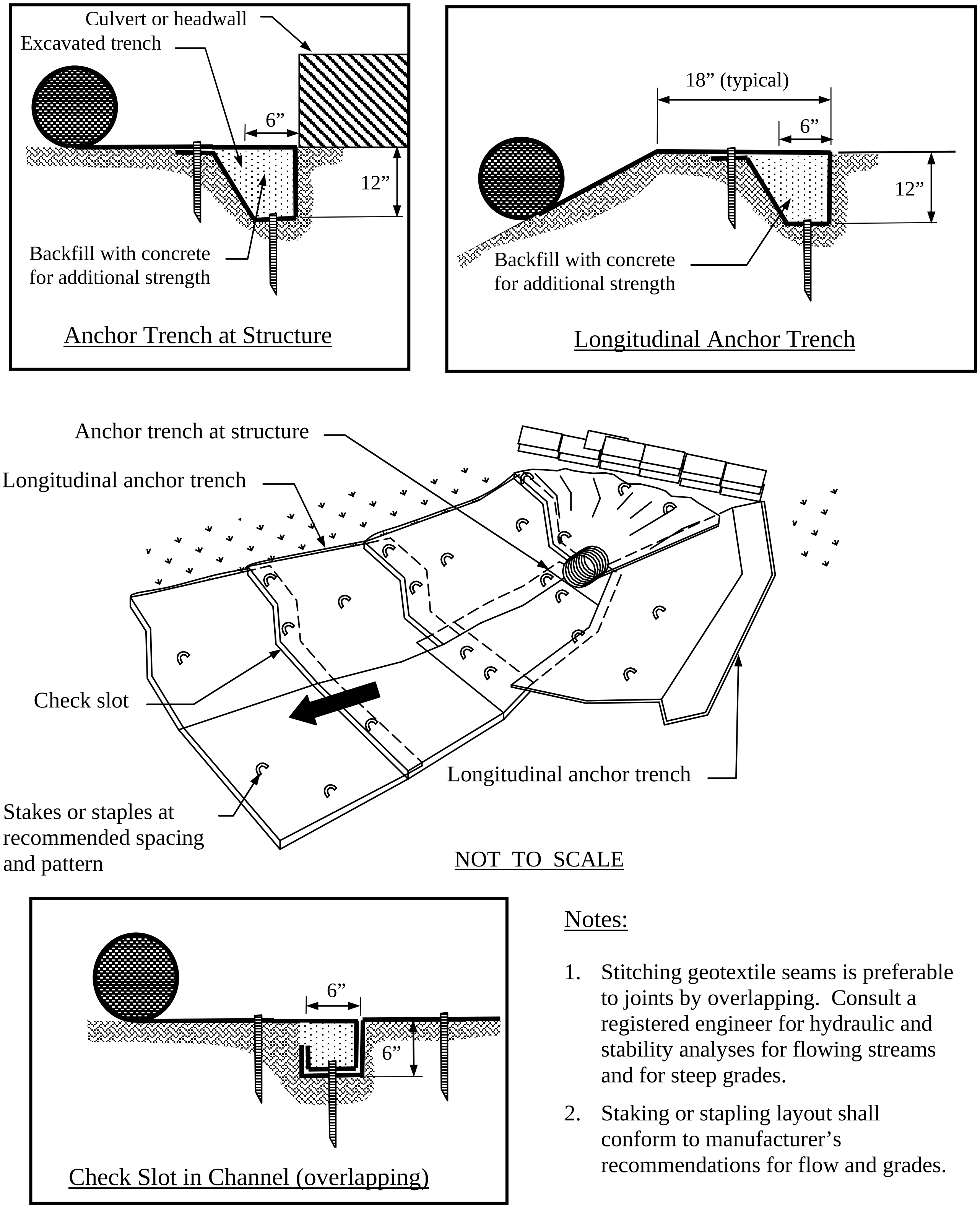
Turf reinforcement mats (or TRMs) is not considered to be a geotextile either; they are very similar to erosion control matting (discussed in ES-11) except with stronger geosynthetic materials. A common application for TRMs is areas where sedimentation is likely to take place, such as at the bottom of slopes or in certain channel reaches.

Maintenance

- Installation of geotextiles shall be inspected after significant rainfalls to check for erosion and undermining. If washout or breakages occur, repair or replace geotextile immediately after repairing the damage to the slope or channel.
- Inspect fiber rolls whenever rain is forecast and perform required maintenance. Inspect fiber rolls following rainfall events and at least daily during prolonged rainfall. Repair or replace fiber rolls that are torn or unraveling.

Limitations

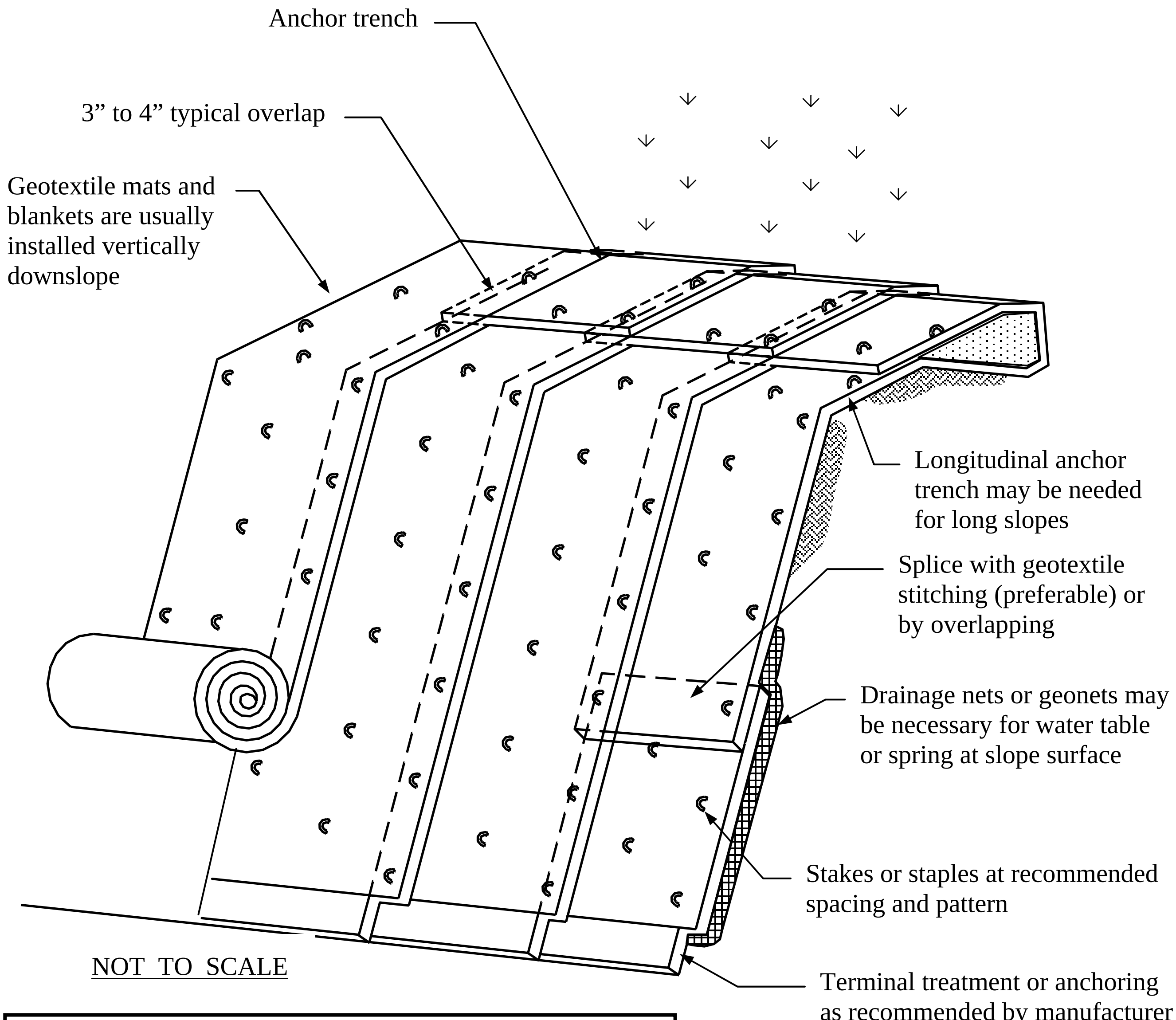
- Some slopes or channels may be difficult for heavy equipment to access, requiring substantial effort such as excavation and filling. Consider access needs early in the design phase and incorporate into design plans.
- Geotextiles may not be suitable in areas where vegetation will be mowed regularly (since stakes and netting can catch in mowers and other equipment).

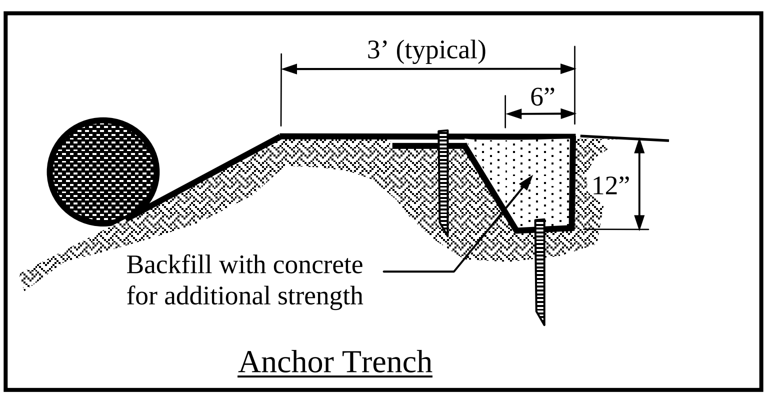


Notes:

1. Stitching geotextile seams is preferable to joints by overlapping. Consult a registered engineer for hydraulic and stability analyses for flowing streams and for steep grades.
2. Staking or stapling layout shall conform to manufacturer’s recommendations for flow and grades.

Figure ES-12-1
Anchoring Geotextiles in Channels

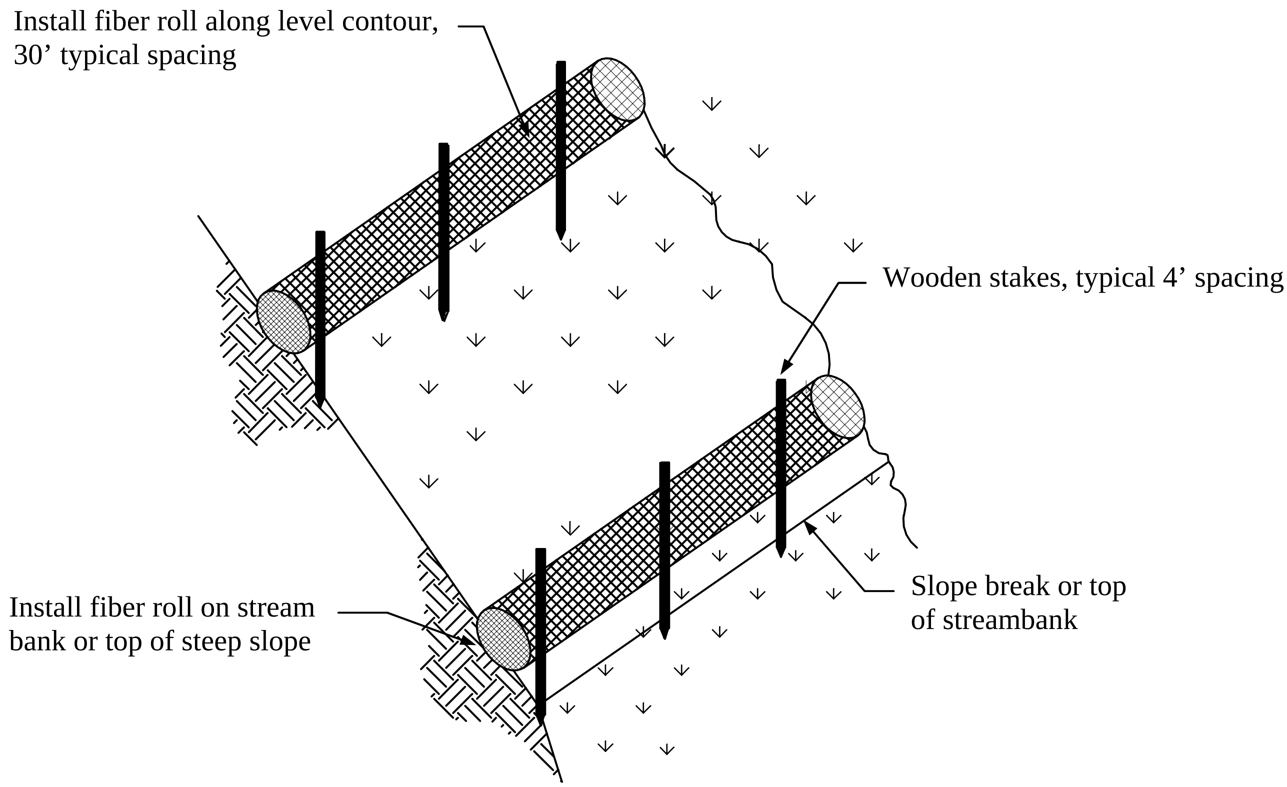


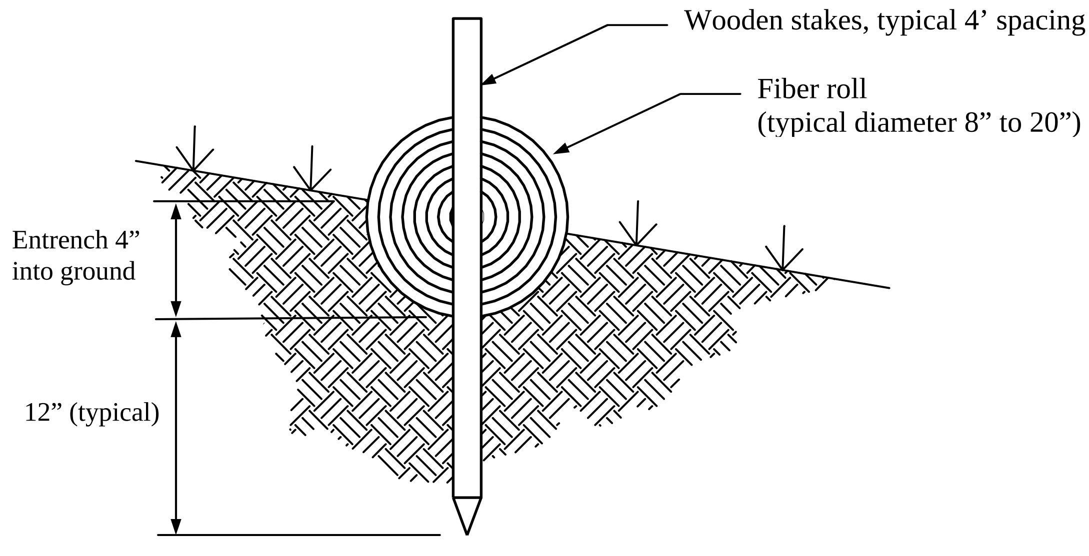


Notes:

1. Stitching geotextile seams is preferable to joints by overlapping. Consult a registered engineer for stability analysis of long grades or grades steeper than 3:1.
2. Staking or stapling layout shall conform to manufacturer's recommendations for flow and grades.

Figure ES-12-2
Anchoring Geotextiles on Embankments

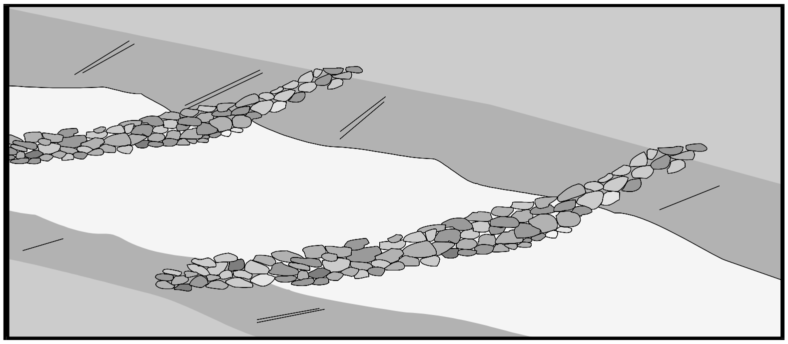




NOT TO SCALE

Figure ES-12-3
Fiber Roll Installation

ACTIVITY: Check Dams | ES – 13



Targeted Constituents				
● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit		
● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances	
○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

Small temporary dams, constructed across a swale or drainage ditch, reduce the velocity of concentrated storm water flows. This reduces erosion of the swale or ditch, and also promotes sedimentation behind the dam. Check dams are usually constructed from large rocks or stones, but other materials can also be used. This practice is likely to create a significant reduction in sediment.

Suitable Applications

- Temporary erosion and sediment control in small open channels that typically drain 5 acres or less.
- During the establishment of permanent vegetation in drainage ditches or channels.
- On steep channels where storm water runoff velocities must be reduced.

Approach

Check dams are used to prevent erosion by reducing the velocity of channel flow in small drainage channels and swales. Check dams control sediment by allowing sediment to settle out above the check dam, and by allowing storm water to flow through a rock filter. Check dams are primarily used in small, steep channels where runoff velocities need to be reduced.

Check dams must be sized and constructed correctly and maintained properly, in order to prevent material from washing out. Check dams are usually constructed from large aggregate or riprap. Other materials may be used, such as natural logs or sandbags filled with gravel, which can withstand the storm water flow velocities and forces. Do not use creosote railroad ties or telephone poles. Check dams in drainage channels are not usually constructed from straw bales or silt fences, since concentrated flows quickly wash out these materials.

Check dams should be placed at a distance and height to allow small pools 2 feet deep to form between each check dam. See typical spacing diagram in Figure ES-13-1. Backwater from a downstream check dam should not exceed the toe of the upstream check dam. The center section of the dam should be lower than the edge sections so that the check dam will act like a weir during major floods. The dam must completely span the ditch or swale to prevent washout.

Since check dams are for temporary installation only, the designer or contractor should make provision for safe and expedient removal of check dams when no longer needed.

Rock Check Dam

Rock check dams are constructed from large aggregate for small drainage areas up to 1 acre. Rock check dams can also be constructed from small riprap for drainage areas up to 5 acres, with an upstream layer of smaller aggregate for filtering. Rock can be placed by hand or by mechanical methods (no dumping of rock) to achieve complete ditch or swale coverage. Provide a minimum slope of 2:1 (H:V) on upstream and downstream faces, as shown in Figure ES-13-1.

Rock check dams may be keyed into the swale or channel bottom, typically a distance of 6 inches. Advantages of keying into the channel bottom are that the check dam will be more stable and less likely to slip or slide. A disadvantage of keying into the channel bottom is that the channel will have to be repaired and reshaped whenever the rock check dam is removed. Geotextile filter fabric should be placed beneath a rock check dam to assist in removal when the check dam is no longer needed.

Log Check Dam

Do not use creosote railroad ties or telephone poles; the creosote soaks into storm water to become a pollution source. Check dams built of natural logs or wood must be secured against floating away during floods; floating logs can be a source of significant damage to bridges and structures. Height and spacing should generally be less than for rock check dams. Log check dams are usually constructed of 4 to 6-inch diameter natural wood logs. Drive logs vertically into soil at least 18 inches, staked, and tied together. A horizontal log, to reinforce the driven logs, is embedded into channel sides for increased stability. Provide overflow weir to prevent erosion to channel banks.

Sandbag Check Dam

Sandbags filled with either aggregate or sand may also be used as a check dam. Sandbags should be staked and tied together, after being placed in a staggered fashion. Provide overflow weir in the center of channel similar to check dam in Figure ES-13-1.

Maintenance

- Inspect for sediment buildup behind the check dam and signs of erosion around the check dam after each rain. Remove accumulated sediment whenever it reaches one-third of the upstream check dam height. Shovel by hand to prevent damage to the filter fabric and check dam. Dispose of accumulated sediment onsite in a manner that prevents additional movement of sediment.

Limitations

- Do not use this BMP for permanent placement without sufficient design for larger storms and additional controls for retaining rocks. Permanent placement must also include guaranteed provisions for sediment removal.
- Not to be used in live or continuously-flowing streams. Generally not used in drainage channels which drain areas greater than 5 acres, but conditions may depend upon the channel slope and velocities versus the size of rock proposed.
- Installation and removal may damage vegetation and channel grades. Do not place in grass-lined channels unless erosion and sediment are expected. Check dams may kill vegetation by excessive sediment or by long periods of submergence.

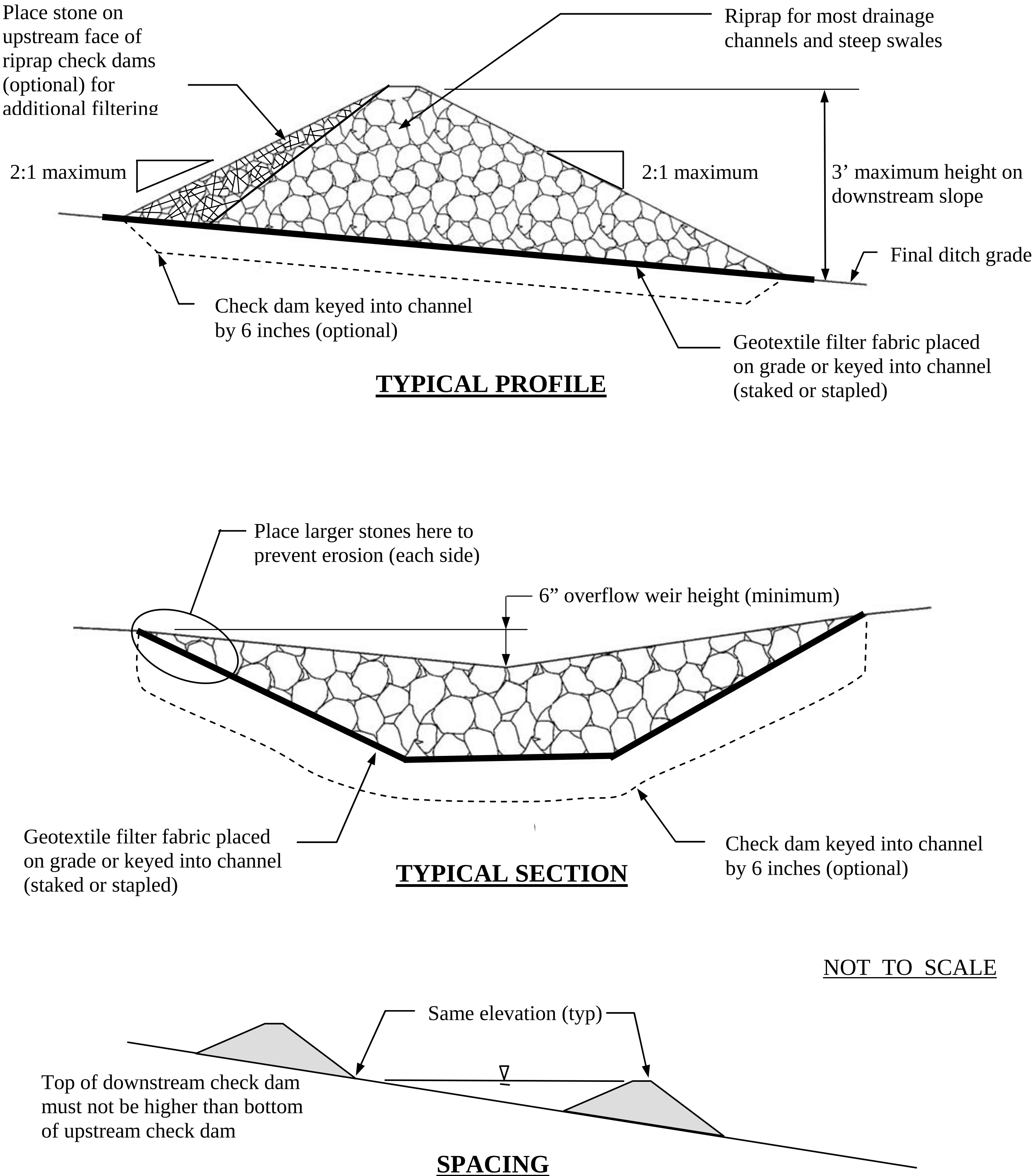
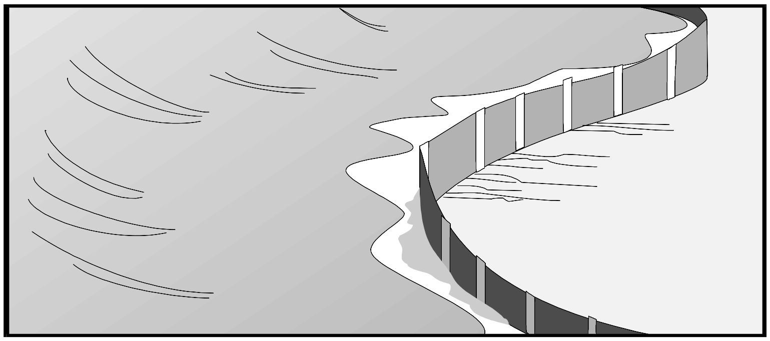


Figure ES-13-1
Rock Check Dams

ACTIVITY: Silt Fence | ES – 14



Targeted Constituents				
● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit		
● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances	
○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

A silt fence is a temporary filter fabric which is attached to supporting posts and entrenched into the ground. The silt fence intercepts small amounts of sediment from disturbed areas during construction operations. It is a fairly versatile tool which is used close to the erosion source or as a perimeter control. This practice is likely to create a significant reduction in sediment.

Suitable Applications

- At the bottom of a cleared slope or disturbed field.
- At the perimeter of disturbed construction areas.
- Along streams and ditches, or to protect sensitive areas.
- Around temporary soil or gravel stockpiles.
- Within a swale or ditch that has gentle slopes and drainage area less than 1 acre.

Approach

Silt fence is a well-known and common method for trapping sediment at or near the potential source of erosion. It also reduces the potential for overland sheet flow to concentrate into rills and gullies. Silt fence can be installed below slopes, along paved areas, in narrow buffer zones, along streams and many other locations without requiring vehicle access. Silt fence can be installed by hand or by using a small piece of trenching equipment. It is very dependable when used properly.

Silt fence must be designed and installed correctly to trap sediment. Silt fence is only meant to handle small quantities of storm water runoff such as sheet flow. Silt fence ponds water and then slowly releases it through the openings in the geotextile fabric. It is crucial that silt fences are sufficiently anchored and supported, and that they follow the contours. Improperly installed silt fence (not entrenched or not following contours) causes worse erosion by concentrating storm water runoff.

Silt fence is more effective in removing sediment than straw bale barriers. Silt fence is also more durable than straw bale barriers, requires less maintenance, and is often more cost-effective for most types of construction projects involving cleared land. Silt fence shall not be used in live or continuously-flowing streams. Silt fence can generally not be used in ditches or swales which drain areas greater than 1 acre. Do not use silt fence in steep ditches or swales where the design flow is greater than 2 feet per second.

A variation of silt fence in common use and manufactured by a few companies is a triangular-shaped structure with silt fence fabric on both sides. The triangular shape comes from a plastic or metal wire frame that provides continuous support similar to the wire reinforcement fabric described below. It requires a combination of staples and anchors to install the triangular silt fence. The outer edges of the triangular silt fence should be buried in a trench for most applications and then adequately stapled or staked. If necessary, a triangular silt fence can be installed with minimal or no trenching for short overland flows on gentle slopes. See Figure ES-14-2 for typical details.

A common variant of a reinforced silt fence (described below using wire reinforcement backing) is to use a staked straw bale barrier as the reinforcement backing for the silt fence. A combined trench can be excavated as the first step, and then both erosion control structures are installed in the normal manner, with the silt fence being upslope.

Materials

- Synthetic filter fabric is typically manufactured from woven or non-woven sheets of polypropylene, nylon or polyester. Silt fence fabric must contain stabilizers to slow degradation from ultraviolet light. Silt fence fabric should resist rotting, mildew, insects and rodents.

- Burlap fabric is not appropriate for use as silt fence.

- Silt fence fabric comes in rolls with a typical width of 36 inches. For most applications, 12 inches will be embedded into the ground and 24 inches will be aboveground to trap sediment. Silt fence can be installed on either wood or steel posts of adequate strength.

- Typical values for silt fence fabric are listed in the table below. Some vendors offer a standard strength fabric and also an extra strength fabric for critical applications. For the flow rate of 0.30 gallons per minute per square foot, the silt fence fabric release rate is 0.07 cubic feet per second for every 100 feet of silt fence with ponded height of 1 foot.

Typical Properties for Silt Fence Fabric

Property	**Typical Values (MARV)**
Tensile strength at 20% elongation:	
Standard strength fabric	50 pounds per linear inch
Extra strength fabric	100 pounds per linear inch
Burst strength	180 psi
Trapezoidal tear strength	50 pounds
Apparent opening size	20 to 30 (US sieve size)
Flow rate	0.30 gallons per minute per square foot

- Wood posts are typically 2” x 2” oak and other hard woods. A larger size post is necessary for pine and other soft woods, such as 4” x 4”. Typical post length is 48 inches, with minimum height of 24 inches above ground and minimum depth of 18 inches below ground. See Figure ES-14-1 for typical post and trenching details.

- Fasteners for wood posts are typically either wire staples or nails. There shall be a minimum of 5 fasteners for each wood post. Use minimum size 17-gauge staples with a minimum embedded length of 1 inch into the wood and a minimum width of 3/4 inch across. Typical nail size is 1 inch long with an oversized nail head (such as 3/4-inch diameter head) to prevent fabric from ripping. Additional nails may be necessary if a small nail head is used.

- Steel posts are typically either C-shape, L-shape, T-shape or U-shape with a minimum weight of 1.33 pounds per linear foot, with sufficient holes and hooks for fasteners. Typical fasteners for steel posts are either installed hog rings, attached loops of cord or string, or sewn pockets within the fabric.

- Steel wire reinforcement fabric may be necessary for installations within storm water channels or on steep slopes. Steel wire reinforcement shall be minimum 14-gauge with a maximum mesh spacing of 6 inches. Typical methods of attaching steel wire reinforcement are tie wires or hog rings.

Installation Guidelines

- The drainage area for a typical silt fence installation at the bottom of a slope shall not exceed 10,000 square feet for every 100 feet of silt fence. For a rectangular area, this means a maximum average slope length of 100 feet which is only permissible for slopes flatter than 2 percent.

Maximum Slope Lengths for Silt Fence Installations	
Land Slope	**Maximum Slope Length**
Less than 2 %	100 feet
From 2 to 5 %	75 feet
From 5 to 10 %	50 feet
From 10 to 20 %	25 feet
More than 20 %	15 feet

- Do not staple silt fence fabric to existing trees, as this does not allow adequate trenching and backfill near the tree trunk. Other erosion control methods may also be appropriate in areas where existing trees and vegetation are to be protected, or where excavating a trench is not feasible.

- Silt fence fabric should be purchased in continuous rolls of acceptable width in order to avoid creating a joint (which would be the potential location of a blowout). When joints are unavoidable, install 2 support posts in close proximity to each other and then overlap the two silt fence fabrics by 1 post in each direction.

- Locate silt fence at least 5 to 7 feet beyond the base of steep slopes. In locations at the bottom of a slope, turn the ends of the silt fence upslope so that a certain depth of storm water may be retained in front of the silt fence. The impounded depth should be at least 12 inches but less than the silt fence height. Install straw bale barriers at the end of the silt fence row as an “emergency overflow” to allow detained water to be filtered quickly. See Figure ES-14-3 for a typical layout using straw bales at the end of silt fence.

- If a silt fence is installed in a storm water ditch or swale, then steel wire reinforcement is highly recommended. Maximum post spacing shall be 4 feet or less. The silt fence should have the ends oriented upstream to resemble a horseshoe pattern, as shown in Figure ES-14-4.

Common problems with silt fence are:

- Not adequately entrenched into the ground.
- Installed too low, particularly at sag point between posts or as fabric stretches.
- Not installed on a level contour.

Installation Procedure

Step 1: Prepare the grade and alignment for the silt fence installation. Clear brush and reshape ground profile as necessary. Ensure that silt fence is installed along a level contour and that maximum slope lengths are not exceeded.

Step 2: Install wood or steel posts at proper spacing to a minimum depth of 18 inches. Maximum length for most installations is 8 feet between posts. Shorten maximum spacing to 6 feet when installing silt fence below steep slopes or 4 feet within a ditch or channel that drains less than 1 acre.

Step 3: Excavate a trench 6 inches deep and 6 inches wide slightly uphill from the posts. Keep excavated soil nearby for use in filling the trench. A minimum depth of 4 inches may be used for locations with shallow bedrock or other difficult conditions.

Step 4: If necessary, attach wire fence reinforcement to posts at locations where washout or heavy flows may occur. Install wire fence reinforcement at least 3 inches into the trench and attach to posts. Wire fence reinforcement should extend a few posts to draw adequate strength from the embedded posts.

Step 5: Install filter fabric into the trench and attach to the posts using recommended materials. Embed into trench as shown in Figure ES-14-1. The minimum height of silt fence shall be 18 inches above the ground surface. Attach filter fabric to the top edge of wire fence reinforcement (if needed) at regular intervals to prevent sagging.

Step 6: Backfill the trench using the excavated soil and firmly compact. Carefully inspect silt fence installation to see if additional supports or posts are needed.

Maintenance

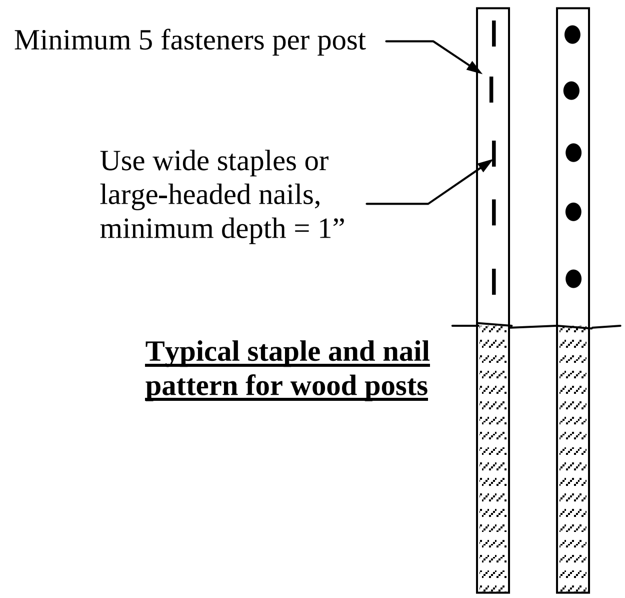
- Inspect silt fence after each rainfall event and also weekly for damaged or loosened fabric, excessive sediment buildup, undercutting flows or flows around end of silt fence. Repair or replace damaged silt fence as necessary.
- Remove accumulated sediment whenever it reaches one-third of the silt fence height. Shovel by hand to prevent damage to the filter fabric and posts. Dispose of accumulated sediment onsite to prevent movement of sediment.
- The expected life of silt fence fabric is usually 6 to 8 months. Inspect silt fence often as the fabric weathers and deteriorates. Install new silt fence as needed to ensure proper erosion control.

Limitations

- Silt fence shall not be used in live or continuously-flowing streams. Silt fence can generally not be used in channels which drain areas larger than 1 acre.
- Installation and removal may damage vegetation and channel grades. Do not place in grass-lined channels unless erosion and sediment are expected. Silt fence may kill vegetation by excessive sediment or by long periods of submergence.

Notes:

1. Post spacing shall 8 feet maximum for typical applications at the bottom of slopes or along site perimeter.
2. Post spacing shall be 6 feet maximum at the bottom of steep slopes. Post spacing shall be 4 feet maximum within a drainage channel.
3. Place silt fence at least 5 to 7 feet away from steep or long slopes to impound storm water runoff. See Figure ES-14-3.
4. Wire fence reinforcement is required below slopes that are over 8' high, or where silt fence is installed immediately adjacent to grading limits. Install reinforcement at locations where washout or heavy flow may occur.



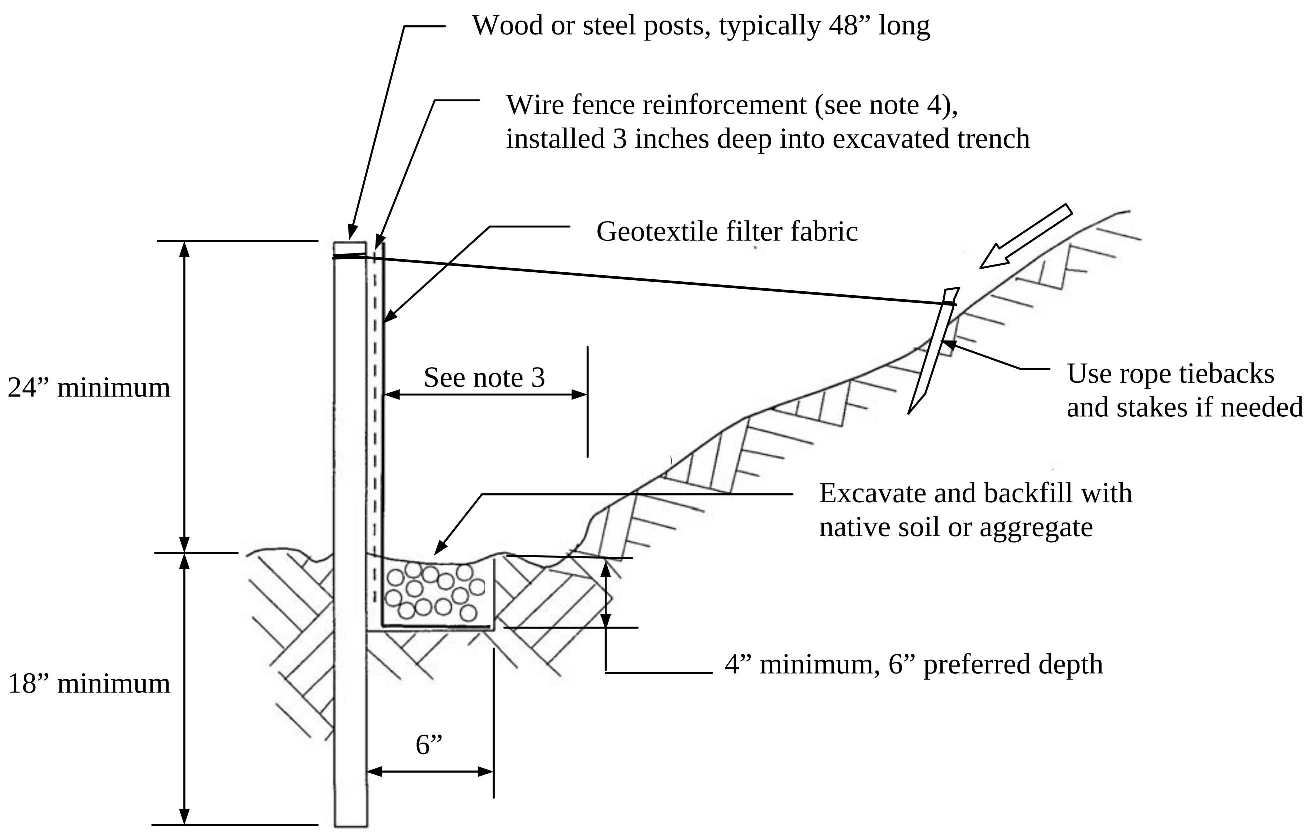


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Figure ES-14-1
Typical Silt Fence Installation

Notes:

1. Two alternative installations are shown for a trenched geotextile fabric and for a geotextile fabric apron. Follow recommendations of manufacturer regarding staples and stakes. Stakes should typically be driven 18” into ground.

2. Typical height is 18” to 24”.

Features of triangular silt fence include:

- Available as prefabricated units from several manufacturers in stackable form
- Triangular shape allows static water pressure to press the structure downward.
- The support frame is reusable.
- Can be adapted to many different uses.
- Trenching may not be necessary for minor overland flow applications if a geotextile fabric apron adheres closely to a prepared ground surface.

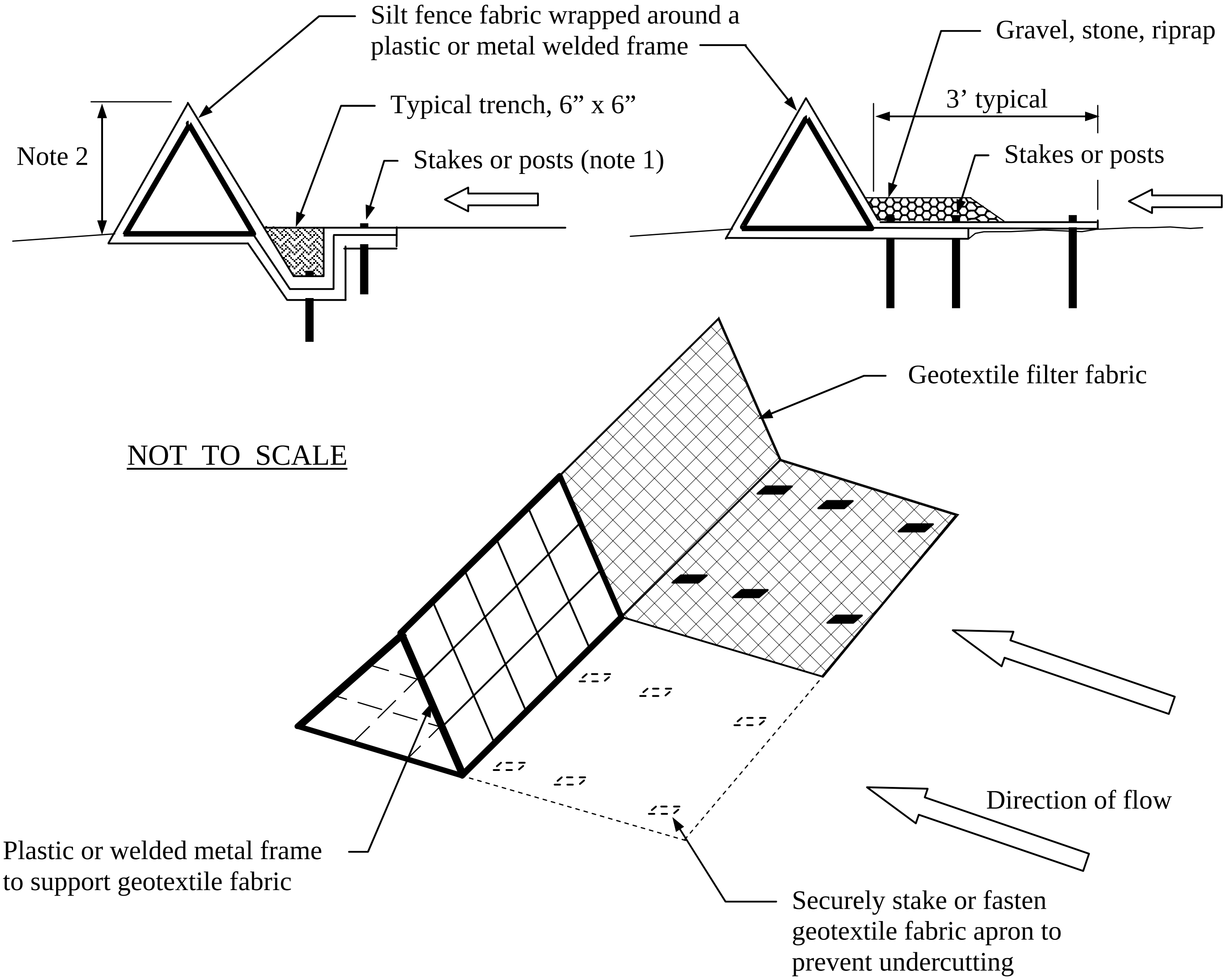


Figure ES-14-2
Triangular Silt Fence

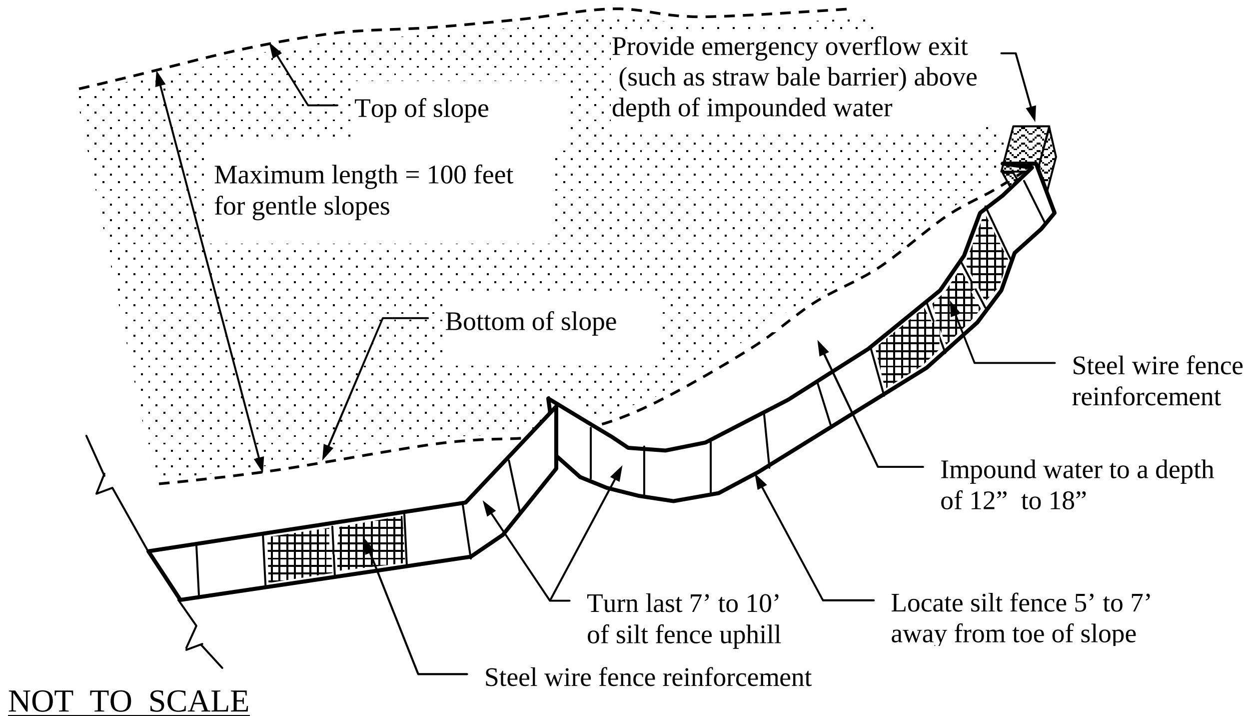


Figure ES-14-3
Silt Fence (Below a steep or long slope)

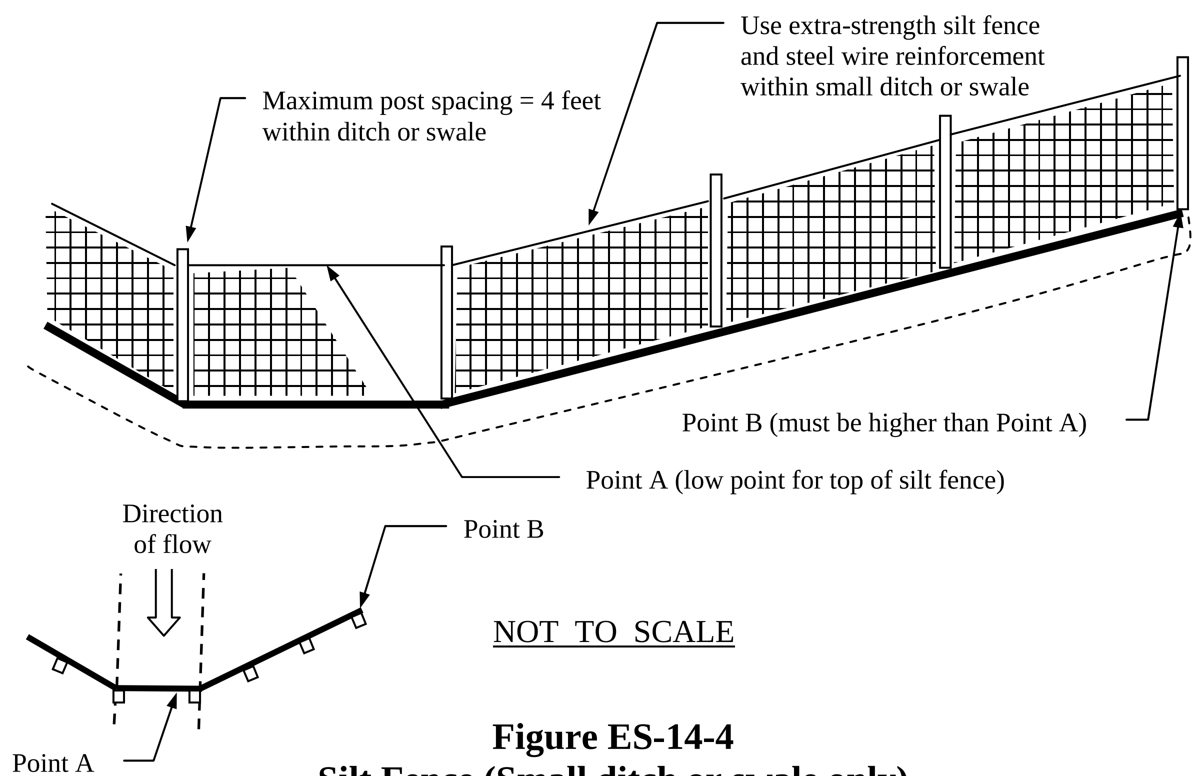
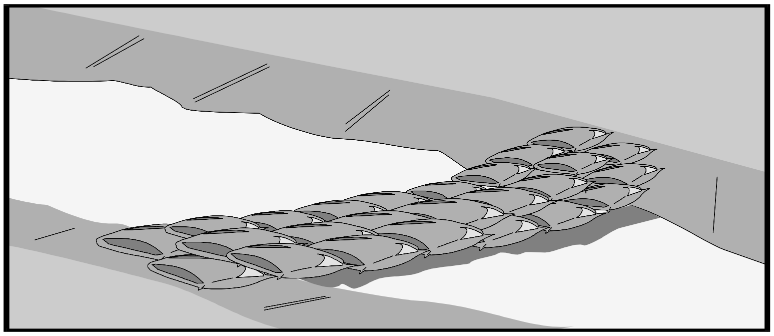


Figure ES-14-4
Silt Fence (Small ditch or swale only)

ACTIVITY: Sandbag Barrier | ES – 15



Targeted Constituents			
● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit	
● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances

○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

Stacking sandbags is a quick and efficient way to create a barrier for detaining sediment-laden water to allow sediment to settle. A sandbag barrier can be deployed on paved surfaces and other areas where it is not feasible to install posts or stakes. This practice is likely to create a significant reduction in sediment.

Suitable Applications

- On paved surfaces, such as streets and parking lots, where it is difficult to install posts and stakes for other types of sediment control devices.
- For use as a check dam across a ditch or channel.
- To create a temporary sediment trap or dewatering impoundment.
- When changing site conditions call for a rapid deployment or adjustment of a sediment barrier.
- Across channels or small streams to serve as a barrier for utility trenches or provide a temporary channel crossing for construction equipment. All activities within a stream require permits that must be approved by KYDOW; see ES-03 for typical stream crossings.
- Sandbags are frequently used for purposes other than erosion control, such as weights for securing materials such as geotextiles, tarps, plywood and tarpaper against wind uplift.

Approach

Sandbag barriers do not filter stormwater runoff. However, sandbags provide a barrier which is easily deployed, portable, durable, reusable and inexpensive. Sandbag barriers are used to create a dam or backwater area, which slows the water down to allow sediment to settle out. Sandbag barriers are typically more durable than straw bales or silt fences, and sandbags tend to conform to the ground surface.

Since sandbag barriers impound water, provisions may be necessary for an outlet structure. Small sections of small-diameter (typically 3” or 4”) PVC pipe may be placed within the sandbag barrier to drain water. An overflow weir can be fashioned by stacking a portion of the sandbag barrier to a lower height.

Placing a drainage pipe at the invert of the barrier allows it drain completely. Placing a drainage pipe at the level of the first or second row of sandbags will allow the pipe to decant the top of the water impoundment, in essence functioning as a temporary sediment trap. A filter cloth can be placed over the drainage pipe to produce a cleaner stormwater discharge.

Installation of sandbag barriers can be labor intensive when compared to silt fence, depending on the potential sources of sand or gravel. However, sandbag barriers may be used for sediment trapping in locations where silt fences and straw bale barriers are not strong enough. In addition, sandbag barriers are appropriate to use when construction of rock check dams is too difficult due to inaccessibility. Sandbag berms may cause fewer disturbances to established vegetation than a rock check dam.

Sandbags are particularly useful for construction projects in the urban environment. Sandbags can be placed along curbs and gutters, across catch basins and drop inlets, across closed streets, and many other configurations. Sandbags can be easily relocated as needed, even to the point of being momentarily removed for vehicle traffic.

Materials

- Sandbag lengths vary but a typical value is 24 inches. A typical width is 16 inches. Sandbag thickness is 6 to 8 inches. Based on these dimensions, the typical weight of a full sandbag is approximately 80 pounds. The recommended minimum weight of a sandbag is typically 50 pounds. Use large sandbags (fully loaded) in drainage channels or other applications with large flows.

- Sandbag material is typically polypropylene, polyethylene or polyamide woven fabric. Minimum unit weight is 4 ounces per square yard, with a burst strength exceeding 300 psi and ultraviolet stability exceeding 70 percent. Use of burlap is not allowed since it rots and deteriorates easily when wet.

- Clean coarse sand or gravel shall be used inside the sandbag. Do not use dirt or soil within sandbags to be placed for erosion control.

- Fasten sandbags securely using hog rings, sewing, or other suitable methods that prevent leakage from bags.

Installation

Sandbag barriers can be placed in several types of locations (streets and parking lots, curb and gutter, ditches). A general recommendation is to install across the direction of stormwater flow, along a level contour, with ends angled uphill at least 6 feet to provide an impoundment and to prevent washout from scour. Storm Water runoff can either be allowed to flow over the tops of the sandbags (by creating an overflow weir) or through short drainage pipes embedded within the sandbag barrier wall.

Barriers which are more than two sandbags high should be constructed by a pyramid approach or with additional reinforcement behind the direction of flow. Sandbags should be stacked in a brick-like fashion so that each sandbag in a row should sit on top of two other sandbags. See Figure ES-15-1 for typical installation.

Maintenance

- Inspect sandbag barriers weekly and after each rainfall event. Reshape or replace damaged sandbags immediately. Repair washouts or other damages as needed.

- Inspect sandbag barriers for sediment accumulations and remove sediments when depth reaches one-third of the barrier height. Dispose of removed sediment properly.
- Remove sandbags when no longer needed. Clean, regrade and stabilize the area.

Limitations

Sandbags do not filter sediment or prevent erosion. Therefore, they only provide a supporting role in reducing stormwater pollution. A sandbag barrier typically functions as a temporary sediment trap.

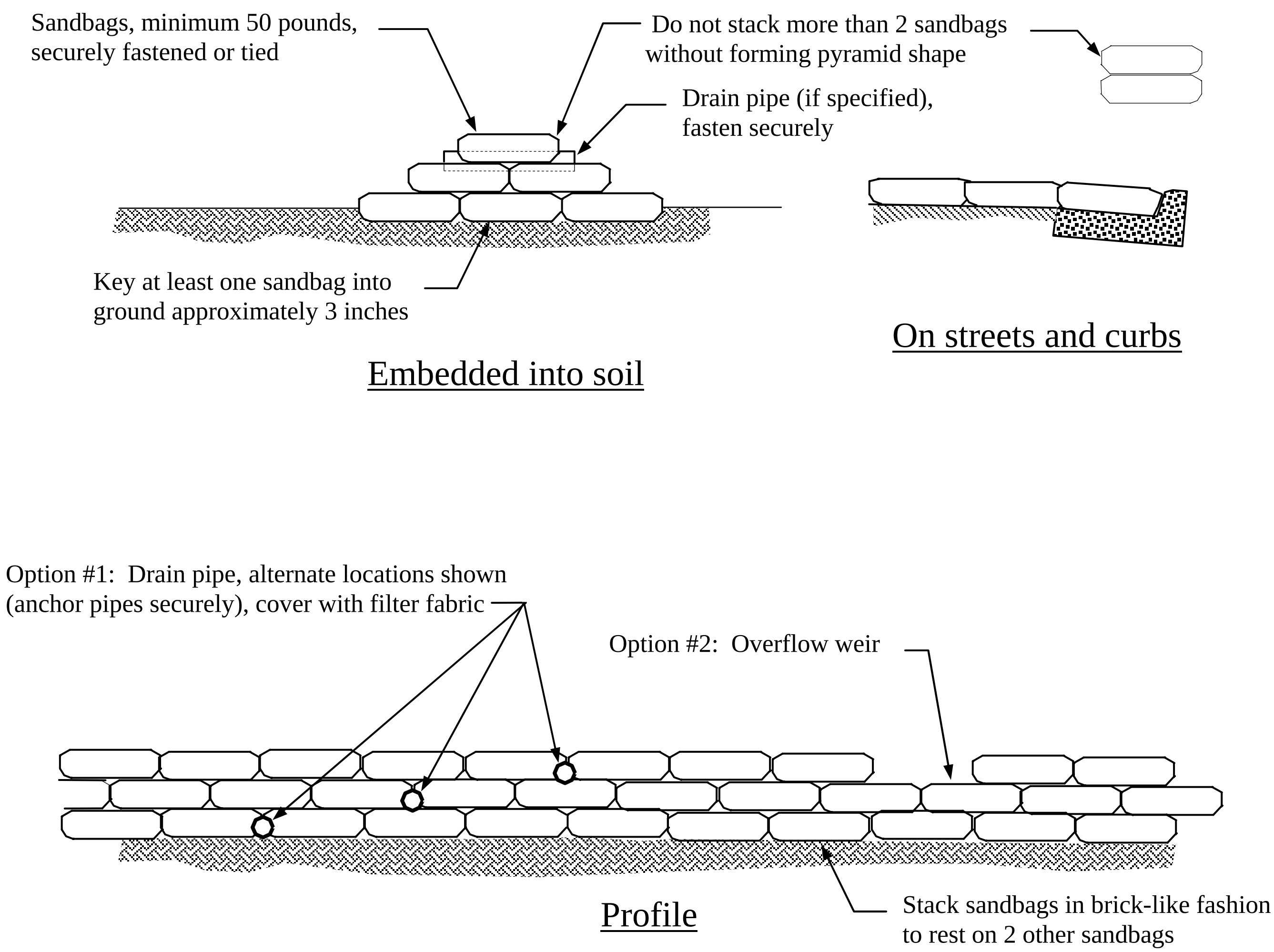


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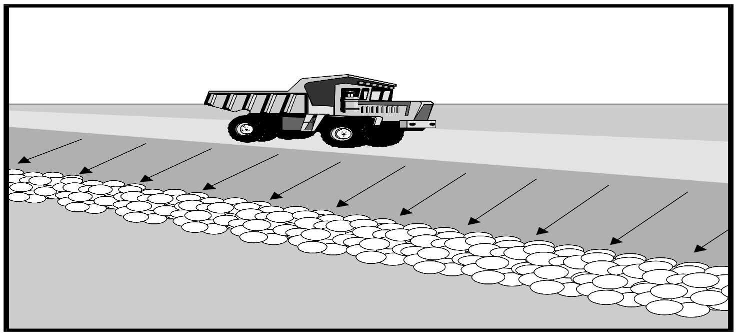
Figure ES-15-1
Sandbag Barrier

ACTIVITY: Brush or Rock Filter Berm

ES – 16



Targeted Constituents

● Significant Benefit ◗ Partial Benefit ○ Low or Unknown Benefit

● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances	
○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

A filter berm, made of natural materials that already occur on the project site, may be both efficient and cost-effective. Filter berms may be constructed of brush or rock materials, either with or without the use of a supplementary geotextile fabric. Both types of filter berms are placed along a level contour where overland sheet flow can be detained and ponded. If properly anchored, brush or rock filter berms may be used for sediment trapping and velocity reduction. This practice significantly reduces sediment.

Suitable Applications

- Below the toe of slopes.
- Along the site perimeter.
- Along streams and channels, or adjacent to roadways.
- Around temporary spoil areas or other small cleared areas.

Approach

A filter berm can often be constructed from natural materials, such as brush or rocks. This is generally an efficient operation for the site contractor if these materials are already present on the project site, both time-wise and in terms of installation cost. Brush and rock filter berms can also be installed with a geotextile fabric to increase sediment removal filtration and the overall stability of the berm. Wire netting (such as poultry fencing) can also be used to increase the stability for brush or rock berms. Gabions and other wire mattresses can also be used as a rock filter for erosion control.

Both types of filter berms are placed along a level contour. Common applications are along the edge of a gravel roadway or 5 to 7 feet beyond the toe of a slope, where overland sheet flow can be detained and ponded. Brush or rock filter berms slow the velocity of overland runoff, allowing sediment to settle out or become trapped in the filter. In this manner, the brush and rock filter berms are very similar in function to ES-13, Check Dams, except that filter berms handle overland sheet flow and check dams handle stormwater runoff channels. A similar application involving sand or gravel is ES-15, Sandbag Barrier.

Brush and rock filter berms both contain materials (dirt, leaves, dust, silt) which could potentially cause more pollution than they might remove. These measures should be constructed and managed carefully in order to become effective BMPs. A silt fence or straw bale barrier may be needed as a secondary measure to control dirt and leaves.

Brush Filter Berms

A brush filter berm is composed of brush, small tree limbs, root mat, grass and leaves, or other material which is commonly generated as waste during the clearing and grubbing stage. The brush filter berm is constructed by piling these materials into a continuous and compacted mound along a level contour which is downhill from a disturbed area. Large logs or tree stumps should generally be avoided as part of the brush filter berm; they cause large voids or gaps in the berm and so defeat the purpose of detaining stormwater. However, large logs by themselves can be used to slow stormwater runoff in wooded areas, along paths and trails, or at the bottom of slopes.

A brush filter berm height of approximately 3 feet is recommended to slow or detain stormwater. The minimum height of 2 feet may be used for short slopes less than 100 feet long. A corresponding width is generally 5 to 10 feet, with a shape that can either be triangular or somewhat rounded. Standard dozers or other grading equipment are used to compact and shape the brush filter berm to be denser. Use rope or sturdy string to shape the brush filter berm and to hold it together.

A geotextile fabric can be used to increase the sediment retention or to provide a more stable brush filter berm. Install the filter fabric into a trench 6 inches deep immediately uphill from the formed berm. Then lay the filter fabric over the front face of the brush filter berm. Secure the filter fabric using staples, stakes, ropes or wires so that the fabric will not be uplifted by winds or storms. Overlap edges of filter fabric by 6 inches.

Brush filter berms are generally not used in developed areas or wherever aesthetics will be of concern. Brush filter berms may also be unpredictable in terms of performance. Since they are composed of natural materials, they may or may not need to be removed after the uphill sites are stabilized. Brush filter berms may provide a habitat for various types of desirable wildlife, or they could harbor pests and rodents in areas where these problems are known to exist.

Rock Filter Berms

A rock filter berm can be created from natural gravel or rock at the project site, or from imported gravel and rock. It is placed and compacted along a level contour, where sheet flow may be detained and ponded to promote sedimentation. Some type of geotextile fabric or wire screen is recommended to keep the berm shape intact. A gabion or wire mattress may be used to construct a rock filter berm, provided that the gabion wire spacing is compatible with size of aggregate or rock.

Rock filter berms can be used along the down-slope edge of roadways or 5 to 7 feet beyond the toe of a slope. Rock filter berms can also be incorporated as part of a gravel road and other type of unpaved traffic area, in order to prevent stormwater from flowing into paved roads.

Construct a rock filter berm by first placing larger rocks as a base. If available, smaller rocks or gravel are placed on the uphill side of the larger rocks to form a natural filter. Geotextile filter fabric can be underneath the rock filter berm itself, which would adequately anchor the fabric. For areas where concentrated flows may occur, use larger rock without any dust or fine material, placed in a gabion or other type of staked woven-wire mattress.

Supplemental Materials

A geotextile filter fabric may be used to increase sediment retention. Burlap or other type of porous cloth material may be used in instances where no sediment is expected. At the toe of a graded slope or other instances with substantial amounts of sediment, a silt fence fabric should be selected. Consult ES-14, Silt Fence, for additional recommendations and trenching for geotextile fabric.

For areas with little potential for sediment, wire netting may be used to stabilize the filter berm. Woven-wire sheathing, such as frequently used for gardens and for poultry fencing, is typically 20-gauge galvanized wire, woven as a hexagonal mesh.

Stakes can be used to secure geotextile fabric or wire netting. Space wood, metal, or biodegradable stakes to prevent damage from wind uplift for geotextile fabric.

Maintenance

- Inspect filter berms after each rainfall event and also weekly for damaged fabric, excessive sediment buildup, undercutting flows or flows around end of filter berms. Repair or replace as necessary.
- Remove accumulated sediments when depth reaches 6 inches in front of filter berm. Dispose at onsite locations where sediment will not erode or become resuspended. Reshape filter berms and replace brush, rock, fabric, or stakes as needed.
- Remove filter berms after uphill drainage areas are stabilized. Natural materials such as brush and rock may be left in place if they do not cause any landscaping or nuisance problem. Remove all manmade materials (wire, stakes, fabric, etc).

Limitations

- Brush or rock filter berms shall not be used in live or continuously-flowing streams. Filter berms require sufficient space for ponded water.
- Installation and removal of filter berms may be difficult or time-consuming in areas with steep slopes or difficult access requirements. Consider how to remove rock filter berms during design phase.
- Not appropriate for contributing drainage areas greater than 2 acres. More reliable structural methods, such as temporary sediment traps and sediment basins, should be used if large amounts of sediment will be generated. Performance of brush filters may be relatively unpredictable.

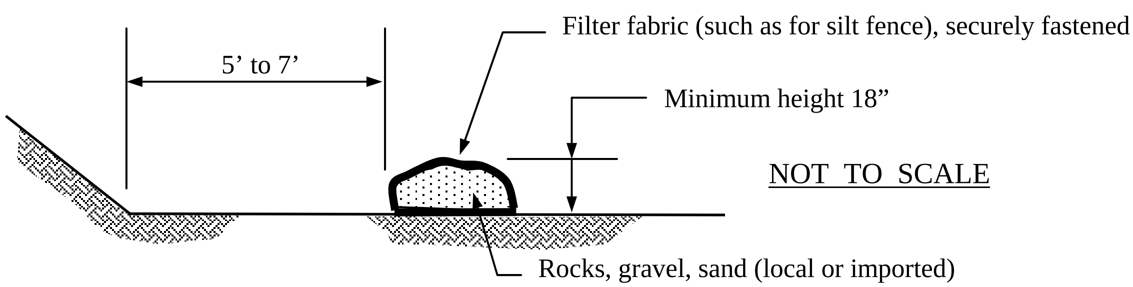
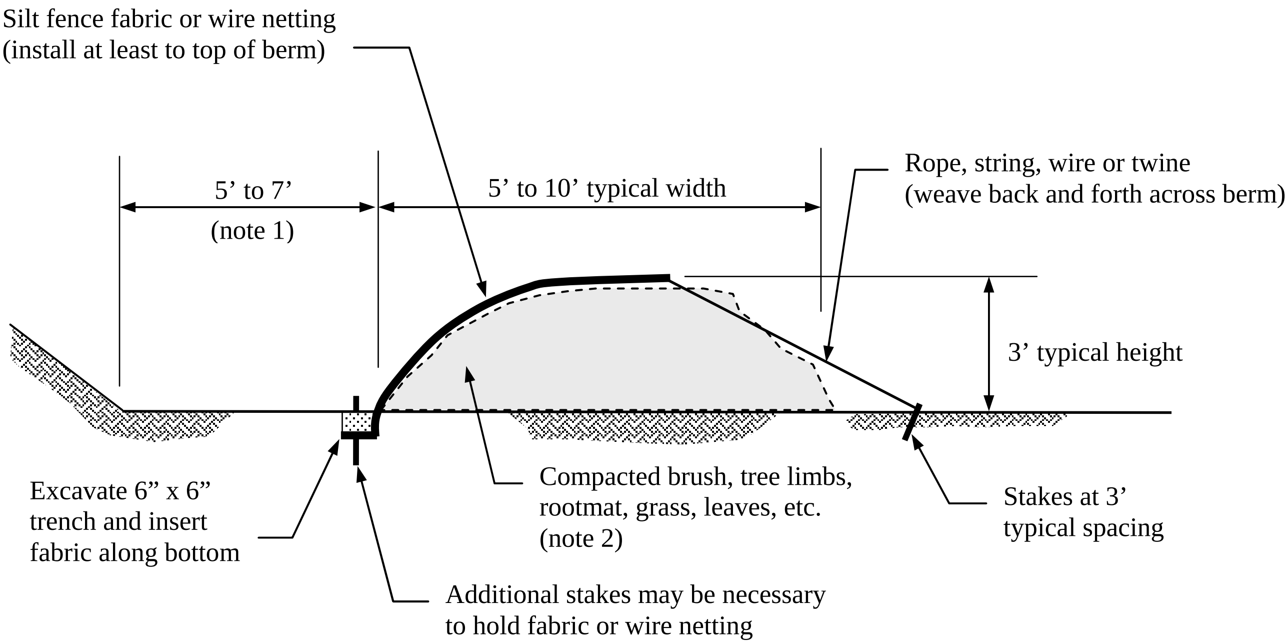


Figure ES-16-1
Rock Filter Berm



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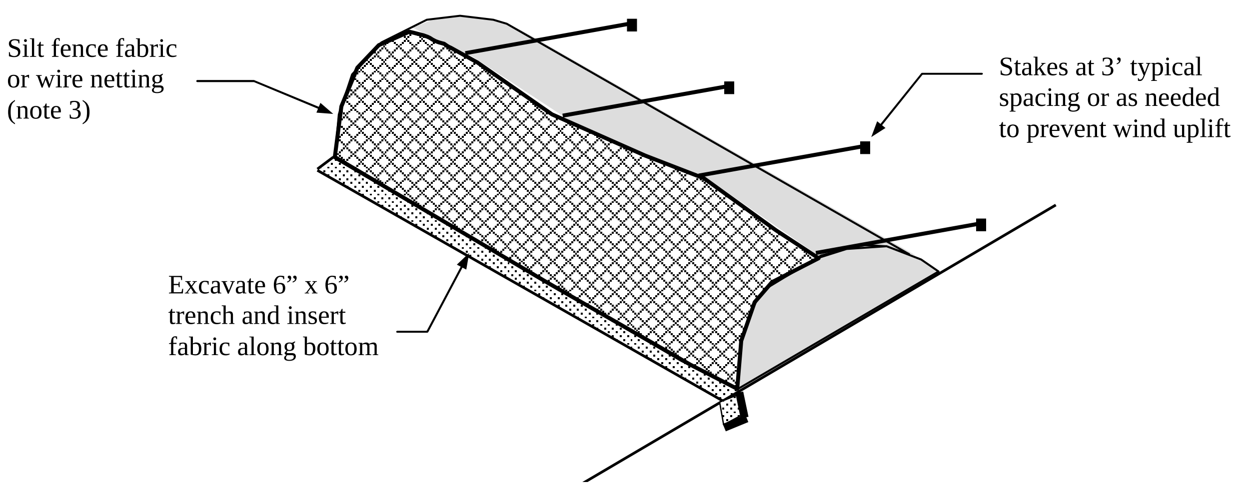


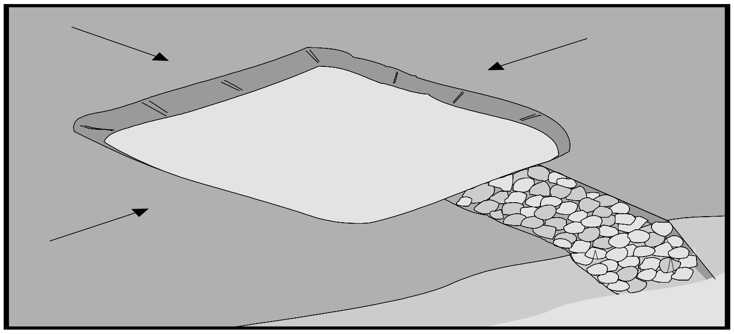
Notes:

1. Place brush filter berm at least 5 to 7 feet away from steep or long slopes to impound stormwater runoff. Wrap ends of brush filter uphill and anchor within slope.

2. Firmly crush and compact brush material so that it forms a dense berm. Prevent sticks and tree limbs from perforating silt fence fabric.

3. Silt fence fabric, if needed, is typically placed on the front half of brush filter berm. Wire netting is typically placed all the way across the brush filter berm.

Figure ES-16-2
Brush Filter Berm



Targeted Constituents				
● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit		
● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances	
○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	◗ Construction Wastes

Description

A sediment trap is a small temporary pond that drains a disturbed area so that sediment can settle out. A sediment trap is constructed early in the construction process using natural divides and favorable topography where possible to minimize grading. This practice will significantly reduce sediment.

Suitable Applications

- Any disturbed area which is less than 5 acres.
- Along the perimeter of a project site to prevent sediment-laden runoff from being discharged.
- Immediately uphill from temporary storm drain inlet protection measures.

Approach

A temporary sediment trap is a small settling pond, built to collect and store sediment from uphill sites cleared and graded during construction. It is intended for use on small tributary areas with no unusual drainage features, and projected for a quick build-out time at the initial construction phases. The principal feature distinguishing a temporary sediment trap from a temporary sediment basin is the lack of a pipe or riser.

A sediment trap is a temporary measure with a typical design life of approximately 6 months and a maximum drainage area of 1 to 5 acres, depending on the manner of construction. The maximum life of a sediment trap shall not be more than 12 months, and also depends on the type of construction chosen. One or more temporary sediment traps are often built early in the construction process to control erosion, before a larger temporary or permanent structure (such as a sediment basin or modified detention basin) can be constructed.

A temporary sediment trap is not as effective as a temporary sediment basin and therefore requires that more sediment control measures must be operative upstream. A sediment trap is effective against coarse sediment, but not against silt or clay particles that remain suspended. A temporary sediment trap requires very frequent maintenance and inspection until the site is permanently protected against erosion.

Place sediment traps at locations that will require minimal clearing and grading. Balance excavation and fill quantities when possible to minimize grading. Natural draws or swales are usually favorable places to build a sediment trap. Sediment traps should be easily accessible for frequent maintenance and inspection, but do not locate in the middle of major construction areas. Do not locate sediment traps where failure can cause property damage or inconvenience to humans.

Undisturbed areas should generally be routed around temporary sediment traps (and also sediment basins and detention basins) early during the construction process. This can achieved by temporary diversions or by permanent channels. This allows “clean” storm water runoff to remain clean. In addition, the total storm water runoff volume to the sediment trap is reduced. This allows silt and clay particles to have less storm water runoff depth to settle through, and these particles are also less likely to be resuspended.

Types of Construction

The basic principles and design guidelines are applicable to various methods for creating a temporary sediment trap. The main differences are with regards to the type of outlet structures that are chosen. The following types are identified and shown with details:

- (A) Overflow (level spreader): Figure ES-17-1
- (B) Rock outlet: Figure ES-17-2
- (C) Combination straw bale and silt fence outlet: Figure ES-17-3

(A) An overflow sediment trap is limited to small areas less than 1 acre, typically with gentle slopes (1 or 2 percent) and without major grading operations. It functions very similarly to a level spreader. If water enters the sediment trap with very slow velocities, the same amount of water will be slowly displaced and leave the other end of the sediment trap. Silt fence, straw bale barriers or grass filter strips are used to “polish” the overflow water as it leaves the sediment trap.

(B) The rock outlet type relies on filtering through layers of aggregate, rock or riprap material to dewater the sediment trap. It is the sturdiest of the sediment trap designs and generally requires less maintenance. It can be used for drainage areas up to 5 acres and for up to 12 months.

(C) The combination straw bale and silt fence outlet uses the two most common sediment-filtering devices to dewater the sediment trap. Additional structural support, such as wood bracing or wire fence installation, is required for these two materials to resist 1 foot or more of ponded water. Straw bales are liable to rot quickly or to blow out; silt fence fabric can rip or tear. The combination straw bale and silt fence outlet should be limited to total drainage areas of less than 1 acre. This type of outlet requires frequent maintenance and adjustments to ensure that the released storm water is free from sediment.

Volume

Minimum volume of a sediment trap shall be 67 cubic yards per acre for the total drainage area. The volume shall be measured at an elevation equivalent to the spillway invert.

Optimal design volume of sediment trap depends on type of soil, size and slope of drainage area, amount of land disturbance, desired sediment removal efficiency, and desired cleanout frequency. A recommended volume for temporary sediment trap in heavily disturbed areas is 134 cubic yards per acre, which equates to 1 inch of storm water runoff. Optimal design of this type of sediment trap includes an upper zone of at least 67 cubic yards per acre (to be dewatered using one of the outlet design alternatives) and a lower wet zone for sediment storage and settling.

Volume of a sediment trap should generally be computed from existing and proposed contour lines, or by using measured cross sections. An approximate method for estimating volume for most sediment traps using a natural draw or swale is:

$$V = 0.4 \times A \times D$$

V = storage volume (below the invert of the emergency spillway)
A = surface area (at the level of the emergency spillway invert)
D = maximum depth (as measured from the emergency spillway invert)

The recommended cleanout volume is 1/4 of the total storage volume of a sediment trap. The nominal volume for sediment removal is therefore 17 cubic yards per acre (which is 1/4 x 67 cubic yards per acre). The recommended sediment depth for the cleanout volume shall be computed. A stake or post shall be installed and marked to assist in identifying the need for sediment cleanout.

Other Physical Parameters

- Maximum total drainage area to a temporary sediment trap is 5 acres, depending on the type of construction. Maximum life span of a temporary sediment trap is 12 months, again depending on the type of construction.

- Maximum height of sediment trap embankment shall not be more than 5.5 feet, as measured from the downstream toe of slope to top of berm.

- Maximum ponded depth of sediment trap shall not be more than 4 feet, as measured from the bottom of the trap to the invert of the emergency spillway.

- Maximum slopes shall be 2:1 (H:V) for excavated areas and for compacted embankments. Most side slopes should be to 3:1 (H:V) or flatter, which will allow people and equipment to safely negotiate slopes or to enter the sediment trap.

- Top width of embankment shall be at least as wide as the actual height of sediment trap embankment, with a minimum width of 3 feet.

- Storm water travel distances should be maximized across the sediment trap. The length to width ratio must be greater than 2:1 (L:W) for the principal flow paths in order to maximize residence time of storm water within the sediment trap. Baffles may be required to prevent short-circuiting of flow.

- A typical baffle design is to use 4’ x 8’ sheets of exterior grade plywood ½ inch thick, mounted on 4” x 4” hard wood posts. Posts shall be firmly set at least 2 feet into the ground with maximum spacing of 8 feet. Posts and plywood shall not be lower than 6 inches below the top of embankment elevation.

Emergency Spillway

The emergency overflow outlet of the temporary sediment trap must be stabilized with rock, riprap, geotextile, vegetation or another suitable material which is resistant to erosion. A stable emergency spillway must be installed to safely convey storm water runoff for the 10-year storm event.

An emergency overflow weir should be provided at an elevation of at least 1.5 feet below the top of embankment, with a minimum freeboard of 1 foot. The minimum bottom width of a trapezoidal section for an emergency overflow weir should be:

4 feet	-	1 acre (total drainage area)
6 feet	-	2 acres (total drainage area)
8 feet	-	3 acres (total drainage area)
10 feet	-	4 acres (total drainage area)
12 feet	-	5 acres (total drainage area)

Installation Guidelines

Temporary sediment traps are usually installed at the beginning of a construction project, immediately after the perimeter erosion control measures have been performed. It is intended that grading, earthwork, trenching and other land-disturbing activities take place early in the construction process, so that the temporary sediment trap should not be necessary for more than 12 months.

Step 1: Place perimeter erosion control measures around sediment trap location. Clear and grub, particularly underneath embankments. Grade and/or excavate to construct the required volume and to provide fill material for any embankments.

Step 2: Construct any embankments needed by using fill material made of clay, which is free of roots, large rocks, and organic material. Place fill in layers 6 inches thick and then compact using a sheeps foot roller or vibratory equipment.

Step 3: Install outlet structures such as rock outlet berm, combination straw bale and silt fence outlet, or an emergency overflow weir. Install geotextile fabric and wire fencing at potential locations of stone outlet failure. Install baffles if necessary to maximize storm water residence time within the sediment trap.

Step 4: Stabilize slopes using temporary vegetation, erosion control matting, straw mulch or other measures. Inspect final work for safety and function. Install warning signs, barricades, perimeter fence or other measures necessary to protect construction workers and equipment.

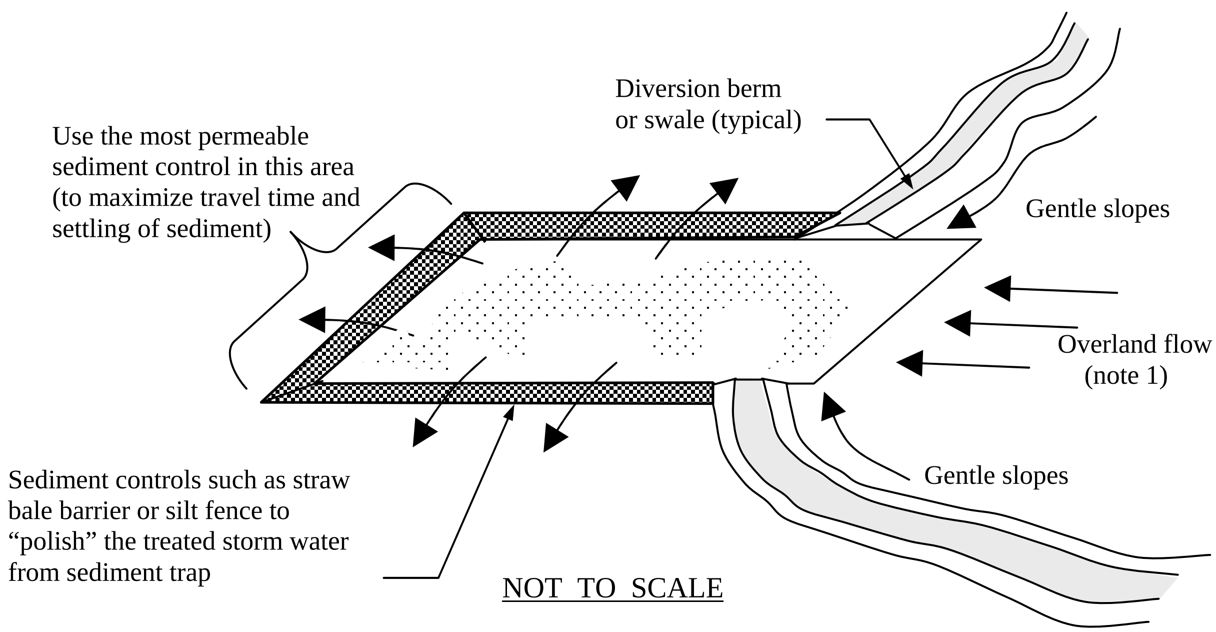
Maintenance

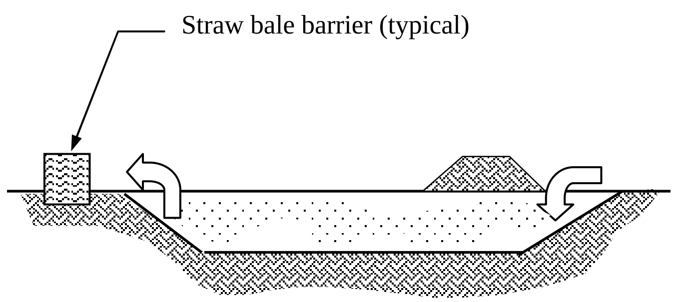
- Inspect sediment traps weekly and after each rainfall event for excessive sediment buildup, undercutting flows or seepage, slope failure, settlement and structural soundness. Regularly inspect water quality being discharged for suspended sediment and color. Identify and perform necessary repairs to improve water quality. Check downstream channel for erosion or sedimentation.

- Remove accumulated sediment whenever it reaches the designated cleanout level, which is one-fourth of the total sediment volume. The nominal volume of sediment (1/4 x 67 cubic yards = 17 cubic yards) usually requires heavy equipment and good weather for sediment cleanout. Shovel by hand adjacent to outlet control structures to prevent equipment damage in this area. Dispose of accumulated sediment onsite at a protected location to prevent resuspension of sediment.

Limitations

- Temporary sediment traps shall not be used in live or continuously-flowing streams. Sediment traps may kill nearby vegetation by excessive sediment or by long periods of submergence.
- Temporary sediment traps only remove coarse particles which settle quickly. Sediment traps are not effective for fine-grained soils such as silt or clay. Additional upstream erosion control measures are necessary.
- Sediment traps can be attractive and dangerous to children. Protective fencing or other access control measures for the project site are recommended. Sediment traps with steep slopes may be difficult for someone to exit.



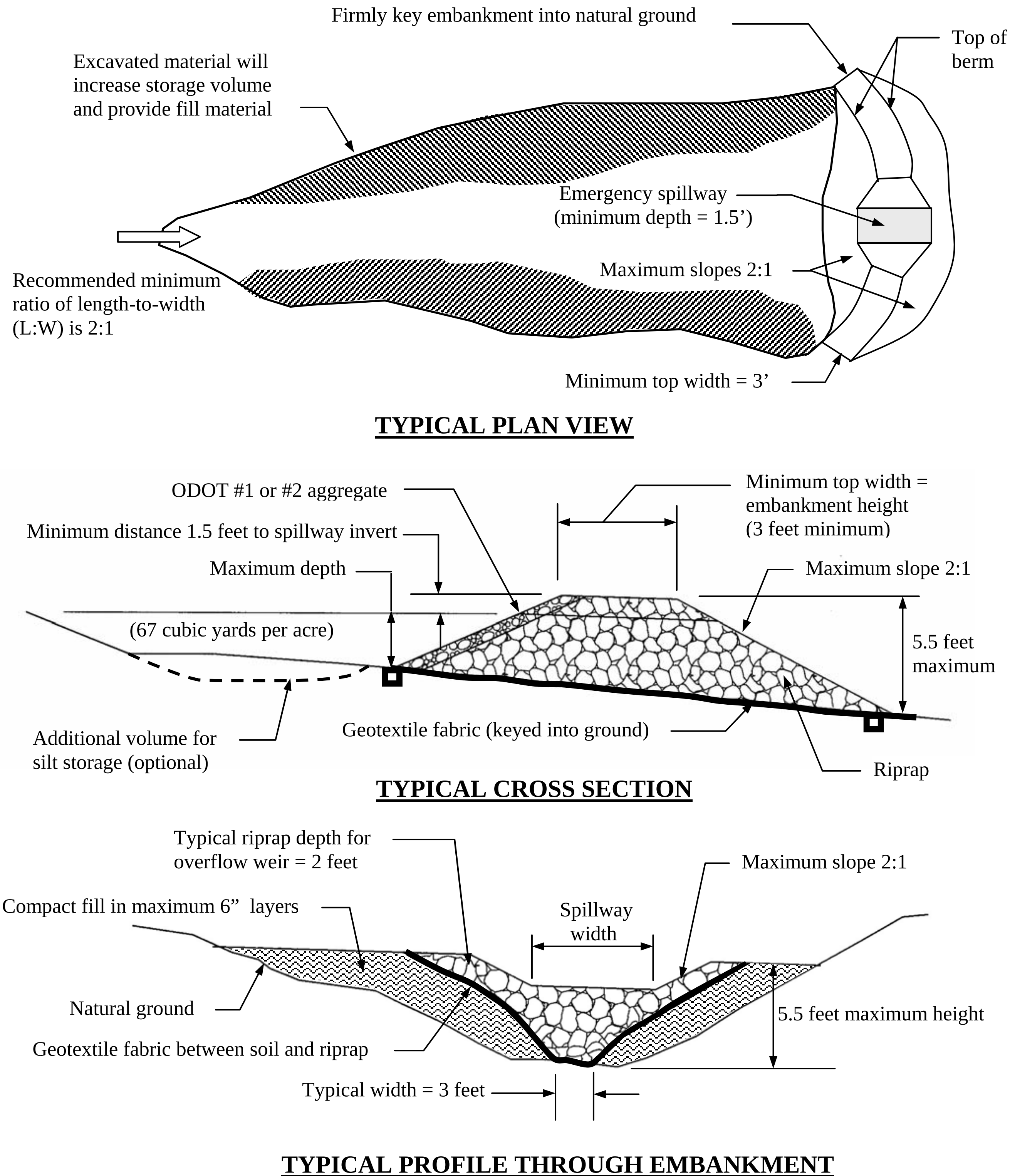


Notes:

1. Maximum area for overflow sediment trap is usually 1 acre. Must have gentle slopes (less than 2% generally) and predominantly overland sheet flow.

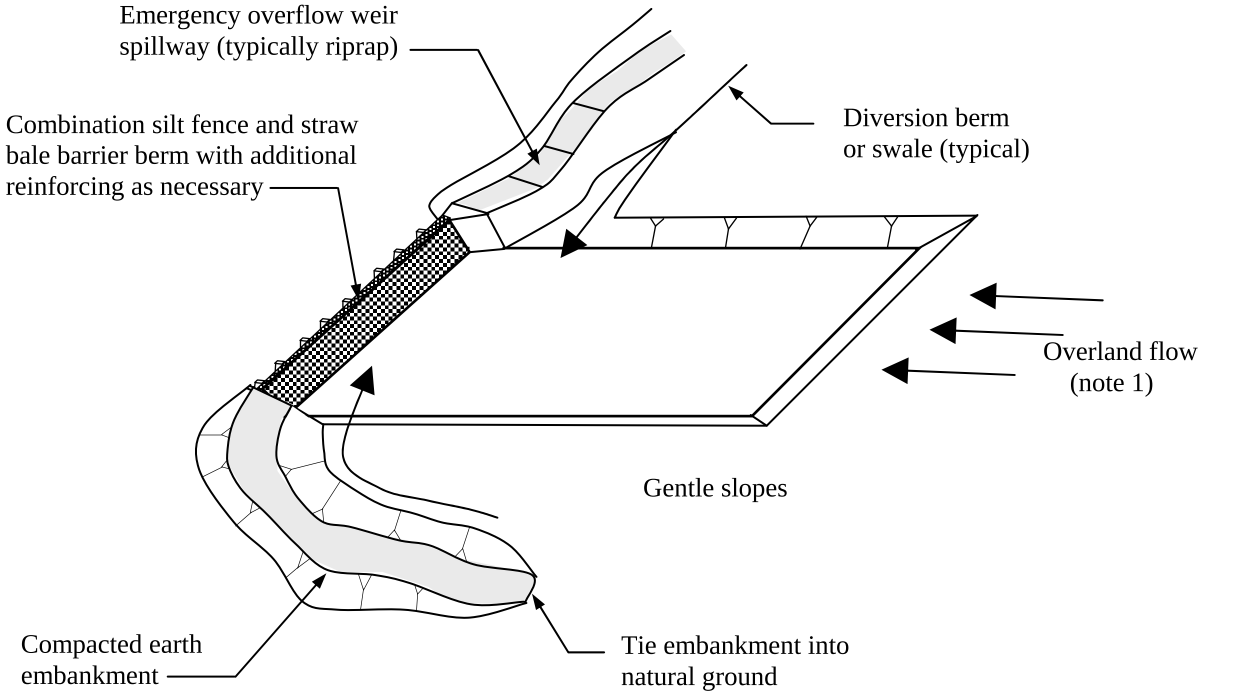
2. Maximum permanent wet depth is 2 feet. Overflow sediment traps may not be effective for high groundwater table and inflows.

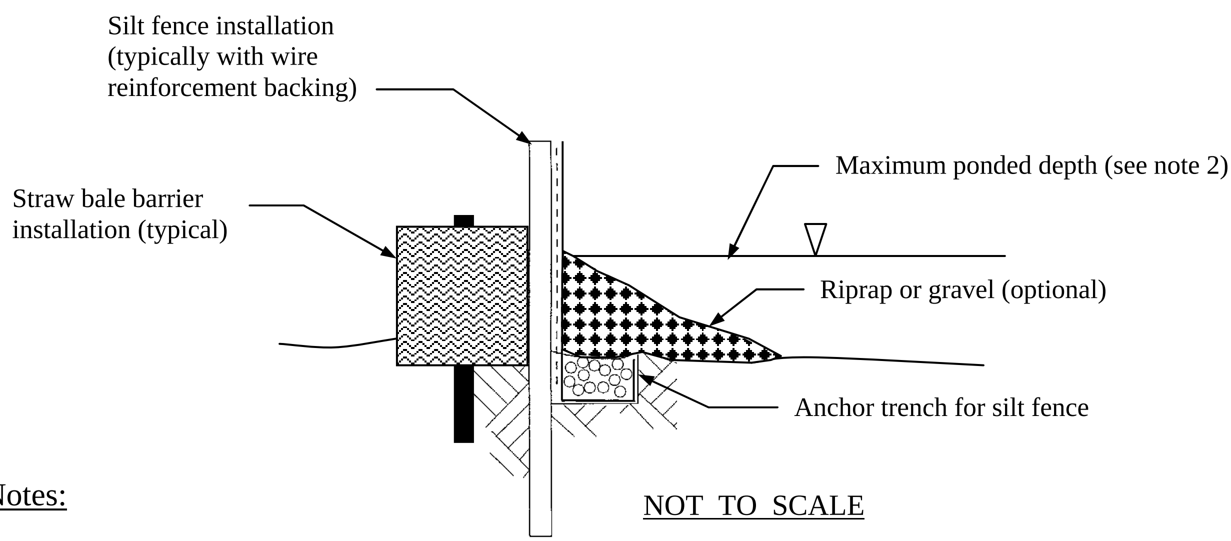
Figure ES-17-1
Temporary Sediment Trap – Overflow



NOT TO SCALE

Figure ES-17-2
Temporary Sediment Trap – Rock Outlet





Notes:

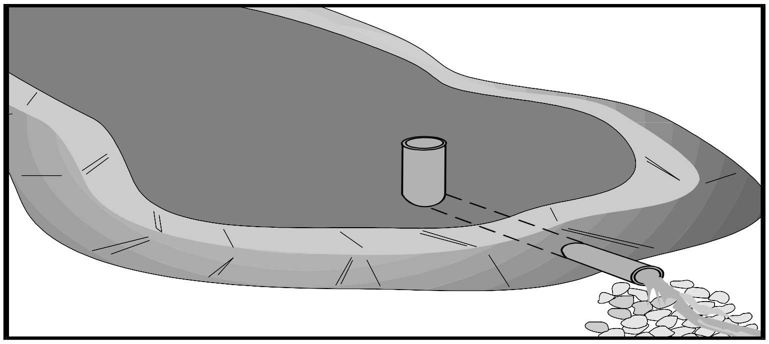
1. Maximum area for sediment trap with a silt fence / straw bale combination outlet is usually 1 acre with gentle slopes and predominantly overland sheet flow.

2. Maximum depth of ponded water is usually 12 inches or less. Provide emergency spillway by constructing riprap channel as necessary.

Figure ES-17-3
Temporary Sediment Trap – Combination Outlet

ACTIVITY: Sediment Basin

ES – 18



Targeted Constituents				
● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit		
● Sediment	○ Heavy Metals	◗ Floatable Materials	○ Oxygen Demanding Substances	
◗ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	◗ Construction Wastes

Description

A sediment basin is an impoundment for the purpose of detaining runoff to allow excessive sediment to settle. A temporary sediment basin can be an impoundment (using natural divides and favorable topography where possible) to remove sediment during a construction project or other land-disturbing activity. A detention basin can also be refitted to temporarily perform as a sediment basin for handling large amounts of silt and eroded soil if good practices such as frequent inspection and maintenance are performed. A sediment basin will significantly reduce sediment.

Suitable Applications

- At the outlet of any disturbed area with major grading, particularly for disturbed watersheds larger than 5 acres.
- At locations with very steep slopes, sloughing or severely eroded soils, or industrial activities that generate sediment and soil particles.

Approach

A sediment basin is a carefully constructed impoundment with a controlled storm water release structure and is usually formed by combination of excavation and embankment to have balanced cut/fill volumes. Sediment basins are more effective in retaining eroded soil and silt than temporary sediment traps (see ES-17); the principal feature distinguishing a sediment basin from a temporary sediment trap is the presence of a pipe, riser, or other outlet structure. A temporary sediment basin shall generally have a maximum lifespan of 2 years, unless designed as a permanent structure by a professional engineer.

Sediment basins may be designed as temporary or permanent structures, depending on the nature of the sediment-generating activity. This BMP is intended to principally cover temporary sediment basins. Permanent sediment basins must be designed to handle much larger flows, typically 25-year to 100-year storm events, with a designed emergency spillway, keyed construction with impermeable soils, anti-seep collars, etc. Permanent sediment basins are generally constructed with much larger sediment volumes in order to reduce the cleanout frequency and maintenance.

Sediment basins must be located and designed so that failure of structure would not result in danger to human life, damage to personal property, inundation of public streets or highways, interruption of public services or utilities, or inconvenience to the general public. Place sediment basins at locations that will require minimal clearing and grading. Natural draws or swales are usually favorable places to build a sediment basin. Sediment basins should be easily accessible for frequent maintenance and inspection, but not located in the middle of major construction areas.

A sediment basin requires frequent maintenance and inspection until the site is permanently protected against erosion. Less maintenance and fewer cleanouts will be required if adequate erosion and sediment control devices are placed upstream. Undisturbed areas should generally be routed around sediment basins early during the construction process. This can be achieved by temporary diversions or by permanent channels. This allows "clean" storm water runoff to remain clean. In addition to keeping offsite storm water clean, the total storm water runoff volume to the sediment basin is reduced. This allows silt and clay particles to have less storm water runoff depth to travel through as they settle, and they are also less likely to be resuspended.

The City of Winchester requires storm water detention for most development and redevelopment projects. Since storm water detention volumes are generally larger than the sediment-detaining volumes, a detention basin can usually function as a temporary sediment basin with relatively few modifications. However, a permanent detention basin must be designed by a professional engineer using appropriate storm water calculations.

Dam Requirements

Consult the Kentucky Division of Water, Dam Safety for information about dam construction, classifications, and permits. Information is available at the Dam Safety website:

http://www.water.ky.gov/damsafety/

Dewatering Methods

The temporary sediment basin can be dewatered by several means, as long as the dewatering outflows are small to allow suspended soils to settle. The dewatering mechanism can either draw water from the top of the storage pool (such as a floating skimmer) or can filter water from any portion of the storage pool.

The sediment basin should generally have a minimum draindown time of at least 1 day for settling. The maximum draindown time should be less than 3 days in order to recover the runoff storage volume. A factor that can affect the selection of dewatering method is whether a temporary sediment basin will be converted into a permanent detention basin.

The most common method is to perforate a CMP riser with small holes typically ½ inch diameter and then cover with a layer of rock or aggregate to filter out sediment. Aggregate size should be approximately ¾ to 1 inch to prevent stones from entering holes. This method of dewatering a temporary sediment basin may also be applicable for a permanent detention basin if approved design procedures are used utilized.

An alternate method to dewater a basin with a CMP riser or a concrete outlet structure is to wrap geotextile filter fabric around the riser. Chain-link fencing should be used on the inside of the fabric, in order to allow water to flow through the filter fabric. Chain-link fencing can also be used to wrap around the outside of the filter fabric, to protect it from floating debris. The geotextile fabric and chain-link fencing should be fastened securely to the structure to prevent movement.

A floating skimmer can be constructed of any type of lightweight pipe, such as PVC or flexible polyethylene pipe, that can be made to float by attaching buoyant materials. The floating skimmer is connected to an orifice in the side of the outlet structure in order to provide elevation drop within the lightweight pipe. This type of skimmer is hard to design because the rate of dewatering is dependent on the type and number of perforations in addition to how deep the lightweight pipe would float on the surface.

Installation Guidelines

Temporary sediment basins are usually installed at the beginning of a construction project, immediately after perimeter erosion control measures have been performed. Most of the grading, earthwork, trenching and other land-disturbing activities usually take place early in the construction process, but in some cases, it may beneficial to phase grading activities to reduce sediment loads.

Step 1: Place perimeter erosion control measures around sediment basin location. Clear and grub, particularly underneath embankments. Grade and/or excavate to construct the required volume and to provide fill material for any embankments.

Step 2: Construct any embankments needed by using fill material made of clay, which is free of roots, large rocks, and organic material. Place fill in layers 6 inches thick and compact well by traversing with a dozer or other equipment. Embankments in critical areas should be compacted to at least 95% of standard maximum density.

Step 3: Install outlet structures, such as a pipe and riser system or an emergency overflow weir, as the embankment is being constructed. Install geotextile fabric and wire fencing at potential locations of stone outlet failure. Install baffles if necessary to maximize storm water residence time within the sediment basin.

Step 4: Stabilize slopes using temporary vegetation, erosion control matting, straw mulch or other measures. Inspect final work for safety and function. Mark or otherwise locate sediment cleanout elevations and thicknesses. Install warning signs, barricades, perimeter fence or other measures necessary to protect construction workers and equipment.

Maintenance

- Inspect sediment basins weekly and after each rainfall event for excessive sediment buildup, undercutting flows or seepage, slope failure, settlement and structural soundness. Regularly inspect water quality being discharged for suspended sediment and color. Identify and perform necessary repairs to improve water quality. Check downstream channel for erosion or sedimentation.

- Remove accumulated sediment whenever it reaches the designated cleanout level from one-fourth to one-third of the total sediment volume. The nominal volume of sediment usually requires heavy equipment and good weather for sediment cleanout. Shovel by hand adjacent to outlet control structures to prevent equipment damage in this area. Dispose accumulated sediment at protected location onsite to prevent resuspension of sediment.

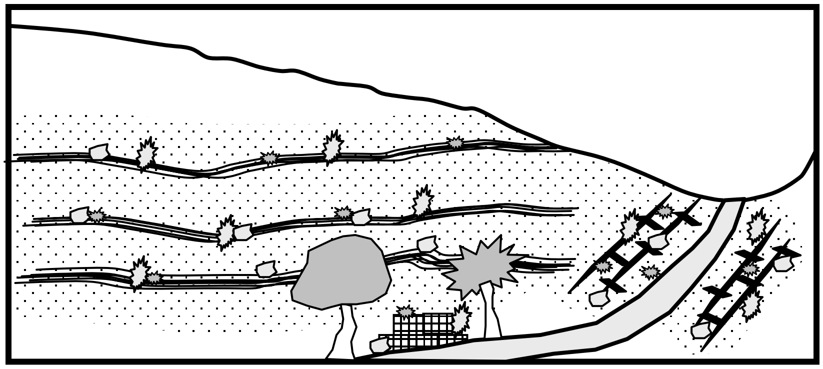
Limitations

- Sediment basins shall not be located in live or continuously-flowing streams. Sediment basins may kill nearby vegetation by excessive sediment or by long periods of submergence.

- Sediment basins may not be effective for fine-grained soils such as silt or clay. Additional upstream erosion control measures are necessary.

- Sediment basins can be attractive and dangerous to children. Large deposits of sediment can act as “quicksand” to young children who may not have the strength to exit. Protective fencing or other access control measures for the project site are highly recommended. Sediment basins with steep slopes may be difficult for someone to exit.

ACTIVITY: Bank Stabilization and Soil Bioengineering	ES – 19



Targeted Constituents				
● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit		
● Sediment	○ Heavy Metals	○ Floatable Materials	○ Oxygen Demanding Substances	
○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

Provide slope stabilization, protection, vegetative cover and erosion reduction through the use of woody vegetation structures alone or in combination with simple retaining structures. This practice is likely to create a significant reduction in sediment.

Suitable Applications

- Protection of steep slopes against surface erosion and shallow mass wasting.
- Protection of earth embankments and for repairs of small gullies.
- Along streambanks and other channels that are experiencing erosion. Any work along a stream or within a stream must be approved by the Kentucky Division of Water (KYDOW) prior to construction.
- Wherever trees, shrubs and dense non-landscaped vegetation may be desired.

Approach

At some locations it is very difficult to establish vegetation. Steep slopes that are subject to weather from prevailing storm patterns are a primary example. It is difficult to plant trees and shrubs on a steep slope in order to establish a stable ground cover. Streambanks are also subject to erosion and severe stresses, for which grass and other vegetation may not be sturdy enough. The techniques in this BMP are generally for slope stabilization; design of stream habitats and vegetation is a lengthy subject for which expert advice and extensive regulatory review is needed.

Bank and slope stabilization can be accomplished using woody materials that are placed in an alternative manner other than planting in a specially prepared hole using nursery stock (as in ES-10, Trees, Shrubs and Vines). The use of native plant materials can also be accomplished using live roots, branches and cuttings. Traditionally willow plants have been used near streams, due to quick sprouting and growth characteristics.

Bank stabilization and soil bioengineering can be incorporated into a standard retaining wall design such as a crib wall or gabion wall by adding live branches and cuttings. A retaining wall is an engineered structure with calculated loads and stresses that are used in material selection and design. Retaining walls must be designed by a professional engineer in accordance with stability calculations, by examining all possible combinations of live loads and dead loads. Adding vegetation to a retaining wall may or may not affect structural stability in the future. A project designer should carefully consider all potential issues of retaining walls during conceptual design.

Site Considerations

- Observe surrounding slopes for types of vegetation, vegetation density and overall plant health. Also observe the directions that nearby slopes are facing. For instance, some plantings generally do better on an eastern exposure and do not survive in a southern exposure. Plant health is a good indicator of soil types and conditions (including moisture).
- Make geologic observations of project site and nearby slopes, noting soil types and any types of failure such as sliding or rotating. Look for groundwater or wet soils. Consider potential freeze/thaw conditions that may contribute to slope failure.
- Retain existing vegetation whenever possible. Limit removal of vegetation by keeping the cleared area to the smallest practical size, limiting duration of the surface disturbance, and retaining existing woody vegetation for future planting.
- Stockpile and protect topsoil removed during clearing. Protect areas exposed during construction with temporary erosion and sediment control practices.

General Installation Techniques

- Grade or terrace a slope in order to eliminate possible failure by sliding or rotating. Flatten slopes to reduce potential slumping or undercutting from storm water flows.
- Installation of bank stabilization methods is best accomplished in late fall at onset of plant dormancy. Plants that are not dormant are less likely to survive. Bank and slope stabilization plantings will not typically take full effect in slowing erosion for at least a year. Temporary or permanent grass seeding may be necessary.
- Keep fresh cuttings and branches moist. Store in a cool place away from direct sunlight. Backfill soil material should have sufficient fine soils and proper drainage depending on the type of vegetation selected. Soil may need lime or slow-release fertilizer in moderate amounts in order to support vegetation.

Live Stakes

Live stakes are the insertion of live, rootable vegetative cuttings into the ground. Live stakes are an appropriate technique for repair of small earth slumps that are frequently wet. Or they can be used to supplement other types of bank stabilization plantings. Live stakes can also be installed through existing riprap or other aggregate materials, allowing a stabilized riprap location to eventually have natural vegetation.

Live stakes are usually 0.5 to 1.5 inches in diameter and approximately 2 to 3 feet in length. Typical spacing is 2 to 3 feet apart. The basal end (or root) is cut to an angled point for easy insertion. The top should be cut square. Willow branches have historically been specified for use as live stakes and are well-suited to the purpose. Other types of tree branches may be selected, depending on soil type and available moisture conditions, such as ash, alder, elm or dogwood.

Gently tamp the live stake into the ground at right angles to the slope. Approximately 80 percent of the live stake length should be installed into the ground. Pack soil firmly around live stake after installation. Do not split the stakes during installation; stakes that split should be removed and replaced. An iron bar can be helpful in establishing a pilot hole for the live stake.

Live Fascine Bundles

A fascine is defined as a bundle of sticks or branches, tied together and used for a definite purpose such as preparing a primitive house, fort, or other structure. A live fascine is defined as a bundle containing live branch cuttings bound together into sausage-like structures, and then placed to provide slope stability or prevent erosion.

Live branch cuttings should be from species that easily root and have long, straight branches. Cuttings are tied together to form live fascine bundles that vary in length from 5 to 30 feet, depending on site conditions and limitations in handling. The completed bundles should be 6 to 8 inches in diameter, with all of the growing tips oriented in the same direction. Stagger the cuttings in the bundles so that tops are evenly distributed throughout the length of the uniformly sized live fascine.

Both live stakes and dead stakes are used to install fascine bundles. Stakes should be at least 2.5 feet long on cut slopes and at least 3 feet long on fill slopes. Dead stakes can be constructed from untreated 2x4 lumber with a minimum length of 2.5 feet. A diagonal cut across the 2x4 lumber will assist in creating stakes quickly.

Prepare the live fascine bundles and live stakes immediately before installation.
Begin at the base of the slope and work upwards. Dig a trench along a level contour just deep enough to contain the live fascine bundle. A typical trench size is 12 to 18 inches across and also 6 to 8 inches deep. Place the live fascine bundle into the trench.

Drive dead stakes directly through the bundle every 2 to 3 feet to securely fasten it. Extra stakes should be used at connections and overlaps. Leave the top of stakes flush with the installed bundle. Live stakes are generally installed on the downslope side of the bundle. Drive the live stakes below and against the bundle between the previously installed dead stout stakes. The live stakes should protrude 2 to 3 inches above the top of the live fascine. Place moist soil along the sides of the live fascine. The top of the fascine should be slightly visible when the installation is completed as shown in Figure ES-19-1. Place straw or similar mulching material between rows. Slopes steeper than 3:1 may need erosion control matting or some type of mesh to prevent erosion. Recommended maximum slope lengths for live fascine bundles are:

Slope (H:V)	Maximum slope length
1 : 1 to 1.5 : 1	15 feet
1.5 : 1 to 2 : 1	20 feet
2 : 1 to 2.5 : 1	30 feet
2.5 : 1 to 3 : 1	40 feet
3 : 1 and flatter	50 feet

A willow mattress (also called a brush mattress) is similar to a fascine roll. Willow branches and cuttings are formed into a layered arrangement approximately 4 to 6 inches thick and then tied with twine or string. Excavate an anchor trench along the bottom of the willow mattress to a depth of 3 inches, to prevent downhill sliding.

Loosen the subgrade soil throughout the mattress installation location; add lime and slow-release fertilizer as needed. A willow mattress is anchored onto a slope by using dead stout stakes and twine. Place 4 to 6 inches of fertile soil upon the willow mattress and tamp firmly.

Branchpacking

Branchpacking (a descriptive name for this method) consists of alternating layers of live branch cuttings and compacted backfill to create bank stabilization vegetation. It is often used to repair small localized slumps, gully washouts, or other small areas where the slope needs to be stabilized. Branchpacking can also be adapted as a method for planting an entire slope (see description below for brush-layering).

Live branch cuttings may range from 1/2 inch to 2 inches in diameter. Cuttings should be long enough to touch the undisturbed soil at the back of the trench. Wooden stakes (typically made from 2x4 lumber, untreated) are 5 feet or longer, depending on the depth of the hole and field conditions. Starting at the lowest point, drive the wooden stakes vertically 3 to 4 feet into the ground, at a typical spacing of 1 to 2 feet apart.

Place a 6-inch layer of live branch cuttings in the bottom of the hole or trench, between the vertical stakes and perpendicular to the slope face (as shown in Figure ES-19-2). Cuttings should be placed in a crisscross configuration with the growing tips generally oriented toward the slope face. Most branch basal ends should touch the back of the hole or slope. Each layer of branches is followed by a layer of compacted soil, typically 6 to 8 inches thick, to ensure soil contact with the branch cuttings. Final grade should match the existing slope, and branches should protrude slightly from the filled face. The soil should be moist so that the live branch cuttings do not dry out.

Branchpacking may not be effective in slumped areas or gullies which are greater than 5 feet wide. Examine the slope closely to determine the cause of slumped areas and gullies. Wet soils, inadequate drainage, excessive storm water runoff or other site conditions may require additional solutions.

Brushlayering is a variation of branchpacking suitable for gentle slopes with only a moderate potential for erosion. The live branch cuttings are oriented perpendicular (up and down) to the slope level contours, installed in a trench or cut slope, and then covered with soil as before. The difference is that the soil for each downhill trench comes from the next excavated trench immediately uphill. The presence of branch cuttings in the soil will limit the amount of compaction that can be obtained on a slope, so that additional erosion control measures may be necessary. Straw mulch, temporary seeding, jute mesh and erosion control mats may be necessary, particularly for slopes steeper than 3:1. Avoid slopes steeper than 2:1 and generally limit slope lengths to 20 feet or less.

Vegetated Crib Wall

A crib wall is a hollow, box-like, interlocking arrangement of structural members to create a retaining wall. A retaining wall is an engineered structure, with calculated loads and stresses used for the material selection and design. Crib walls made from prefabricated metal or reinforced concrete beams can be designed as very tall retaining walls that can handle large surcharge loads and traffic impacts; these types of crib walls must be designed by a professional engineer. Crib walls are filled with compacted soil or gravel, with provisions for subsurface drainage.

Adding vegetation may or may not affect structural stability of a retaining wall in the future. It would certainly affect large structural crib walls, but should not impact small crib walls such as the type shown in Figure ES-19-3 for a relatively short height using untreated logs or timber. The structure is filled with suitable backfill material and layers of live branch cuttings which will root inside the crib structure and extend upward into the slope or outward into the wall face. This technique is appropriate at the base of a slope where a low wall may be required to stabilize the toe.

Live branch cuttings should be long enough to reach the back of the wooden crib structure. Logs or timbers are usually 6 inches in diameter or thickness. Large nails or rebar are required to secure the logs or timbers together. Place foundation of wall 2 to 3 feet below grade, as shown on Figure ES-19-3.

Place the first course of logs or timbers at the front and back of the excavated foundation, approximately 4 to 5 feet apart. Place the second course of logs or timbers at right angles (perpendicular to the slope) on top of the previous course to overhang the front and back of the previous course by 3 to 6 inches. Repeat course in same manner and nail to the preceding course with nails or reinforcement bars. When the crib wall structure reaches the existing ground elevation, place live branch cuttings on the backfill perpendicular to the slope. Then cover the branch cuttings using fertile soil as backfill and compact firmly.

Vegetated Gabion Wall

A gabion is a wire basket, usually galvanized or with plastic coating, designed to hold and retain rock, riprap, aggregate, etc. The wire baskets come in standard rectangular sizes with one or more compartments. A typical gabion has triple-twisted, hexagonal mesh with openings of 1 inch more or less, depending on the type of rock that is being retained. Empty gabions are usually delivered to the project site flat, assembled and then placed into position, wired to adjoining gabions, filled with stones and then folded shut and wired at the ends and sides.

Gabion walls can be used as a designed retaining wall, with certain estimated properties and the ability to resist surcharged loads. Gabion walls which are over 4 feet tall or which are located in critical areas need to be designed by a professional engineer. Follow gabion manufacturer’s recommendations and design guidelines in designing a gabion wall.

Since a gabion wall does not contain soil as part of its structure, the live branch cuttings are typically extended through the gabions to the backfilled soil behind the wall (as shown on Figure ES-19-4). Live branches are placed on each consecutive layer between the rock-filled baskets. Eventually the roots will take hold in the backfilled soil and will also help to consolidate the structure and bind it to the slope.

Vegetated Rock Wall

A vegetated rock wall can be constructed to take advantage of live cuttings to stabilize a very low embankment or at the base of a gentle slope. The rock wall can constructed with or without mortar, depending on the types of rocks and the skill of the rock masons involved. Additional erosion control measures such as straw mulch, temporary seeding, jute mesh and erosion control mats may be necessary. A retaining wall over 4 feet high must be designed and analyzed by a professional engineer, particularly in applications which could endanger health or property.

Live cuttings should be long enough to reach the undisturbed soil behind the wall. Rock sizes normally range from 8 to 24 inches in diameter, with larger boulders used for the base. Excavate and construct a stable foundation 2 to 3 feet below existing grade as shown on Figure ES-19-5. Drainage considerations may require weepholes or other methods to remove moisture and to prevent frost damage. Provide subsurface drainage if the water table is above the wall foundation, or if the retaining wall is adjacent to impervious surfaces such as parking lot.

Place rocks with at least three contact points bearing on the layer below. Place rocks so that the center of gravity is as low as possible, with the long axis slanting inward toward the slope if possible.

Limitations

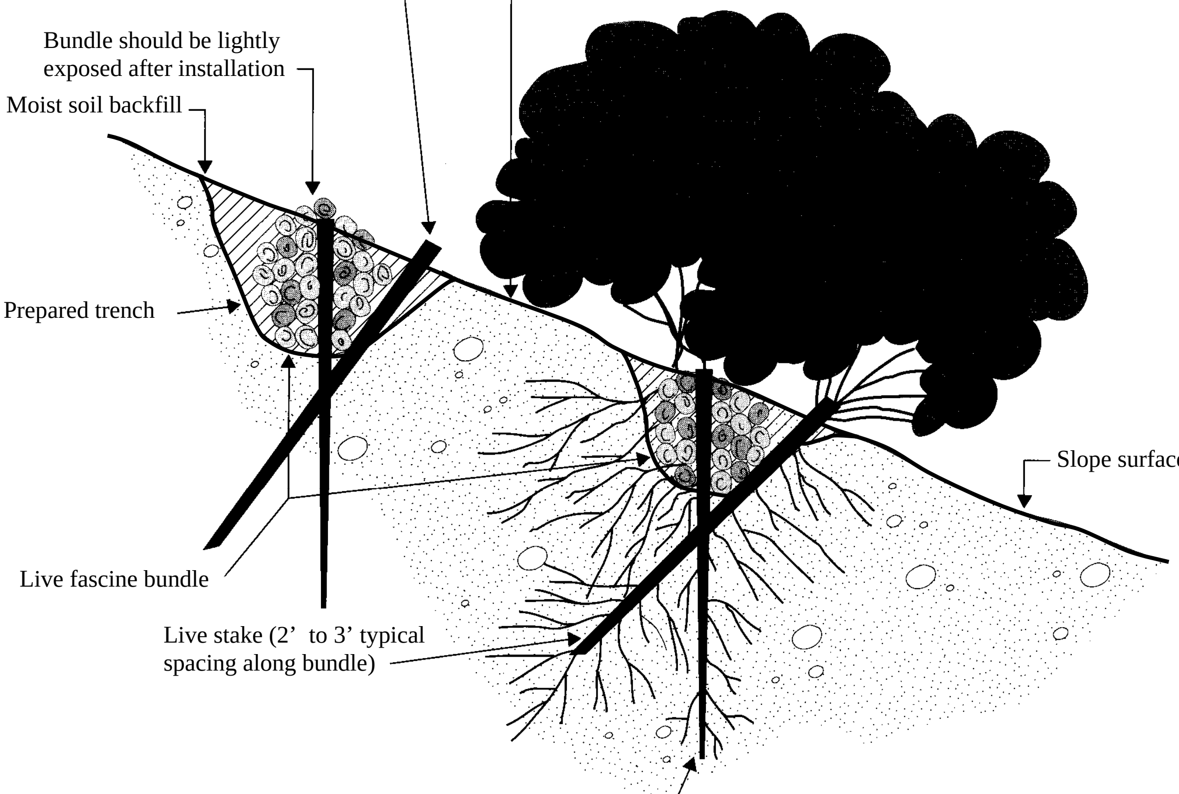
- Streams and streambanks should not be disturbed or modified unless permission is granted by KYDOW. Permits must be obtained from KYDOW prior to any work within or along any stream.
- Constraints on planting times or availability of suitable plant materials during the allowable planting times may limit soil bioengineering methods.
- Rapid vegetative establishment may be difficult on extremely steep slopes. Rocky or gravelly slopes can lack sufficient fines or moisture for plant growth.
- Soil bioengineering and bank stabilization methods take considerable time and effort to accomplish. Other methods, such as hydroseeding and the use of erosion control mats, may be much cheaper and quicker.

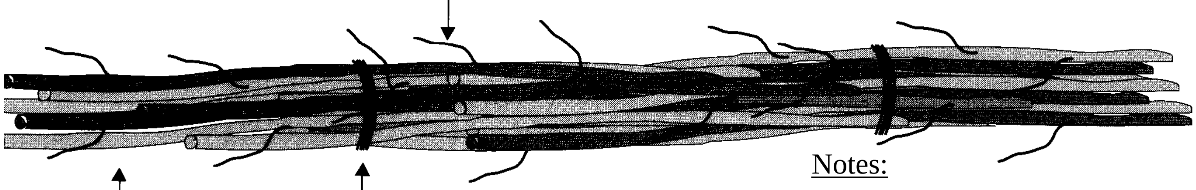
Maintenance

- During the two weeks of the establishment period, inspect cuttings daily and replace any dead vegetation with fresh stock. Inspect bi-weekly for the first 2 months, looking for insect infestations, inadequate soil moisture, and other conditions that could lead to poor survivability. Take immediate action to remedy any site conditions as warranted.
- Inspect monthly for the next 22 months. Extra inspections should be conducted during periods of drought or heavy rains. Systems which are not in acceptable growing condition should be noted and, as soon as seasonal conditions permit, should be removed from the site and replaced with materials of the same species and sizes as originally specified. Repair damaged sections immediately.
- Final inspection – A final inspection should be held 2 years after installation is completed. Healthy growing conditions include assessment of overall leaf development and the rooted stems. Growth should be continuous with no open spaces more than 2 feet. The following list has a typical rate for each type of planting, particularly when good techniques and preparation have been used.

  Live stakes ---------------------------- At least 75% growing
  Live fascines -------------------------- At least 50% growing

Branchpacking (repairs) ------------- At least 50% growing
Vegetated crib wall ------------------- Approx 50% growing
Vegetated gabion wall ---------------- Approx 50% growing
Vegetated rock wall ------------------- Approx 50% growing





Notes:

1. Rooted/leafed condition of the living plant material (shown in part of detail) is not representative of the time of installation.
2. Use a combination of live stakes and dead stakes to anchor fascine bundles.

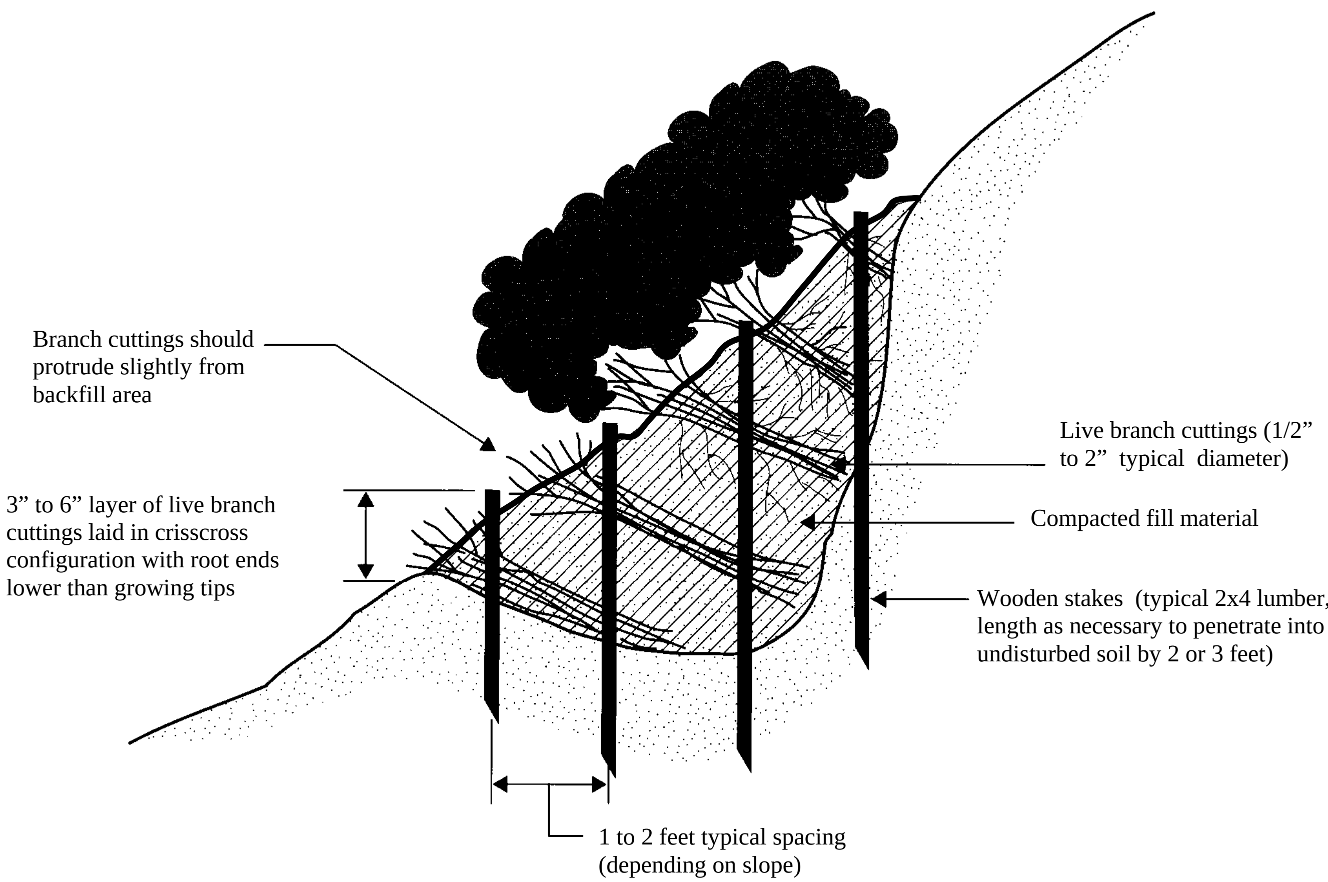
NOT TO SCALE

Figure ES-19-1
Live Fascine Details

Notes:

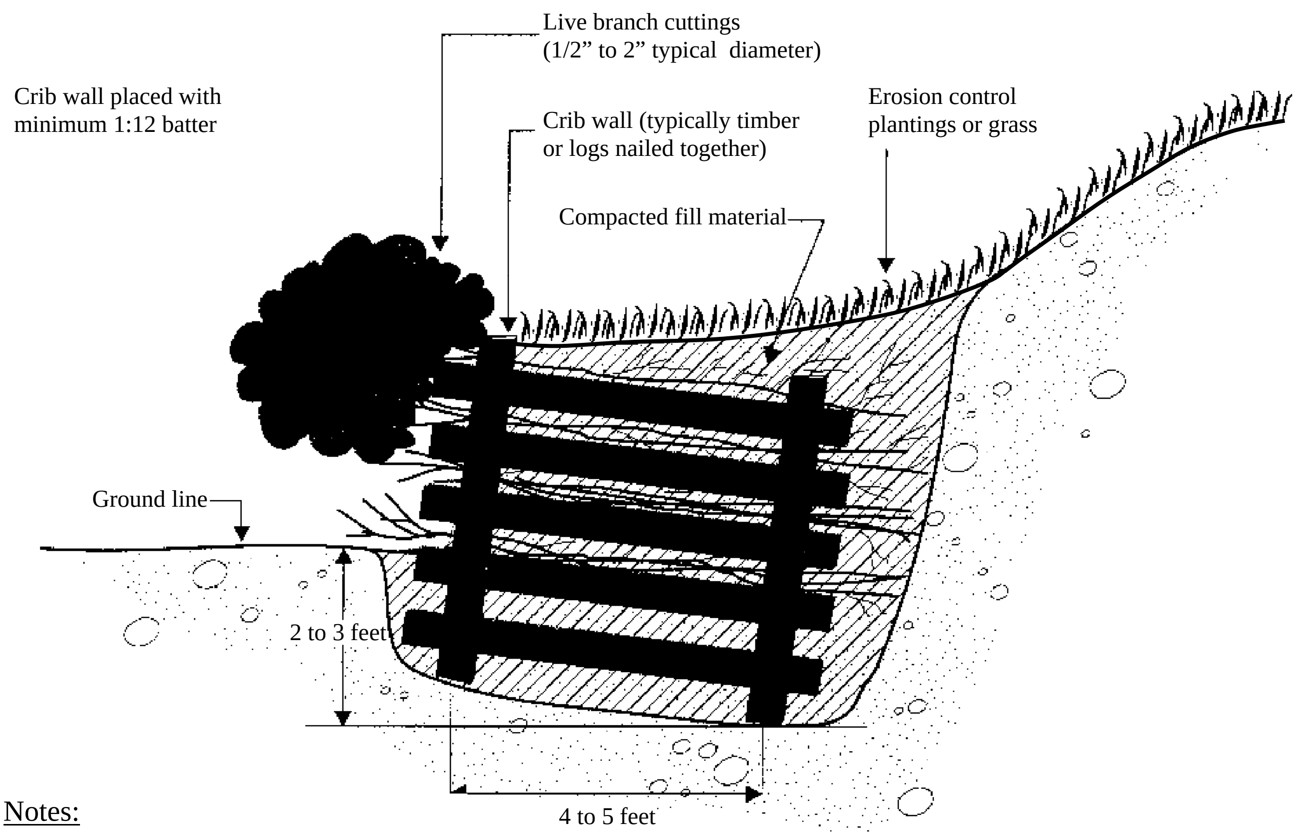
1. Rooted/leafed condition of the living plant material (shown in part of detail) is not representative of the time of installation.

2. Branchpacking locations are typically for small repairs of a slope or gully. Carefully examine site conditions to determine cause of needed repair, such as wet soils or excessive storm water runoff, before conducting repairs.



NOT TO SCALE

Figure ES-19-2
Branchpacking Details



Notes:

1. Rooted/leafed condition of the living plant material (shown in part of detail) is not representative of the time of installation.

2. Crib walls are typically an engineered structure with calculated loads and stresses used in the material selection and design. Adding vegetation to the crib wall may or may not affect structural stability. Consult a professional engineer for walls at the base of steep slopes. Retaining walls over 4’ high must be designed by a professional engineer.

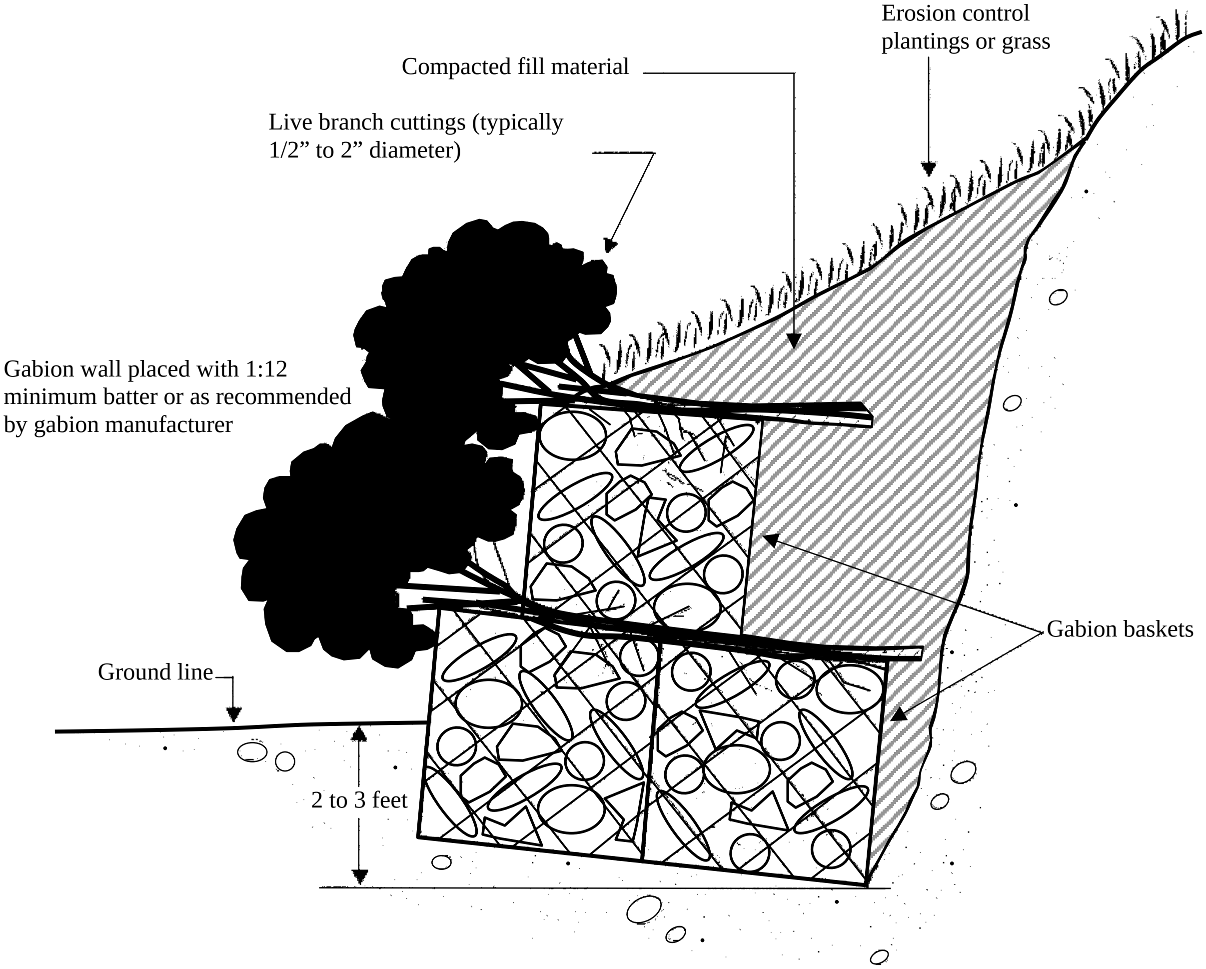
NOT TO SCALE

Figure ES-19-3
Vegetated Cribwall

Notes:

3. Gabion baskets are not generally recommended for stabilization use along stream banks; however, if they are designed and used, vegetation is highly recommended.

4. Rooted/leafed condition of the living plant material (shown in part of detail) is not representative of the time of installation.



1. Gabion walls are typically an engineered structure with calculated loads and stresses used in the material selection and design. Adding vegetation to the gabion wall may or may not affect structural stability. Consult a professional engineer for walls at the base of steep slopes. Retaining walls over 4' high must be designed by a professional engineer.

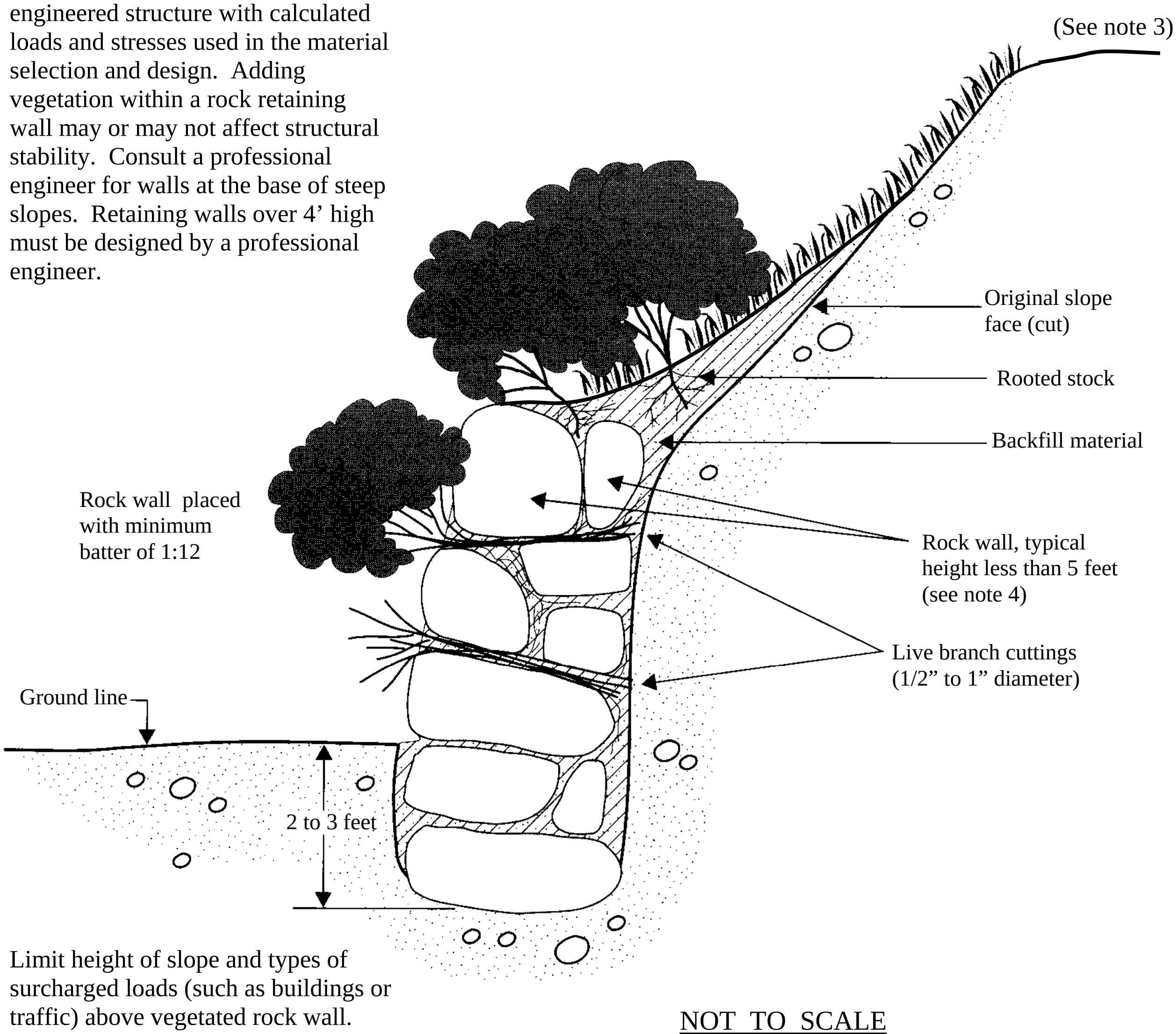
NOT TO SCALE

Figure ES-19-4
Vegetated Rock Gabion

Notes:

1. Rooted/leafed condition of the living plant material (shown in part of detail) is not representative of the time of installation.

2. Retaining walls are typically an engineered structure with calculated loads and stresses used in the material selection and design. Adding vegetation within a rock retaining wall may or may not affect structural stability. Consult a professional engineer for walls at the base of steep slopes. Retaining walls over 4' high must be designed by a professional engineer.



3. Limit height of slope and types of surcharged loads (such as buildings or traffic) above vegetated rock wall.

4. Rock wall may be constructed with or without mortar. Subsurface drainage (such as a gravel drainage layer or weep holes) should be considered in design.

5. For stream bank stabilization, vertical rock walls are generally not recommended. An angled rock toe is more appropriate for stream applications. However, if this method is designed vegetation is highly recommended.

Figure ES-19-5
Vegetated Rock Wall